Turkish Journal of Medical Sciences

http://journals.tubitak.gov.tr/medical/

Research Article

Turk J Med Sci
(2014) 44: 137-144

doi:10.3906/sag-1212-22

Indoor air quality in primary schools in Keçiören, Ankara*

Mustafa Alparslan BABAYİĞİT[1,], Bilal BAKIR[2], Ömer Faruk TEKBAŞ[2], Recai OĞUR[2], Abdullah KILIÇ[3], Serdar ULUS[1]**

[1]Turkish Armed Forces Health Command, Ankara, Turkey

[2]Department of Public Health, Gülhane Military Medical Academy, Ankara, Turkey

[3]Department of Microbiology, Gülhane Military Medical Academy, Ankara, Turkey

Received: 06.12.2012 • **Accepted:** 11.04.2013 • **Published Online:** 02.01.2014 • **Printed:** 24.01.2014

Aim: To increase the awareness of environmental risk factors by determining the indoor air quality status of primary schools.

Materials and methods: Indoor air quality parameters in 172 classrooms of 31 primary schools in Keçiören, Ankara, were examined for the purpose of assessing the levels of air pollutants (CO, CO_2, SO_2, NO_2, and formaldehyde) within primary schools.

Results: Schools near heavy traffic had a statistically significant mean average of CO and SO_2 ($P < 0.05$). The classrooms that had more than 35 students had higher and statistically significant averages of CO_2, SO_2, NO_2, and formaldehyde compared to classrooms that had fewer than 35 students ($P < 0.05$). Of all classrooms, 29% had 100 CFU/100 mL and higher concentrations of microorganisms, which were not pathogens.

Conclusion: Indoor air quality management should continually be maintained in primary schools for the prevention and control of acute and chronic diseases, particularly considering biological and chemical pollution.

Key words: Primary schools, air pollutants, air microbiology

1. Introduction

Primary education is the largest public enterprise in Turkey, employing 484,161 teachers who instruct over 10 million children in 344,710 classrooms and 31,176 schools (1).

School health programs are inclusive of the location and layout of the school, school building construction features, status, materials used, infrastructure facilities, plumbing safety, indoor air quality and water quality levels, toilets, playing areas, heating and lighting levels, service hygiene, and prevention of bio-geo-physicochemical pollution in the schools (2,3). A healthy and safe school environment encompasses the physical surroundings and the psychosocial, learning, and health-promoting environment of the school (4).

These programs should include the health assessment of the students and school staff, developing, achieving, and maintaining a healthy school life for not only students, but also for school staff (5). They target the state of complete physical, mental, and social well-being of students, teachers, and the other staff in schools (6).

Air pollution is formed by a complex mixture of many pollutants. The potential health risks of air pollution vary depending on the content of this mixture, the amount and the hours of the occurrence, and the day or time of year. However, in recent years, due to the cost of energy, building designs allow less air exchange, and both the chemicals used in the construction of household goods and furniture in homes and schools and the microbiological and allergic organisms in indoor environments have become more threatening (7). In particular, children, who spend 80% to 90% of their time in indoor environments such as home, child care, school, or after-school care, constitute a risk group in this sense (8). Despite the large population and concerns regarding poor indoor air quality (IAQ), systematic assessments of IAQ and health and comfort issues have rarely been undertaken in schools (9).

Preschool and school-aged children often spend significant periods of time in school settings. These settings are often the first significant indoor exposure for the children to a physical environment different from the home (10). Exposure may be especially likely in portable classrooms containing composite wood products (e.g.,

* The findings of this publication were presented at the 22nd Annual Meeting of the International Society of Exposure Science Conference (Lessons Learned: Contributions of Exposure Science to Environmental and Occupational Health), 28 October to 1 November 2012, Seattle, Washington, USA.

** Correspondence: musalpbaba@yahoo.com

plywood, particleboard). Paints, adhesives, cleaning materials, and building materials all contain volatile organic compounds (VOCs) that are associated with respiratory and other health problems (7).

IAQ is an important health concern stimulating global initiatives and actions from organization such as the US Environmental Protection Agency (US EPA), as well. Pollutants that contribute to poor IAQ might be secondhand smoke, molds and other biological products, lead and heavy metals, pesticides, sanitizers, disinfectants, and combustion byproducts (8,11). Many factors contribute to IAQ. The concentration of indoor air pollutants can vary from room to room and even within a single classroom. Levels may also vary according to the activity occurring in the space and variations in airflow (e.g., caused by opening windows).

Toxic chemicals in the environment are of particular concern as potential causes of disease in children, because children are generally more susceptible to environmental exposure than adults. Children experience heavier exposure to chemicals per kilogram of body weight. In addition, children's rapid growth can be disrupted easily by toxic exposure, they have more future years to develop diseases as a result of early exposure, and they have age-dependent differences in the absorption, distribution, metabolism, and excretion of chemical residues (12,13). Furthermore, the brain is not fully developed until adolescence, and thus children's brains are more vulnerable than adults' brains to such toxins as metals, solvents, insecticides, and certain gases (11).

The goals of this study are to characterize selected IAQ parameters in public primary schools, assess the variability in pollutant levels within schools, and link pollutants to classroom size, school locations, and other factors.

2. Materials and methods

This cross-sectional study was conducted in the primary schools of the Keçiören district of Ankara between November 2008 and May 2009. Of the 83 public primary schools in the district, 31 were selected by a random sampling method. The research sample was calculated on the basis of the formula of "the sample size calculation when the universe is known". Since the state of indoor air pollution of primary schools in Keçiören was not known exactly, the frequency of risky schools in that region was regarded as 50% when calculating the sample size.

2.1. Study planning

We aimed to assess the IAQ levels of public primary schools. Measurements were started in the morning on weekdays in the schools. Since the study had been planned to include a large number of parameters and considering the distances between schools, the measurements could be made in only one school each weekday.

If the school had a single building, the measurements were started from the upper to the lower floors of the buildings, by selecting 2 classrooms (right and left) from each aisle of rooms. If the school had more than 1 building, the measurements were started from the highest building, by selecting only 1 classroom from each aisle.

2.2. Indoor air quality assessments

2.2.1. Method of chemical measurements

A Miran SapphIRe 205B series portable infrared ambient air analyzer (Thermo Electron Corporation, Waltham, MA, USA) was used to measure the concentration of some indoor air pollutants (sulfur dioxide, nitrogen dioxide, formaldehyde, carbon dioxide, and carbon monoxide) in selected classrooms of the primary schools with a team from the Keçiören Municipality Indoor Air Quality Department. This device makes precise spot measurements, and it was able to measure a wide range of chemical substances including CO_2, CO, formaldehyde, or organic vapors. It had an accuracy of 5.0% and a sensitivity of 0.1 ppm. Its pump flow rate was 14 L/min. Analysis time following purge (typical) was 20 s for single wavelength, 50 s for 5 wavelengths, and 165 s for the spectral scan. This equipment had a zero gas filter and we calibrated the analyzer every time before starting the measurement.

2.2.2. Method of microbiological measurements

The Microbial Air Sampler MAS-100 NT (MBV AG, Stäfa, Switzerland) was used to measure the microbial burden of the classrooms. Each sample was analyzed at the Gülhane Military Medical Faculty (GMMF) Department of Public Health Laboratories within 3 h. For microbiologic analyses, samples were initially inoculated into the total viable medium and then kept for 24 h at 36 °C in an incubator (Nuve EN 120 Incubator, Ankara, Turkey), and colonies were counted as colony forming units (CFUs).

According to the standards, classroom size should be 35 students, sufficient air volume per student should be 6.0 m^3, and sufficient space per student should be 1.2 m^2 (14,15).

The required administrative permission related to the research was taken from the dean of the GMMF and the Ankara Provincial Directorate of National Education. Ethical approval was also taken from the GMMF Ethics Committee.

2.3. Study limitations

Due to transportation difficulties, time limitation, and so on, this research could not be conducted at all primary schools in Ankara. The fact that this study was implemented only in public primary schools might be a restriction. Since the schools' settlements were in urban areas, there were no opportunities for comparisons with rural (slum area or village) schools. As a project supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK; Project No.: 108S013), this research was planned to assess various environmental risk factors of the primary schools, such as electromagnetic radiation, noise, illumination, temperature, IAQ, and water quality. All of these measurements were conducted at the same time. Since this paper was a part of such a large project, we had no chance to measure outdoor air quality levels, humidity, or air exchange ratio. This might also be a restriction for assessing the real exposure levels of the indoor environment of the primary schools. Due to insufficient budget and time, we had no opportunity to collect data for school achievement and/or health symptoms related to IAQ.

2.4. Statistical analysis

Distributions of continuous variables (measurements) were considered as means ± standard deviations. This was the number and percentage frequency for the categorical variables. Statistical analysis was performed using SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov goodness-of-fit test was used to test the normality of data. Homogeneity of the variances was tested using Levene's test. For normally distributed continuous data, groups were compared using the Student t-test. The Kruskal–Wallis and Mann–Whitney U test were used for nonparametric comparisons. $P < 0.05$ indicated statistical significance.

3. Results

Of the primary schools (31 schools, 280 measurements), 54.8% were on main streets with heavy traffic less than 100 m away, and 51.6% had more than 1 building on the school grounds. The mean age of the buildings (n = 54) was 20.6 ± 15.0 years, and 24.1% of buildings were over 30 years old. All of the primary schools had central heating. Indoor air pollutant levels of Keçiören primary schools are presented in Table 1.

Of all classrooms, only 8.1% of the classes had sufficient air volume per student, while 61.0% had sufficient space per student. Classrooms which had <6 m^3 air volume had a higher mean average of CO, CO_2, formaldehyde, NO_2, and SO_2 ($P > 0.05$; Table 2).

The classrooms that had more than 35 students had higher and statistically significant averages of CO_2, SO_2, NO_2, and formaldehyde compared to the classrooms that had less than 35 students ($P < 0.05$; Table 3).

Table 1. Indoor air pollutants in primary schools of Keçiören, Ankara (mean ± SD).

Air pollutants (ppm)	Classrooms, n = 172	Kindergartens, n = 30	Computer classrooms, n = 28	Science laboratories, n = 27	Libraries, n = 23	P
CO	1.8 ± 1.8	2.3 ± 2.7	2.0 ± 2.4	1.6 ± 1.4	1.8 ± 2.5	>0.05
CO_2	717.3 ± 646.3*	449.3 ± 556.3*	552.5 ± 724.4*	320.3 ± 516.5*	86.2 ± 184.3*	**<0.05**
Formaldehyde	0.6 ± 0.5	0.8 ± 0.7	0.6 ± 0.6	0.6 ± 0.5	0.6 ± 0.6	>0.05
NO_2	2.0 ± 1.3*	1.2 ± 1.1*	1.2 ± 1.2*	0.8 ± 1.1*	0.4 ± 0.7*	**<0.05**
SO_2	4.1 ± 3.6	7.2 ± 8.0	3.2 ± 3.2	3.3 ± 3.4	3.3 ± 3.2	>0.05

*: Kruskal–Wallis and Mann–Whitney U test with Bonferroni correction.
Bolded values are statistically significant.

Table 2. Comparison of indoor air pollutants according to the volume per person in Keçiören primary schools.

Air pollutants (ppm)	Mean ± SD		P
	Air volume per person of <6 m^3, n = 153	Air volume per person of ≥6 m^3, n = 14	
CO	1.8 ± 1.9	1.1 ± 0.7	>0.05*
CO_2	729.0 ± 643.9	589.5 ± 682.8	>0.05*
Formaldehyde	0.6 ± 0.5	0.4 ± 0.4	>0.05**
NO_2	2.0 ± 1.3	1.6 ± 1.2	>0.05**
SO_2	4.1 ± 3.5	4.0 ± 4.6	>0.05*

*: Mann–Whitney U test.
**: Student's t-test.

Table 3. Comparison of indoor air pollutants according to the number of students in the classrooms of Keçiören primary schools.

Air pollutants (ppm)	Mean ± SD		P
	Number of students <35, n = 69	Number of students ≥35, n = 98	
CO	1.7 ± 2.0	1.8 ± 1.6	>0.05
CO_2	561.2 ± 511.2	**827.3 ± 708.5**	**<0.05****
Formaldehyde	0.5 ± 0.4	**0.7 ± 0.5**	**<0.05****
NO_2	1.7 ± 1.2	**2.1 ± 1.3**	**<0.05****
SO_2	4.8 ± 3.5	**3.6 ± 3.6**	**<0.05***

*: Mann–Whitney U test.
**: Student's t-test.
Bolded values are statistically significant.

Schools near heavy traffic had a statistically significant mean average of CO and SO_2 ($P < 0.05$; Table 4).

Microbiological air quality levels measured from the classrooms, kindergartens, school canteens, and restrooms of the primary schools are presented in Table 5. None of the microorganisms were found to be pathogens. Of all classrooms, 29.0% had 100 CFU/100 mL and higher concentrations according to the microbiological air quality assessment. Over 100 CFU/100 mL concentrations were seen in 32.2%, 3.2%, 19.3%, and 16.1% of the kindergartens, school canteens, and male and female restrooms, respectively.

The classrooms that had more than 35 students and kindergartens had higher and statistically significant averages of gram-positive cocci, gram-negative bacilli, and total viable microorganisms compared to the schools canteens, restrooms, and the classrooms that had fewer than 35 students ($P < 0.05$). Primary schools' canteens were the places in which the microbiological burden was the lowest (Table 5).

4. Discussion

Faulty construction and neglected maintenance are the primary causes of structural hazards in schools. The building systems in schools have significant defects that may degrade IAQ by leading to inadequate ventilation and moisture accumulation. Poor ventilation can also lead to the buildup of combustion byproducts (e.g., CO and nitrogen oxide compounds), especially when wood-burning stoves, gas cooking stoves, or fuel space heaters are used for heating. In addition, synthetic components of building materials may emit toxic or respiratory irritant chemicals, such as formaldehyde (9,16). Poor IAQ, diesel exhaust emitted from school buses, hazardous materials, pesticides, contaminated drinking water, and lead are environmental hazards that are sometimes found in

Table 4. Comparison of indoor air pollutants according to the distance from heavy traffic of Keçiören primary schools.

Air pollutants (ppm)	(Min–max) median		P
	Distance to the heavy traffic <100 m, n = 107	Distance to the heavy traffic ≥100 m, n = 60	
CO	(0–13.9) **1.7**	(0–4.4) 1.0	**<0.05***
CO_2	(0–3460) 560.0	(0–3080) 546.5	>0.05*
Formaldehyde	(0–2.1) 0.5	(0–2.1) 0.6	>0.05**
NO_2	(0–5.9) 2.0	(0–4.8) 1.8	>0.05**
SO_2	(0–12.9) **4.1**	(0–14.9) 2.1	**<0.05***

*: Mann–Whitney U test.
**: Student t-test.
Bolded values are statistically significant.

Table 5. Types and concentrations of total viable microorganisms (CFU/100 mL) in ambient air of classrooms, kindergartens, school canteens, and restrooms of Keçiören primary schools.

Types of microorganisms	Classrooms, n = 87		Kindergartens, n = 28, (min–max) median	School canteens, n = 23, (min–max) median	Boys' restrooms, n = 28, (min–max) median	Girls' restrooms, n = 28, (min–max) median
	Number of students <35, n = 33, (min–max) median	Number of students ≥35, n = 54, (min–max) median				
Gram-positive cocci*	(13–108) 44.0**	(5–134) 53.0**	(3–174) 56.0**	(0–90) 16.0**	(4–193) 37.5**	(5–130) 31.5**
Micrococcus	(0–30) 0.0	(0–37) 0.0	(0–16) 0.0	(0–10) 0.0	(0–10) 0.0	(0–39) 0.0
Gram-negative bacilli*	(0–127) 3.0	(0–204) 14.5**	(0–71) 9.0**	(0–87) 2.0**	(0–97) 6.5	(0–45) 5.5
Mold/fungi	(0–10) 2.0	(0–16) 2.0	(0–10) 1.0	(0–6) 1.0	(0–13) 1.5	(0–13) 0.5
Total viable microorganisms*	(0–230) 27.0	(0–26.9) 35.5**	(15–214) 74.5**	(3–180) 24.0**	(9–251) 45.5**	(8–160) 41.5**

*: $P < 0.05$, Kruskal–Wallis test.
**: $P < 0.0083$ (corrected), Mann–Whitney U test.

schools and can adversely affect the health, attendance, and academic success of students, as well as the health of teachers and other staff (11). Pollutant emissions can occur in many school settings, e.g., cafeterias, wood shops, gyms, swimming pools, science labs (often without fume hoods), arts and crafts rooms, and computer rooms (9).

In this study, we found that nearly the half of the primary schools had more than one building on the school grounds. This situation restricts the school grounds and playgrounds, which are crucial for children's physical activity improvement. The variables that are consistently associated with children's physical activity are healthy diet, program/facility access, time spent outdoors, and opportunities to exercise (17). Instead of constructing an additional building in the area of the school grounds, appropriate land planning should be identified and compliance with standards should be maintained while constructing new buildings. Municipalities should also take into account the growing school population.

The air quality standards set forth by the World Health Organization and the US EPA indicate that primary and secondary pollutants (ozone, particulate matter, lead, sulfur dioxide, carbon monoxide, formaldehyde, nitrous oxide, etc.) threaten human health (7,18). Although the limit values that should not be exceeded for these pollutants have been published, only the measurements for hourly, 8-h, and annual averages allow standard comparisons. In our study, due to the high number of samples from each school and the excessive distances between schools, environmental parameters were measured in real-time, so standard measurement methods and measurement results reflect instantaneous values. The values found in this study have not been discussed by comparison with US EPA standards.

In our study, the classrooms that had more than 35 students had higher and statistically significant averages of CO_2, SO_2, NO_2, and formaldehyde compared to the classrooms that had fewer than 35 students. One study of IAQ investigated CO_2 levels in 91 child care centers in Quebec, Canada. Ninety percent had CO_2 levels that exceeded the office building standard. Increased CO_2 levels were associated with the number of children in a given area. A high CO_2 level (>1000 ppm) can be used as a rough indicator of the effectiveness of ventilation and can serve as a marker for other indoor air pollutants (8). Santamouris et al. monitored the air flow and the associated indoor CO_2 concentrations in 62 classrooms of 27 naturally ventilated schools in Athens, Greece. The specific ventilation patterns as well as the associated CO_2 concentrations before, during, and after the teaching period were analyzed in detail. About 52% of the classrooms presented a mean indoor CO_2 concentration of higher than 1000 ppm (19). In our study, this rate was 25.8%. It has been reported that, according to the studies conducted on IAQs in European schools, CO_2 concentrations at most of the schools were above 1000 ppm. The averages of CO_2 concentrations in 2 Swedish schools were 1420 and 1850 ppm, whereas the median in 10 Swedish schools was 1070 (range: 800–1600) ppm. Furthermore, 11 schools in Denmark had an average concentration of 1000 (500–1500) ppm CO_2 (20).

Formaldehyde may cause irritation of the mouth, throat, nose, and eyes; worsen asthma symptoms; and cause headache and nausea (7). In some European schools, the limit values for concentrations of formaldehyde were 0.05 to 0.08 ppm. Although the averages were found to be 0.05 ppm at 20 schools in Milan and Paris, the average was 0.35 ppm in 10 Danish schools, which was more than 5 times than the normal average and is related to eye, ear, and throat mucous membrane irritation (20). In this study, the average of formaldehyde concentration in 172 classrooms was found to be 0.6 ppm.

One of the most remarkable findings of our study was more than half of the primary schools were on a main street and close to heavy traffic (less than 100 m away). Accordingly, primary schools near heavy traffic had a statistically significant mean average of CO and SO_2. For economic reasons, schools are frequently built on relatively undesirable land. They are often situated near highways, exposing children to automotive emissions and lead. They may be near old industrial sites with benzene and arsenic deposits (10). In one study, carbon dioxide measurements were taken in classrooms and students were given a health symptom questionnaire. The students' scores on the concentration test were lower and their health symptom responses to the questionnaire were inferior when carbon dioxide levels increased. This finding, which was statistically significant, suggests that reduced ventilation rates (and higher indoor pollution) are associated with a decreased ability to concentrate, along with increased adverse health symptoms. Another study of students showed similar results when using subjective reports of performance, while laboratory studies of the effects of a mixture of VOCs on adults showed that elevated VOCs can decrease performance of sensitive adults, although not necessarily that of adults who are not sensitive (21). Building-associated health effects can also increase students' or teacher's absenteeism from school and degrade the performance of children or teachers while in school. Respiratory health effects, such as respiratory infections and asthma, are the illnesses most closely associated with increased absenteeism (22–26).

The term "bioaerosol contamination" refers to various agents that result from biological sources such as viruses, bacteria, bacterial endotoxins, fungi, mold, and allergens in an indoor environment (20). Indoor bioaerosols can originate from outdoor air or from internal sources such as building occupants and their activities and building materials that host microbiological growth. Fungal and bacterial growth, in and on water-damaged building materials, is a potential health hazard and many recent reports contain evidence to support this observation (27). High levels of humidity are manifested in the formation of bacteria, mold, allergens, and fungi, especially in indoor environments and in water-damaged buildings, and this increases the prevalence of respiratory diseases (28). Environmental measurements of indoor air toxins in 2 primary schools in the southeastern part of the United States have identified many health-threatening opportunistic bacteria (29). In a study of bacteria and fungi in the indoor air in public buildings in Korea, total average concentrations were 404 and 382 CFU/m^3, 931 and 536 CFU/m^3, and 294 and 334 CFU/m^3 for hospitals, kindergartens, and nursing homes, respectively. The differences were statistically significant (30). In a study on environmental measurements in 13 classes of 6 schools in the US state of Florida, bacteria, fungi, and allergens were analyzed. The concentrations of bacteria in indoor environments were 60–270 CFU/m^3 for 1 school and 1050 CFU/m^3 for another school, while the ambient air concentration was 160 CFU/m^3. Fungus levels for the indoor environments have been found to be lower than those in the ambient air (31). SO_2, NO_2, formaldehyde, particulate matter, and biological agents were investigated in indoor environments of 5 schools in Hong Kong in which the average biological counts were below the Hong Kong Interim Indoor Air Quality Guidelines level of 1000 CFU/m^3, but some outdoor samples had total bacterial counts exceeding 800 CFU/m^3. Indoor bacteria samples had lower concentrations than outdoor samples (32). According to international standards, an acceptable limit is 100 CFU/m^3. Concentrations over 1000 CFU/m^3 play a significant role in terms of health concerns and immediate action should be taken (27,33). The most common types found in the literature were gram-negative rods and cocci such as *Micrococcus*, *Bacillus* spp., and *Flavobacterium* (20). In our study, of all the classrooms, 29% had concentrations of 100 CFU/100 mL or higher. However, none of the microorganisms were found to be pathogens. Therefore, none of the levels measured required immediate action. In order to ensure a sustainable environment in schools for both children and staff, the materials used in the construction of school buildings (e.g., composite wood products, paints, adhesives, carpets, cleaning products, and building materials) should be safe and efficient heating, ventilation, and air conditioning systems should be designed. A school environmental health system that evaluates and monitors the IAQ at periodic intervals should be initiated.

The results of our study indicate that: 1) primary schools near heavy traffic had a statistically significant mean average of CO and SO_2; 2) more crowded classrooms had higher and statistically significant averages of CO_2, SO_2, NO_2, and formaldehyde; and 3) of all classrooms, 29% had concentrations of 100 CFU/100 mL or higher of microorganisms that were not pathogens. IAQ management should continually be maintained in primary schools for the prevention and control of acute and chronic diseases, particularly considering biological and chemical pollution.

Acknowledgments
We thank Dr Karen Braxley, coordinator of writing tutoring at the University of Georgia (Athens, GA, USA), for reviewing this paper grammatically.

References

1. Türkiye İstatistik Kurumu. 2011–2012 Eğitim Öğretim Yılı Eğitim Kurumlarının Kademelere göre Okul, Öğrenci, Öğretmen ve Derslik Sayısı. Ankara, Turkey, TÜİK; 2012. Available from http://www.tuik.gov.tr/VeriBilgi.do?alt_id=14 (report in Turkish).
2. Tekbaş ÖF, Vaizoğlu SA. Okul Çevre Sağlığı. Ankara, Turkey: Yazıt Yayıncılık; 2008 (book in Turkish).
3. Tekbaş ÖF. Okul çevre sağlığı. In: Tekbaş ÖF editor. Çevre sağlığı. Ankara, Turkey: Gülhane Askeri Tıp Akademisi Basımevi; 2010. p.261–298 (book chapter in Turkish).
4. Jones SE, Fisher CJ, Greene BZ, Hertz MF, Pritzl J. Healthy and safe school environment, Part I: Results from the School Health Policies and Programs Study 2006. J Sch Health 2007; 77: 522–543.
5. Pekcan H. Okul sağlığı. In: Güler Ç, Akın L, editors. Halk Sağlığı Temel Bilgiler. Ankara, Turkey: Hacettepe Üniversitesi Yayınları; 2006. p.454–479 (book chapter in Turkish).
6. Akın A, Hodoğlugil N, Koçoğlu G, Supramaniam DA, Aydın Y, Bacanlı A, Barut C, Başar K, Çağlar P. Altındağ merkez sağlık ocağı bölgesindeki beş ilkögretim okulundaki okul sağlığı uygulamalarının değerlendirilmesi. Hacettepe Toplum Hekimliği Bülteni 2000; 3 (article in Turkish).
7. American Academy of Pediatrics Council on Environmental Health. Schools. In: Etzel RA, editor. Pediatric Environmental Health. 3rd ed. Elk Grove Village, IL, USA: American Academy of Pediatrics; 2012. p.133–150.
8. American Academy of Pediatrics Council on Environmental Health. Child care settings. In: Etzel RA, editor. Pediatric Environmental Health. 3rd ed. Elk Grove Village, IL, USA: American Academy of Pediatrics; 2012. p.109–131.

9. Godwin C, Batterman S. Indoor air quality in Michigan schools. Indoor Air 2007; 17: 109–121.

10. Gitterman BA, Bearer CF. A developmental approach to pediatric environmental health. In: Davis C, Paulson JA, editors. The Pediatric Clinics of North America: Children's Environmental Health. Orlando, FL, USA: WB Saunders Company; 2001. p.1071–1083.

11. Jones SE, Axelrad R, Wattigney WA. Healthy and safe school environment, Part II: Results from the School Health Policies and Programs Study 2006. J Sch Health; 2007; 77: 544–556.

12. Landrigan PJ. Children's environmental health. In: Davis C, Paulson JA, editors. The Pediatric Clinics of North America: Children's Environmental Health. Orlando, FL, USA: WB Saunders Company; 2001. p.1319–1330.

13. Wigle DT, Arbuckle TE, Walker M, Wade MG, Liu S, Krewski D. Environmental hazards: evidence for effects on child health. J Toxicol Environ Health B 2007; 10: 3–39.

14. Türk Standartları Enstitüsü. Türk Standardı 9518. İlköğretim Okulları Fiziki Yerleşim Genel Kurallar. Ankara, Turkey: Türk Standartları Enstitüsü; 2000 (standard in Turkish).

15. Türk Standartları Enstitüsü. Türk Standardı 12014. Çevre Sağlığı - Okullar. Ankara: Türk Standartları Enstitüsü; 1996 (standard in Turkish).

16. Cummins SK, Jackson RJ. The built environment and children's health. In: Davis C, Paulson JA, editors. The Pediatric Clinics of North America: Children's Environmental Health. Orlando, FL, USA: WB Saunders Company; 2001. p.1241–1252.

17. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 2000; 32: 963–975.

18. World Health Organization Regional Office for Europe. European Series, No. 91. Air Quality Guidelines for Europe. 2nd ed. Geneva, Switzerland: WHO; 2000. Available from www.euro.who.int/document/e71922.pdf.

19. Santamouris M, Synnefa A, Asssimakopoulos M, Livada I, Pavlou K, Papaglastra N, Gaitani D, Kolokotsa D, Assimakopoulos V. Experimental investigation of the air flow and indoor carbon dioxide concentration in classrooms with intermittent natural ventilation. Energy Buildings 2008; 40: 1833–1843.

20. Daisey JM, Angell WJ, Apte MG. Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. Indoor Air 2003; 13: 53–64.

21. Otto DA, Hudnell HK, House DE, Mølhave L, Counts W. Exposure of humans to a volatile organic mixture. I. Behavioral assessment. Arch Environ Health 1992; 47: 23–30.

22. Douglas JWB, Ross JM. The effects of absence on primary school performance. Br J Educ Psychol 1965; 35: 28–40.

23. Weitzman M, Klerman LV, Lamb G, Menary J, Alpert JJ. School absence: a problem for the pediatrician. Pediatrics 1982; 69: 739–746.

24. O'Neil SL, Barysh N, Setear SJ. Determining school programming needs of special population groups: a study of asthmatic children. J Sch Health 1985; 55: 237–239.

25. Silverstein MD, Mair JE, Katusic SK, Wollan PC, O'Connell EJ, Yunginger JW. School attendance and school performance: a population-based study of children with asthma. J Pediatr 2001; 139: 278–283.

26. Pilotto LS, Douglas RM, Attewell RG, Wilson SR. Respiratory effects associated with indoor nitrogen dioxide exposure in children. Int J Epidemiol 1997; 26: 788–796.

27. Fabian MP, Miller SL, Reponen T, Hernandez MT. Ambient bioaerosol indices for indoor air quality assessments of flood reclamation. J Aerosol Sci 2005; 36: 763–783.

28. Franchi M, Carrer P. Indoor air quality in schools: the EFA project. Monaldi Arch Chest Dis 2002; 57: 120–122.

29. Liu LJ, Krahmer M, Fox A, Feigley CE, Featherstone A, Saraf A, Larsson L. Investigation of the concentration of bacteria and their cell envelope components in indoor air in two elementary schools. J Air Waste Manag Assoc 2000; 50: 1957–1967.

30. Kim KY, Kim CN. Airborne microbiological characteristics in public buildings of Korea. Build Environ 2007; 42: 2188–2196.

31. Bates JM, Mahaffy DJ. Relationship of reported allergy symptoms, relative humidity, and airborne biologicals in thirteen Florida classrooms. Proceedings of the 7th International Conference on Indoor Air Quality and Climate, Nagoya, Japan; 1996.

32. Lee SC, Chang M. Indoor and outdoor air quality investigation at schools in Hong Kong. Chemosphere 2000; 41: 109–113.

33. Rao CY, Burge HA, Chang JCS. Review of quantitative standards and guidelines for fungi in indoor air. J Air Waste Manag Assoc 1996; 46: 899–908.