Air quality in Polish schools—pupils' self-estimation

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ABSTRACT
The system of education in Poland is affected by rapid and deep political, organizational, demographic and financial changes. Although requirements for indoor air quality are described in detail in Polish building codes and standards, the real state of indoor environment in classrooms is not well documented. However, published studies show that in schools with conventional stack ventilation indoor air quality is rather poor. Unintentionally, very often problems are related to modernized buildings where energy conservation measures have been applied. This paper describes newly developed study designed to investigate pupils' self-estimation of indoor environment in schools. Results based on inspection of 235 schools showed the basic reasons and magnitude of self-estimated dissatisfaction.

INDEX TERMS
Schools; Indoor environment; Surveys; Questionnaire; Self-estimation

INTRODUCTION

Starting from 1989, social life in Poland has been affected by great changes due to transformation of the political system and economy. The Polish schools also had to undergo intensive changes. The most significant forces influencing this process were:

- reform of administration: basic education is no longer administered by state government but by local authorities of communities and districts, schools may be owned by foundations, associations and private persons;
- reform of education systems: two-step model of basic education (8 years primary school and 4–5 years secondary school) was changed into three-step model (6 years primary school, 3 years grammar school and 3 years secondary school);
- demographic changes: great number of children born in the 1980s are in secondary schools while the number of pupils in primary schools is rapidly decreasing,
- general financial situation of the state.

Therefore, recently some primary schools have been closed, some have been adopted for grammar schools. A noticeable number of new schools have been organized in buildings that were not originally designed for educational purposes.

On the other hand, like in many other countries, school buildings in Poland receive special care on the part of legislative and executive authorities as well as local governments. This is based on the assumption that children at school acquire not only systematized knowledge but also some solutions and behaviour patterns. Modern schools, where these solutions are applied, started to appear in Poland too, but because approximately 70% of school buildings are older than 20 years, existing buildings' modernization is a crucial problem. However, it is the reduction of operation costs that seems to be the driving force of this modernization, not the improvement in the quality of teaching. It is assumed that in 2010, the energy

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consumption for space heating in educational sector should drop down to 25–30% of energy consumed in 1995 for these purposes (PNECA, 1996). The ambitious goals explain why in the last 10 years, Polish government, supporting energy conservation in residential and public sector, offered special grants for thermo-modernization investments. The most popular modernization investments in schools were: additional thermal insulation of walls, replacement of old leaky windows by new airtight ones, installation of modern boilers and advanced automatic control of heating systems. However, almost all schools in Poland are naturally ventilated, installation of airtight windows without air vents. This means that obligatory requirements for indoor air quality are not fulfilled.

POLISH REQUIREMENTS FOR INDOOR AIR QUALITY IN SCHOOLS

The Polish building law often stipulates requirements based on 'wishful thinking'. For instance, there is a provision, set out in § 309 of technical conditions for buildings and their location, which requires that '*materials and products used for the construction of buildings as well as construction methods should not be hazardous for hygiene and health of their occupants or neighbors...*' (MI, 2002). Unfortunately, as is usually the case with similar regulations, there are no sufficiently detailed rules for implementation of these requirements.

Table 1 Permissible concentration of substances emitted by building materials, equipment and furnishing (MHSC, 1996)

No.	Substance	Maximum permissible concentration $\mu g/m^3$ (24 h average)	No.	Substance	Maximum permissible concentration $\mu g/m^3$ (24 h average)
1.	Acryloamide	1	19.	Cresols	25
2.	Acrylonitrile	2	20.	Xylene	100
3.	Ammonia	300	21.	*p*-Kumylophenol	40
4.	Benzene	10	22.	Maleic anhydride	50
5.	Butadiene	100	23.	Naphthalene	100
6.	Butyl alcohol	300	24.	Butyl acetate	100
7.	Chlorobenzene	15	25.	Ethyl acetate	100
8.	Chlorophenols (excl. pentachlorophenol)	15	26.	Vinyl acetate	50
			27.	Ozone	100
9.	Chlorophtalenes	15	28.	Pentachlorophenol	5
10.	Cyclohexane	250	29.	Mercury	1
11.	Cyklohexanone	40	30.	Styrene	20
12.	Dichlorobenzene	30	31.	Carbon monoxide (30 min)	3000 (10 000)
13.	Ehtylbenzene	100			
14.	Phenol	20	32.	Toluene	200
15.	Formaldehyde	50	33.	Trichloroethane	75
16.	Dibutyl phthalate	100	34.	Trichloroethylene	150
17.	Phthalic anhydride	40	35.	Vinyl chloride	5
18.	Ethylene glycol	15			

Permissible values of concentration and intensity of factors hazardous to health, emitted in all living areas by building materials, equipment and furnishing, are set out in a Regulation of the Minister of Health and Social Care of 12 March 1996 (MHSC, 1996). The Regulation sets two categories of rooms, i.e. A and B. Table 1 presents the permissible concentration (average

24 h) for 35 chemicals for rooms category A (e.g. classrooms). It should be noted that smoking outside clearly marked smoking areas in schools and educational institutions is also legally forbidden in Poland.

Standards of air quality may also be indirectly established, for instance, by defining required ventilation rate. In Poland, the minimum flow of outdoor air in apartment houses, residential buildings and public buildings, which include schools, is specified in the Polish Standard PN-83 B-03430 (PCS, 2000). This Standard requires at least 20 m^3/h of outdoor air for each occupant in rooms permanently or temporarily occupied by people. The Standard does not specify the type of ventilation in school buildings leaving this decision to the architect. Practically, as it was previously mentioned, almost all classrooms are ventilated with stack ventilation.

It should be noted that, in public buildings, it is forbidden to design outdoor air supply exceeding 2 air changes per hour due to negative pressure in rooms. In exceptional cases, only schools and kindergartens may be designed with natural air supply up to 3 changes per hour.

CHARACTERISTICS OF INDOOR ENVIRONMENT IN POLISH SCHOOLS

Polish sanitary-epidemiological stations are obliged to inspect all school buildings every year. In the year 2000, 35 080 schools from the total number of 35 959 were checked (97.6%) and evaluation of results showed that (Ignar-Golinowska, 2002):

- 7.2% of schools buildings were in bad technical state;
- 5.4% of schools were located in buildings not adapted to educational functions;
- hygiene state of 1.6% of schools was unacceptable.

More detailed information describing indoor environment conditions in Polish schools can be found in the report from the random control of 266 grammar schools, ca. 5% of the total number of this type of schools in Poland (Ignar-Golinowska and Gajewska, 2002).

A total of 26.3% of the investigated classrooms were reported as rooms with unsatisfactory natural lighting. The ratio of window area to floor area was less than 1 : 5 whereas ministerial requirements state that this indicator should be within the range 1 : 4–1 : 5. The majority of the classrooms have the additional fluorescent lighting (78%). In the rest of the classes conventional bulb lighting systems were installed.

Large differences in occupation density were observed; 5.3% of the investigated classrooms should be regarded as very crowded (floor area per pupil was less than 1.4 m^2). In majority of classes (68.5%) one pupil corresponded to 1.4–2.4 m^2 of floor area. In 4.5% of classrooms this ratio was 2.5 m^2, the value recommended by the ministry and 21.7% of classrooms had floor area exceeding 2.6 m^2 per person. The study showed that in 60% of the class rooms, the floor was covered by PVC tiles. Thirty per cent of classes had floor made of wood. Other types of floor covering materials were not popular (3% rubber, 1.1% ceramic tiles, 0.8% carpets).

Modern airtight windows were mounted in 37.2 % of the classrooms whereas 13.5% of classes had traditional wood framed windows but without small casements for airing. According to Polish building code (MI, 2002), every naturally ventilated room for permanent occupation should be equipped with exhaust stacks. However, in 11.3% of investigated classrooms such stacks were not present. In an additional 3% of classrooms the stacks were not permeable. Luckily, a vast majority of classrooms (84.6%) were aired during every break between lessons. In 14.3% of classrooms, windows were opened from time to time during the beaks and 1.1% of classrooms were not aired at all.

There are very few studies on indoor air quality in Polish schools. The investigation of 28

classrooms in 24 school buildings in Warsaw was the most extensive study (Sowa, 2001). Schools were randomly chosen from the lists provided by local district authorities. In each school building, typical rooms (in respect of size, furnishing, wear and tear, etc) were selected. The tests were performed in 16 classrooms in elementary schools, 4 classrooms in grammar schools and 8 classrooms in secondary schools.

The study showed that natural ventilation systems applied in all schools were not able to ensure proper ventilation rate (Sowa, 2002). Inefficient ventilation systems resulted in very high CO_2 concentration (up to 4200 ppm) in the classrooms throughout most of the time that classes were held. In the tested ventilation systems, the only practical possibility to increase ventilation rate was to open the windows. Unfortunately, in many schools situated in busy town areas it was impossible to open windows during the classes due to traffic and street noise. Moreover, in cooler seasons, open windows could cause discomfort for pupils sitting near the windows. Airing classrooms during breaks was a certain solution. Analyses of variable CO_2 concentration showed that classrooms were periodically aired during the tests.

In view of the above comments on ventilation rate, the problem of polluting classrooms with chemicals emitted by building materials or furnishing was a secondary one. If ventilation rate was intensified to reach the required conditions (2–10 times), higher formaldehyde concentration (up to 70 $\mu g/m^3$) and TVOC levels (up to 1800 $\mu g/m^3$) would come down to the permissible level. This suggests that school furniture manufactured nowadays does not emit excessive formaldehyde whereas emission from old furniture has lowered to the permissible level with time. The tests performed in schools have shown that classrooms are generally overheated. Central heating control systems do not compensate heat gains coming from persons, electric lighting or solar radiation. This causes excessive energy consumption and possible thermal discomfort and creates conditions that increase possible negative symptoms resulting from air quality.

DEVELOPMENT OF NEW STUDY FOR IAQ SELF-ESTIMATION BY PUPILS

Taking the advantage that each few years National Sanitary Inspection checks randomly selected schools, the authors developed the special questionnaire covering information on ventilation systems, potential source of emissions, airing practices and a special part for examination of perception of indoor environment by pupils. Special place in the questionnaire was provided for the description of windows, small casements or air vents were open or closed during the test. The inspectors were trained how to fill the questionnaire. Examples of properly filled questionnaires were prepared. The questionnaire has two pages of A4 format. Depending on the investigated room, the inspector had to fill out from 60 to 70 fields.

As the data collection was not associated with additional funds, the developed procedure had to be very simple. In randomly selected classroom, during one lecture pupils were asked the question ‘At the moment do you feel uncomfortable due to: draught?, too high air temperature?, temperature changing in time?, too low air temperature?, stuffy air?, dry air?, unpleasant smell?, stale air?, chemical smell?, static electricity?, other (please specify)?’ The pupils raised hands to vote ‘yes’ for each question. Earlier the investigator asked the children to express their opinions freely and not to take into consideration opinions expressed by other children. Serious doubts were associated with the method of voting because children may have not listened to the request for individual assessment. On the other hand, individual voting on sheets of paper, which is a much more time-consuming process, might have not be free from this influence too.

Table 2 Pupils' self-estimation of indoor environment parameters in Polish schools (based on a questionnaire survey carried out in 235 classrooms)

Reason of discomfort	Classrooms with dissatisfied pupils (%)	Range of declared dissatisfaction		Statistics of declared dissatisfaction (all classrooms)		Statistics of declared dissatisfaction (classrooms with dissatisfied pupils)	
		Min. (%)	Max. (%)	Mean (%)	SD (%)	Mean (%)	SD (%)
Stuffy air[a]	54.04	0.00	100.00	16.43	23.01	20.11	23.97
Dry air[a]	45.53	0.00	100.00	12.31	20.84	15.06	22.15
Too high air temperature[a]	44.26	0.00	100.00	12.54	20.44	15.35	21.65
Unpleasant smell[a]	37.02	0.00	100.00	7.93	14.66	9.71	15.68
Stale air[a]	32.77	0.00	82.35	6.52	12.94	7.98	13.91
Temperature changing in time[a]	31.49	0.00	100.00	9.18	19.52	11.12	21.06
Draught[a]	21.70	0.00	40.91	2.54	6.00	3.10	6.51
Too low air temperature[a]	19.57	0.00	91.67	3.91	12.07	4.79	13.20
Unspecified	13.62	0.00	61.54	1.90	6.36	2.32	6.97
Chemical smell[a]	11.91	0.00	88.89	1.69	7.35	2.07	8.09
Dust	11.06	0.00	82.35	2.02	8.78	2.48	9.66
Static electricity[a]	9.36	0.00	86.67	2.00	9.71	2.44	10.69
Flower smell	4.26	0.00	91.67	1.06	8.42	1.30	9.31
Chalk powder	1.70	0.00	15.38	0.13	1.16	0.16	1.28
Noise	0.85	0.00	96.88	0.56	6.73	0.69	7.44
Fumes from street	0.85	0.00	22.22	0.12	1.50	0.15	1.66
Solar radiation	0.85	0.00	40.00	0.19	2.62	0.23	2.90
Smell of cosmetics	0.85	0.00	13.04	0.07	0.89	0.09	0.99
Smell of sweat	0.43	0.00	54.55	0.23	3.56	0.28	3.94
Chalk smell	0.43	0.00	100.00	0.43	6.52	0.52	7.22
Smell from street	0.43	0.00	47.06	0.20	3.07	0.25	3.40
Smoke	0.43	0.00	64.71	0.28	4.22	0.34	4.67

[a]Reasons suggested by the questionnaire.

The lower quality of data was, to some extent, compensated by the number of schools analysed. A total of 235 classrooms/schools were examined, that is, 4.5% of all grammar schools in Poland. Randomly selected schools were distributed in all regions of Poland. The inspections were carried out in March 2003. The magnitude of self-declared dissatisfaction is presented in Table 2. Reasons of discomfort were sorted according to the percentage of classrooms with dissatisfied pupils, with the most important ones being: stuffy air, dry air, too high air temperature, unpleasant smell, stale air and temperature changing in time. In 43 classrooms, pupils did not declare any reason of dissatisfaction. In these cases, the pupils probably did not have the provision to express their opinions freely. This may indicate that the doubts related to the method of voting were justified. Therefore, the results presented in Table 2 contain two statistics: first calculated for all schools and second calculated only for the schools with at least 1 dissatisfied pupil. From the other hand in 12 cases 100% of pupils declared discomfort due to certain reason. These results were regarded as rather unique but possible.

CONCLUSIONS

Very few studies have been devoted to investigation of indoor environment in Polish schools. The developed study was the very first investigation of pupils' self-estimation of indoor environment in schools. Results showed that the most important reasons of pupils dissatisfaction like stuffy air, dry air, too high air temperature, unpleasant smell, stale air and temperature changing in time were similar to findings with measurement projects (Sowa, 2001, 2002). The magnitude of self-declared dissatisfaction has to be interpreted taking into account the voting method as well as the fact that variability of pupils' opinions may be affected by different level of adaptation to the indoor environment. Nevertheless, one more research project indicated that in schools with conventional stack ventilation, the indoor air quality is rather poor.

The data obtained will be evaluated in the future to find potential correlation between percentage of pupils who declare dissatisfaction and other parameters collected in the questionnaires, however due to limitations in the voting method, no strong relationships are expected.

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