Assessment of indoor air quality in different indoor environments

Summary of PhD dissertation

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Introduction

Air pollution is currently the most important environmental health problem, causing 8,000 to 12,000 premature deaths per year in Hungary. People spend a significant proportion of their time, approximately 80-90%, indoors; thus, ensuring good indoor air quality (IAQ) is of paramount importance to protect human health. IAQ is recently unregulated in numerous regions worldwide, including Hungary. However, the World Health Organization (WHO) and several European Union countries have established guidelines or limit values for indoor concentrations of various air pollutants. The air quality in the indoor environments can vary significantly due to various factors, including indoor pollutant sources, outdoor air quality, air change rates, chemical reactions, and the implementation of techniques used for the removal of air pollutants.

The school environment, in addition to the outdoor and home environments, has a significant impact on the health of schoolchildren, who spend an average of 6-8 hours in school each day. As children are one of the most vulnerable populations, it is crucial to closely monitor the impact of the indoor environment on their well-being and health. Over the past two decades, numerous national and international projects have focused on investigating IAQ in primary schools and assessing the impact of indoor air pollutants on children's health. The results of these studies revealed persistent problems with IAQ in school buildings, with classrooms often having higher concentrations of certain air pollutants compared to the corresponding outdoor levels.

As the ongoing global energy crisis escalates the cost of building maintenance and the detrimental effects of environmental pollution are continuously intensifying, energy-efficient building solutions, particularly the Passive House technology, are gaining significant attention. Consequently, the Passive House technology has become a prominent architectural solution worldwide. As with any emerging technology, the question arises as to whether Passive Houses can provide, besides energy saving, better IAQ compared to conventional houses. Conducting research on the most critical air pollutants can assist professionals in designing buildings that effectively mitigate or minimize the sources of these pollutants.

Objectives

The research projects focused on the assessment of the indoor air quality and the associated health risks in primary schools and passive buildings.

In the framework of the InAirQ project (*Transnational Adaption Actions for Integrated Indoor Air Quality Management*), the indoor and outdoor air quality of 64 primary schools across five Central European countries (Czech Republic, Hungary, Italy, Poland and Slovenia) was investigated during the heating season of 2017/2018. The measurements were carried out in one classroom and one outdoor sampling site per school within each selected primary school. The study aimed to assess IAQ parameters and to evaluate the associated non-carcinogenic and carcinogenic health risks associated with the indoor concentrations of the investigated air pollutants. In addition, the relationship between indoor air pollutant concentrations and children's health by using a questionnaire to assess the health status of the children in the monitored classrooms.

The Directive 2010/31/EU states that from January 2021 all new buildings in the European Union should use energy-saving techniques and be 'nearly net zero energy buildings'. Consequently, the requirements, standards, and energy legislation for new buildings in Hungary are progressively becoming more stringent. In such energy-efficient buildings, which are characterized by specific mechanical design, airtight windows, and sufficient thermal insulation, the air change rate is often low. This reduced air change rate can lead to the accumulation of indoor air pollutants originating from indoor sources, potentially negatively affecting the health of the occupants. Recognizing these concerns, the National Public Health Center conducted a survey between 2019 and 2021 to assess the air quality in Passive Houses across Hungary. Thus, the main objectives of this study were (i) to measure physical and chemical parameters in 15 Passive Houses in Hungary; (ii) to evaluate the seasonal variation of IAQ; (iii) to compare the concentrations of the investigated air pollutants with the health-based reference values established by international organizations and with the results obtained in other studies; and (iv) to identify the main IAQ problems in these buildings.

Materials and methods

I. Characterization of indoor and outdoor air quality in primary school buildings

The selection of the school buildings was based on some criteria developed during the InAirQ project, i.e. the selected school buildings must represent (i) the building stock of the country/region in terms of typology, construction technology, and age; (ii) the ventilation type applied in the country/region; and (iii) the location of the school buildings. The selection of classrooms was also based on a pre-defined set of criteria. In each school building, one classroom was selected to best represent the characteristics of the majority of classrooms in the building. In total, sixty-four primary school buildings were investigated in the Czech Republic (n = 12), Hungary (n = 16), Italy (n = 12), Poland (n = 12), and Slovenia (n = 12). The InAirQ detailed sampling campaign was carried out in the heating period of 2017/2018 (from the November 6, 2017, until the April 6, 2018) for 5 consecutive days in each primary school building. The IAQ was investigated from Monday morning to Friday afternoon; however, the sampling took place only when the classroom was occupied (from 6 to 8 h daily) in order to provide a better estimate of exposure. The list of indoor air pollutants to be investigated in the school buildings was based on the accumulated knowledge on the concentrations of air pollutants in public settings for children and their health relevance. Concentrations of ten VOCs (benzene, toluene, ethylbenzene, xylenes, trichloroethylene, tetrachloroethylene, *α*-pinene, *d*-limonene, 2-ethylhexanol and styrene), five aldehydes (formaldehyde, acetaldehyde, propionaldehyde, benzaldehyde and hexanal), particulate matter with an aerodynamical diameter smaller than 2.5 μm ($PM_{2.5}$), carbon dioxide, radon, and physical parameters (temperature and relative humidity) were measured in the study. In addition to the investigation of IAQ, a questionnaire was used to survey the prevalence of allergy and the occurrence of past-year asthma-like and recent (<3 months) respiratory, ocular, dermal and general symptoms of the children in the monitored classroom. A questionnaire, administered to the parents or legal guardians, was used alongside the IAQ assessment to investigate the prevalence of allergies and the occurrence of asthma-like symptoms within the past year. Additionally, recent (<3 months) respiratory, ocular, dermal, and general symptoms among the children in the monitored classroom were surveyed.

Sampling devices were placed at a height ranging from approximately 0.8 to 1 m above the floor, aligning with the breathing zone of seated children, following the guidelines outlined in ISO 16000-1:2004. Whenever feasible, the devices were placed in the center of the classroom, but always at least 1 m from the walls or windows. Simultaneously, sampling and monitoring were undertaken outdoors with identical samplers and monitors at each building. The outdoor location was chosen preferably either at the air intake of the mechanical ventilation system or at the same height as the floor level of the selected classroom.

Radiello® passive samplers were applied for the sampling of volatile organic compounds (VOCs) and aldehydes. Sampling started in the morning and finished when the pupils left the classroom each day. This procedure was repeated on the other weekdays with the same sampler resulting in a total sampling time of between 30 and 40 h depending on the occupancy of the classroom. A thermal desorption-gas chromatography-mass spectrometry method was applied to determine the concentration of the target VOCs according to the ISO 16017–2:2003 standard. The aldehyde samples were analyzed by liquid chromatography with UV detection after sample preparation according to the ISO 16000–4:2011 standard. $PM_{2.5}$ samples were collected by low-volume aerosol samplers operating at a flow rate of either 10 L min^{-1} onto quartz fiber filters (Ø 37 or 47 mm, Pallflex® Tissuquartz). After sampling, the mass of the filters was determined gravimetrically. In the case of radon, one CR-39 type trace detector (RSKS Type) was placed at each investigated classroom for 3 months, and then analyzed according to the ISO 11665-4:2012 standard. Carbon dioxide concentration, temperature and relative humidity were continuously monitored by calibrated devices with a data logger.

After sampling, the samplers (Radiello® passive samplers, loaded quartz fiber filters, CR-39 type trace detector) were sent in cooled packages to the National Public Health Center. All samples were analyzed at the National Public Health Center, which served as the central laboratory for the project.

II. Characterization of indoor and outdoor air quality in Hungarian Passive Houses

The detailed sampling campaign was carried out between 2019 and 2021 in both the heating and non-heating seasons. The field campaign was carried out over 7 days in each passive building in each season. The investigation of air quality parameters was conducted in 15 Hungarian Passive Houses. The concentrations of ten VOCs (benzene, toluene, ethylbenzene, xylenes, trichloroethylene, tetrachloroethylene, α-pinene, limonene, 2-ethylhexanol, styrene), five aldehydes (formaldehyde, acetaldehyde, propionaldehyde, benzaldehyde, hexanal), $PM_{2.5}$ mass, carbon dioxide, ozone, nitrogen dioxide, as well as temperature, relative humidity, air change rate were investigated simultaneously at one indoor location and outdoors in each site. A checklist was used to describe each sampling site in terms of general information, ventilation, building materials, quality of the surrounding environment, furniture, daily activities in the dwelling, etc.

The monitoring campaign was designed according to the ISO 16000–1:2004 standard. The samplers and the monitors were placed in the center of the living room, at a height of approximately 1–1.5 m above the floor level and not closer than 1 m to any walls or other factors (e.g., ventilation ducts, windows) that could significantly influence the results. Simultaneously, sampling and monitoring were undertaken outdoors with identical samplers and monitors. The outdoor location was chosen close to the air intake of the ventilation system.

Radiello® passive samplers were applied for the sampling of VOCs and aldehydes. Sampling started in the morning of a weekday and finished one week later resulting in a total sampling time of approximately 168 h. The determination of the concentration of the target VOCs was performed on gas chromatographic (GC) system equipped with a flame ionization detector (FID) according to the ISO 16200–2:2000 standard. The aldehyde samplers were analyzed by high-performance liquid chromatography (HPLC) - UV detection method after sample preparation according to the ISO 16000–4:2011 standard. The $PM_{2.5}$ samples were collected by low volume aerosol samplers operating at a flow rate of 10 L min^{-1} onto quartz fiber filters (Ø 37 mm, Pallflex® Tissuquartz). After sampling, the mass of the filters was weighed on a microbalance. The concentrations of ozone, nitrogen dioxide and carbon dioxide, as well as physical parameters (temperature, relative humidity, air flow rate) were monitored with calibrated devices.

III. Statistical data evaluation for both studies

The statistical analyses were performed by the IBM SPSS Statistics software package (version 24.0; IBM Corporation, Armonk, NY, USA) and the STATISTICA software package (version 7.1; StatSoft Inc.). The Shapiro–Wilk test was used to determine the distribution of the data, which influenced the selection of the statistical method used for analysis. A p-value below 0.05 was considered statistically significant.

Regarding the InAirQ project, the non-parametric Kruskal–Wallis and the Mann–Whitney U tests were used to investigate significant spatial differences in IAQ across the countries if data showed non-normal distribution. Otherwise, one-way ANOVA and two-sample t tests were applied. Spearman's rank correlation coefficients and the corresponding p-values were produced to show the relationship between the indoor and outdoor concentrations of each air pollutant and also between the comfort parameters.

The potential health effects of IAQ in the classrooms studied were assessed by calculating both non-carcinogenic risks (hazard quotient, hazard index, maximum cumulative ratio) and carcinogenic risk (excess lifetime cancer risk) using different methods. Hazard quotient (HQ) was calculated to evaluate the non-carcinogenic risk for each compound. The HQ evaluates the risks on a substance-by-substance basis and does not provide information on the risk caused by the combined health effects due to exposure to different substances. Thus, the health risk associated with the co-exposure to multiple air pollutants was assessed with the hazard index (HI), which is the sum of the HQ values. However, the HI alone does not provide information on whether the health risk is driven by one or more substances. Therefore, the maximum cumulative ratio (MCR) was also calculated to assess the combined effect of multiple substances. Excess lifetime cancer risk (ELCR) values were calculated to determine carcinogenic risk. ELRC values are considered acceptable if they are below the recommended acceptable risk threshold (1×10^{-6}) for the lifetime exposure (70 years) to a substance, as set by the US Environmental Protection Agency (US EPA). However, it should be noted that the assessment solely accounted for exposure within the monitored microenvironment and did not consider exposure to air pollutants in other microenvironments (e.g., home) and outdoors, due to the absence of corresponding exposure data. Therefore, I defined a case-specific acceptable risk value (1.88×10^{-8}) based on a time proportion basis (8 hours per day, 180 days per year, and 8 years).

Based on the completed questionnaire by parents, chi-square test was used to analyze the variations and similarities in the health status of schoolchildren among the surveyed countries. In addition, logistic regression analyses were performed to investigate the associations between IAQ parameters and the reported recent health symptoms.

For passive buildings, a paired Wilcoxon test was performed to determine whether there was a significant difference between the medians of the air quality parameters measured during the heating and non-heating periods.

Results, statements of the thesis

I. Characterization of indoor and outdoor air quality in primary school buildings [1, 2]

T1. I determined the indoor and outdoor concentrations of VOCs (n=10), aldehydes (n=5), $PM_{2.5}$, carbon dioxide and radon, as well as comfort parameters in 64 primary school buildings across 5 Central European countries. I observed significant spatial differences in the concentration of several indoor air pollutants across the countries. The results of the InAirQ project revealed that most of the measured VOCs were present at significantly higher concentrations in the Italian primary school buildings compared to those measured in other countries. Furthermore, significantly higher $PM_{2.5}$ mass (median: 46 μg m^{-3}) and radon concentrations (median: 145 Bq m^{-3}) were observed in the Hungarian and Slovenian school buildings, respectively, compared to the classrooms studied in the other countries. Most of the investigated schools (n = 52) could not manage to comply with the recommended concentration range (i.e., below 1000 ppm) for carbon dioxide, indicating inadequate ventilation. Spatial variation was obtained also in the case of the comfort parameters (temperature and relative humidity) across the countries. The highest temperature values were measured in the Czech Republic (mean: 23.7°C), while the lowest values were recorded in Poland (mean: 21.4°C). Based on the results of the monitoring campaign, 44% (n = 28) of the mean temperature values recorded in the classrooms were outside the suggested range (20-23°C). Overheating was observed in 38% of the cases. The highest and the lowest relative humidity values were recorded in Slovenia (mean: 39.9%) and in Italy (mean: 30%), respectively. The mean relative humidity was below the recommended range in 80% (n = 51) of the school buildings, while it never exceeded the upper limit. I compared the results of the InAirQ study with international studies conducted in school buildings over the past two decades. The findings revealed that the major IAQ-related problems observed in Central Europe were common and similar across the investigated buildings. This suggests the lack of implementation of the risk reduction measures formulated in previous projects.

T2. The median indoor/outdoor concentration ratios for VOCs ranged from 0.93 (benzene) to 23.2 (limonene), while for aldehydes, the ratios varied from 1.62 (propionaldehyde) to 7.86 (acetaldehyde). Based on the results, I determined that several VOCs and aldehydes have significant indoor sources and accumulate in the indoor environment due to the low air change rate (median value of 1.49 h^{-1}). The median indoor/outdoor $PM_{2.5}$ mass concentration ratios varied between 0.76 and 1.34 across the countries, indicating that the fine particles were mostly of outdoor origin.

T3. I evaluated both the carcinogenic and non-carcinogenic health risks associated with the measured air pollutants. All HQ values were below the threshold value of 1 (with one exception for 2-ethylhexanol (1.88)), which indicates that neither the investigated VOCs nor the aldehydes posed individually a significant non-carcinogenic health risk by using this substance-by-substance approach. In contrast, 31% (n = 20) of the school buildings were characterized by HI values higher than 1, indicating that the combined exposure to indoor air pollutants might posed considerable health risk in some cases. The MCR values ranged widely, from 1.7 to 6.9. Almost all cases were either in Group II (n = 44; 68.8%) or in Group IIIB (n = 18; 28.1%), indicating that the concern for non-carcinogenic health effects attributable to the investigated VOCs and aldehydes was either low or the health risk was driven by more substances, respectively. On average, 81 and 95% of the indoor $PM_{2.5}$ mass concentration values exceeded the short-term (24-h mean; 15 µg m^{-3}) and long-term (annual mean; 5 µg m^{-3}) guideline values set by the WHO in 2021. The median values of ELCR for radon and formaldehyde exceeded the recommended acceptable value of 1×10^{-6} set by the US EPA. In the case of acetaldehyde, benzene, and ethylbenzene, the ELCR values were higher than the case-specific acceptable value (1.88×10^{-8}) in 100, 100, and 79% of the school buildings, respectively.

T4. As part of the InAirQ project, children's health status and symptoms were assessed using parent-reported questionnaires. The questionnaire was used to survey the prevalence of allergy and the occurrence of doctor-diagnosed asthma and asthma-like symptoms, as well as recent (<3 months) respiratory, ocular, dermal, and general symptoms of the children in the monitored classroom. In total, 1084 questionnaires were completed by the parents or the legal guardians. I identified significant spatial differences in the reported symptoms. While the highest frequencies of doctor-diagnosed asthma and asthma-like symptoms were reported among the Slovenian schoolchildren, the highest occurrences of recent respiratory, dermal and general symptoms (headache, feeling cold, fatigue) were found in Poland

T5. I used logistic regression analyses to investigate the associations between IAQ parameters and the reported recent health symptoms. The evaluation of the associations between indoor air pollutants and respiratory symptoms revealed significant associations between the prevalence of respiratory symptoms and the concentrations of aldehydes, $PM_{2.5}$, carbon dioxide, and the HI. Elevated levels of aromatic hydrocarbons were linked to a higher occurrence of dermal symptoms. Significant associations were found between the general symptoms (headache and fatigue) and the levels of air stuffiness, and hexanal concentrations. Previous studies investigating the associations between IAQ and health symptoms of schoolchildren have created a substantial knowledge; however, there were still inconsistencies and knowledge gaps. Our results confirmed some previous findings and also extended the existing knowledge in the field.

II. Characterization of indoor and outdoor air quality in Hungarian Passive Houses [3]

T6. I determined the indoor and outdoor concentrations of VOCs (n=10), aldehydes (n=5), $PM_{2.5}$, ozone, nitrogen dioxide, carbon dioxide as well as physical parameters in 15 Hungarian Passive Houses. In almost all cases, the outdoor concentrations of benzene, $PM_{2.5}$, ozone, and nitrogen dioxide exceeded the indoor values, suggesting that these pollutants primarily originate from outdoor sources. In contrast, the other measured VOCs and aldehydes exhibited higher concentrations in the indoor environment. I observed significant seasonal differences for all physical parameters (temperature, relative humidity, air change rate), for certain VOCs (benzene, α-pinene, limonene) and acetaldehyde. During the non-heating season, the physical parameters exhibited higher values, whereas the heating period showed higher concentrations for the majority of the investigated air pollutants. The weekly mean indoor temperature values ranged between 23.2 and 28.2 °C in the non-heating season, while mean values varying between 22.2 and 25.8 °C were obtained in the heating season. The weekly mean relative humidity values ranged between 32.4 and 61.0% during the non-heating season, while significantly lower values varying between 30.0 and 53.8% were obtained during the heating season. The median air change rates of 0.52 and 0.47 h^{-1} were obtained in the non-heating and heating seasons, respectively. In both seasons, limonene was present in the highest concentration among the investigated VOCs in the dwellings, with median values of 11.4 and 48.8 $\mu g\ m^{-3}$ in the non-heating and heating seasons, respectively. The other investigated terpene, α-pinene, also showed high concentrations with median values of 10.3

and 16.2 μg m^{-3} in the non-heating and heating seasons, respectively. The seasonal difference was significant for both terpenes. The concentration of benzene was significantly higher in the heating season (1.87 μg m^{-3}) compared to the non-heating season (0.79 μg m^{-3}). Among the aldehydes, significant seasonal variation was obtained only for acetaldehyde, which was present in higher concentrations in the heating season (17.0 μg m^{-3} vs. 11.1 μg m^{-3}). As a result, it can be stated that residents may be exposed to elevated levels of certain air pollutants during the heating season.

T7. I evaluated the potential non-carcinogenic health effects of the air pollutants by comparing the measured concentrations with air quality guidelines, thresholds or national target/limit values. The indoor concentrations of $PM_{2.5}$ and nitrogen dioxide in the investigated Passive Houses exceeded the annual guideline values set by the WHO in all cases. However, for the other air pollutants, such as trichloroethylene, α-pinene, propionaldehyde, and benzaldehyde, the measured values only exceeded the recommended chronic reference values in a few cases.

T8. To the best of my knowledge, this study represents the first comprehensive investigation of air quality parameters in Passive Houses used for residential purposes in Hungary. Furthermore, only a limited number of studies are available in the literature that have conducted detailed IAQ measurements. Overheating, the lack of proper particle filters in the mechanical ventilation system, and low air change rate and relative humidity were identified as frequent problems related to the building characteristics. The emissions from building materials and furniture, the proximity of construction works and unpaved roads might considerably influence IAQ. The results highlight that risk reduction measures are needed to create healthier indoor environment in the Passive Houses. The results highlight the importance of increasing the air exchange rate, conducting regular maintenance of air handling units, and reducing sources of air pollutants to improve IAQ in passive buildings.

Papers forming the basis of the dissertation

Papers published in peer-reviewed international journals:

1. **Szabados, M.**, Csákó, Z., Kotlík, B., Kazmarová, H., Kozajda, A., Jutraz, A., Kukec, A., Otorepec, P., Dongiovanni, A., Di Maggio, A., Fraire, S., Szigeti, T. (2021). Indoor air quality and the associated health risk in primary school buildings in Central Europe – The InAirQ study. Indoor Air, 31(4), 989–1003.
   https://doi.org/10.1111/ina.12802
   IF = 6.554 (D2) (2021)
2. **Szabados, M.**, Kakucs, R., Páldy, A., Kotlík, B., Kazmarová, H., Dongiovanni, A., Di Maggio, A., Kozajda, A., Jutraz, A., Kukec, A., Otorepec, P., Szigeti, T. (2022). Association of parent-reported health symptoms with indoor air quality in primary school buildings – The InAirQ study, Building and Environment, 221, 109339.
   https://doi.org/10.1016/j.buildenv.2022.109339
   IF: 7,093 (D2) (2021)
3. **Szabados, M.**, Magyar, D., Tischner, Zs., Szigeti, T. (2023). Indoor air quality in Hungarian Passive Houses, Atmospheric Environment, 307, 119857.
   https://doi.org/10.1016/j.atmosenv.2023.119857
   IF: 5,755 (Q1) (2023)

Paper published in national journal:

1. **Szabados, M.**, Csákó, Z., Kotlík, B., Kazmarová, H., Kozajda, A., Jutraz, A., Kukec, A., Otorepec, P., Dongiovanni, A., Di Maggio, A., Fraire, S., Szigeti, T. (2021). Általános iskolák beltéri levegőminősége Közép-Európában - Az InAirQ projekt. Egészségtudomány, 65(2): 51-71.
   https://doi.org/10.29179/EgTud.2021.2.51-71

Other papers

1. Lange, R., Vogel, N., Schmidt, P., Gerofke, A., Luijten, M., Bil, W., Santonen, T., Schoeters, G., Gilles, L., Sakhi, A. K., Line, S. H., Jensen, T. K., Frederiksen, H., Holger, M. K., Szigeti, T., **Szabados, M.,** Tratnik, J. S., Mazej, D., Gabriel, C., Sarigiannis, D., Dzhedzheia, V., Karakitsios, S., Rambaud, L., Riou, M., Koppen, G., Covaci, A., Zvonař, M., Piler, P., Klánová, J., Fábelová, L., Richterová, D., Kosjek, T., Runkel, A., Pedraza-Díaz, S., Verheyen, V., Bastiaensen, M., Esteban-López, M., Castaño, A., & Kolossa-Gehring, M. (2022). Cumulative risk assessment of five phthalates in European children and adolescents. International Journal of Hygiene and Environmental Health, 246, 114052.
   https://doi.org/10.1016/j.ijheh.2022.114052
   IF: 7,401 (2021)

Conference attendances

Presentations:

1. **Beltéri levegőminőség általános iskolákban – Az InAirQ projekt**
   Szabados Máté, Csákó Zsófia, Balogh Boglárka Sára, Középesy Szilvia, Magyar Donát, Rudnai Péter, Páldy Anna, Szigeti Tamás
   Népegészségügyi Képző- és Kutatóhelyek Országos Egyesületének XII. Konferenciája
   2018. augusztus 29-31., Budapest

2. **Nemzetközi együttműködés általános iskolák beltéri levegőminőségének javítására - Az InAirQ projekt**
   Szabados Máté, Csákó Zsófia, Balogh Boglárka Sára, Szigeti Tamás
   Magyar Higiénikusok Társasága XLV. Vándorgyűlése
   2018. október 8-10., Budapest

3. **Health risk of indoor air pollutants in primary school buildings in Central Europe**
   Máté Szabados, Bohumil Kotlik, Helena Kazmarová, Anna Kozajda, Anja Jutraz, Andreja Kukec, Peter Otorepec, Arianna Dongiovanni, Andrea Di Maggio, Tamás Szigeti
   Joint meeting of the International Society Of Exposure Science and the International Society Of Indoor Air Quality And Climate
   2019. augusztus 18-22., Kaunas, Litvánia

4. **A beltéri levegőminőség javításának lehetőségei általános iskolákban – Az InAirQ projekt**
   Szabados Máté, Szigeti Tamás
   Magyar Higiénikusok Társaságának LXVI. Vándorgyűlése
   2019. október 1-3., Sarlóspuszta

5. **A lakosság allergiás érintettségének felmérése**
   Szigeti Tamás, Páldy Anna, Szabados Máté, Málnási Tibor
   Magyar Higiénikusok Társaságának XI. Nemzeti Kongresszusa
   2021. szeptember 28-29., Budapest

6. **Lágyítószerek biomarkerei általános iskolás gyermekek vizeletében**
   Szigeti Tamás, Szabados Máté, Kakucs Réka, Középesy Szilvia, Csákó Zsófia
   Magyar Higiénikusok Társaságának XI. Nemzeti Kongresszusa
   2021. szeptember 28-29., Budapest

7. **Általános iskolák beltéri levegőminősége és a gyermekek egészségi állapota közötti kapcsolat – Az InAirQ projekt**
   Szabados Máté, Kakucs Réka, Páldy Anna, Szigeti Tamás
   XIV. Fiatal Higiénikusok Fóruma
   2022. május 13., Budapest

8. **Közép-európai általános iskolák beltéri levegőminősége és a gyermekek akut tünetei közötti kapcsolat - Az InAirQ projekt**
   Szabados Máté, Kakucs Réka, Páldy Anna, Szigeti Tamás
   Magyar Higiénikusok Társaságának LXVII. Vándorgyűlése
   2022. szeptember 12-13., Balatonakarattya

Posters:

1. **Indoor air quality in primary school buildings across Central Europe – The InAirQ study**
   Máté Szabados, Zsófia Csákó, Anna Kozajda, Andreja Kukec, Anja Jutraz, Peter Otorepec, Bohumil Kotlik, Helena Kazmarová, Arianna Dongiovanni, Andrea Di Maggio, Péter Rudnai, Tamás Szigeti
   Indoor Air Toxicology - International Conference on Risk Assessment of Indoor Air Chemicals
   2018. szeptember 16-18., Berlin

2. **Illékony szerves vegyületek és aldehidek meghatározása általános iskolákban – Az InAirQ projekt**
   Szabados Máté, Csákó Zsófia, Balogh Boglárka Sára, Szigeti Tamás
   Elválasztástudományi Vándorgyűlés
   2018. november 8-10., Tapolca

3. **Evaluating the health risk of indoor air pollutants in Central European primary schools**
   Máté Szabados, Bohumil Kotlik, Helena Kazmarová, Anna Kozajda, Anja Jutraz, Andreja Kukec, Peter Otorepec, Arianna Dongiovanni, Andrea Di Maggio, Tamás Szigeti
   International Conference on Integrated Problem-Solving Approaches to Ensure Schoolchildren's Health
   2019. május 23-24., Budapest

4. **Attempt for indoor air quality improvement in a primary school by an air cleaner**
   Máté Szabados, Zsófia Csákó, Tamás Szigeti
   International Conference on Integrated Problem-Solving Approaches to Ensure Schoolchildren's Health
   2019. május 23-24., Budapest

5. **Levoglükozán a vizeletben: a fatüzelés egy lehetséges biomarkerének nyomában**
   Csákó Zsófia, Nyiri Zoltán, Szabados Máté, Erdélyi Norbert, Balogh Boglárka Sára, Kakucs Réka, Szigeti Tamás
   Magyar Higiénikusok Társaságának XI. Nemzeti Kongresszusa
   2021. szeptember 28-29., Budapest

6. **Passzív épületek levegőminősége**
   Szabados Máté, Magyar Donát, Szigeti Tamás
   Magyar Higiénikusok Társaságának XI. Nemzeti Kongresszusa
   2021. szeptember 28-29., Budapest