

THE QUALITY OF INDOOR AIR IN CLASSROOM

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Abstract: *This paper investigates the problematic of quality indoor air in classrooms. The main goal of this research is determination quality and quantity emission VOC (Volatile organic compounds) emitted by indoor air of the various kind of classrooms. The measurements were done continuously during two year seasons (summer and autumn) and three locations (Mendel University in Brno, grammar school in Brno, secondary school in Opava). The results were evaluated quantitatively and qualitatively. Quantitative difference of entire emitted organic compounds showed the measured values of TVOC. The testing was focused also on the contain of the VOC emitted blends e.g. benzene, toluene, ethyl benzene, xylene and terpene (limonene). Measured amounts of VOC were compared with results of indoor air quality in classrooms without any workshops in the same building. All reached results were compared with limits mandated in the standard of Ministry of Health of the Czech Republic.*

Key words: *VOC, gas chromatography, classroom, indoor air, TVOC*

Introduction

Influence emissions VOC on human health

The emissions of chemicals into the air with environmental impact have been exponentially growing in the recent decades both as to the quantities and diversity of released chemical compounds. People of the current middle-age group are the first generation that has been exposed daily to the effects of chemical air pollutants for their entire lives since birth. They thus are becoming the first test group in studies of the impact of environment upon human health. The effects of the slow acting chemicals may become apparent only after long-term exposures.

The so-called Volatile Organic Compounds (VOC) are among the largest pollution sources of both the internal and external environments. Some of the identified and measured 50 to 300 volatile chemicals in the air of interiors were shown to be carcinogenic and dangerous to the human health

The VOC play significant role in evolvement of newly recognized sicknesses and illnesses. So far two conditions have been recognized: Sick Building Syndrome (SBS) and Building Related Illness (BRI). The SBS is manifested by a number of symptoms

such as nausea dizziness, hyperactivity reaction, eye, nose or throat irritation, pulmonary effects, dry cough, dry itchy skin, sensitivity to odours, fatigue and difficulty in concentrating. Most of the complainants report relief soon after leaving the causative building. The term BRI is used when symptoms of diagnosable illness are identified and can be attribute directly to airborne building contaminants. Indicators of BRI include symptoms such as cough, chest tightness, fever chills and muscle aches. Complainants may require prolonged recovery times after leaving the polluted building environment.

There were mandated limits of seriously dangerous organic chemicals in classrooms indoor air of in the standard MZCR 6/2003. Emissions limits are in the table 1.

Table 1: Emissions limits in Czech republic

| Volatile organic compounds | Formula | PEL (permissible exposition limit) long-term [$\mu\text{g}\cdot\text{m}^{-3}$] |
|-----------------------------------|--|--|
| Benzene | C_6H_6 | 7 |
| Toluene | $\text{C}_6\text{H}_5\text{CH}_3$ | 300 |
| o,m,p-Xylene | $\text{C}_6\text{H}_4(\text{CH}_3)_2$ | 200 |
| Styrene | $\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$ | 40 |
| Ethylbenzene | $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$ | 200 |
| Formaldehyde | HCHO | 60 |
| Trichlorethylene | CCl_2CHCl | 150 |
| Tetrachlorethylene | CCl_2CCl_2 | 150 |

In the connection with the term VOC there is the new term TVOC (total volatile organic compounds) which is used to describe the total amount of volatile organic compounds in the indoor atmosphere. The TVOC value indicates the level of indoor air pollution.

The TVOC value can be obtained on the gas chromatograph as the sum of all peak areas of all VOCs which are emitted between hexane and hexadecane, which is calibrated to the value which is equivalent to the toluene.

Table 2: Requirements determinate for the amount of TVOC in indoor air (Jokl, 2002)

| Toxic VOC | PEL average [$\mu\text{g}\cdot\text{m}^{-3}$] | | PEL optimal [$\mu\text{g}\cdot\text{m}^{-3}$] | | Annotation |
|------------------|---|-----------|---|-----------|---|
| | short-term | long-term | short-term | long-term | |
| Formaldehyde | 120 | 60 | 60 | 60 | |
| TVOC | 600 | 300 | 300 | 300 | Component VOC could not exceed the limit mandated in the standard MZCR 6/2003 |

Goal of the Research

The contribution deals with emissions of volatile organic substances volatilize to sojourn environment. The main of goal of this research is determination quality and quantity emission VOC (Volatile organic compounds) emitted by indoor air of the various kind of classrooms.

The measurement of volatile organic compounds was kept in the long range, during two seasons (summer, autumn) and three locations (Mendel University in Brno, grammar school in Brno, secondary school in Opava). The article investigates the influence the VOC emissions emitted into the indoor air during the working exercises in the school workshop on the quality and quantity VOC emissions in the indoor air of the classrooms in the same building. The results of these measurements are compared with the results of the VOC emissions measurements contained in the indoor air of classrooms situated in the building without school workshops. In the contribution there is solved the question of the influence outdoor air on the quality of indoor air.

Materials, equipment and methods

Assessment rooms

- classic classrooms
 - ▶ Mendel University in Brno
 - ▶ elementary school in Opava
 - ▶ secondary school in Opava

- specialized classroom
 - ▶ Mendel University in Brno (computer classroom)

- school specialized laboratory
 - ▶ Mendel University in Brno (laboratory for testing organic coating and adhesives)

- school joinery workshops
 - ▶ Mendel University in Brno
 - ▶ secondary school in Opava

Used equipment

- short path thermal desorption tube, Silco treated Thermal Desorption Tube 786090-100, inner diameter 4 mm, fill in with 100 mg of Tenax TA (Scientific Instrument Services company) for collection of VOCs emissions emitted from tested samples in to the air in chamber;
- air sampler Gilian – LFS 113 SENSIDINE with air flow 6 l.h⁻¹. and 12 l.h⁻¹; the pump has been calibrated in CMI;
- gas chromatograph Agilent GC 6890 N with MS (mass spectrometer) detector 5973 with cryofocustion, thermal desorption and library of spectra NIS 05, column type HP – 5 (AGILENT USA).

Methods of VOC testing were set via standards:

ISO 16000: 2004 Indoor air

ISO 16000-1: 2004 General aspects of sampling strategy

ISO 16000-5: 2005 Measurement strategy for volatile organic compounds (VOCs)

ISO 16000-11: 2004 Determination of the emission of volatile organic compounds- sampling, storage of samples and preparation of test specimens

The intimation 6/2003 the intimation for determination hygienic limits of chemical, physical and biological indices for indoor air sojourn rooms of some building

The methodology for measurement and determination chemical, physical and biological indices of quality indoor air according to intimation 6/2003

Results of measuring

- a) The comparison various kind of classrooms in term of load by emission VOC (Mendel University in Brno) in dependence on year season (summer and autumn)

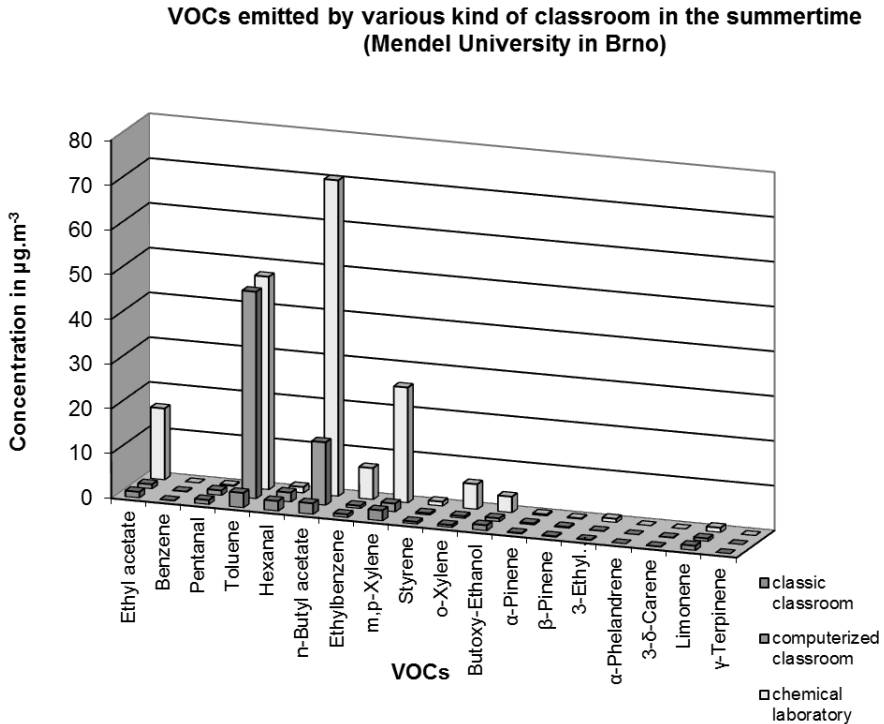


Figure 1: VOC emitted by various kind of classroom in the summertime (Mendel University in Brno)

Figure 1 shows VOCs emitted by various kind of classroom in the summertime, locality – Mendel University in Brno. There were measured small amounts of

compounds as Benzene, Pentanal, Hexanal, Styrene, 3-Ethyl-Toluene, α -Phelandrene, 3- δ -Carene or γ -Terpinene. Air of classroom contains the most important volume of VOCs'. It could be seen especially in the start and the end of this picture. In indoor air of classrooms there are over $40 \mu\text{g.m}^{-3}$ of toluene and n-butyl acetate, over $20 \mu\text{g.m}^{-3}$ of Σ m,p,o-xylene from computerized classroom and chemical laboratory. The highest emission of VOCs was measured from specialized chemical laboratory.

**VOCs emitted by various kind of classroom in the autumn
(Mendel University in Brno)**

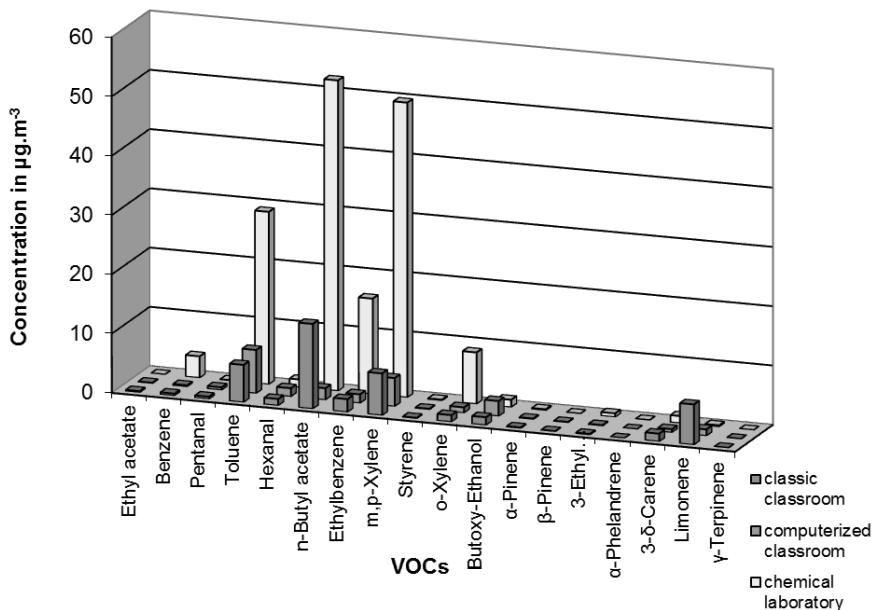


Figure 2: VOC emitted by various kind of classroom in the autumn (Mendel University in Brno)

Figure 2 shows the VOCs emitted by various kind of classroom in the autumn, locality- Mendel University in Brno. There were measured small amounts of compounds as Ethyl acetate, Benzene, Pentanal, Hexanal, Styrene, Butoxy-Ethanol, α and β -Pinene, 3-Ethyl-Toluene, α -Phelandrene, 3- δ -Carene, Limonene or γ -Terpinene. The tested indoor air of specialized chemical contains the most important volume of Toluene (over $29 \mu\text{g.m}^{-3}$), n-Butyl acetate and Σ m,p,o-Xylene (over $50 \mu\text{g.m}^{-3}$) and over $15 \mu\text{g.m}^{-3}$ of Ethyl benzene. The results of measuring ensue, that the most of emission VOC was emitted by specialized chemical laboratory.

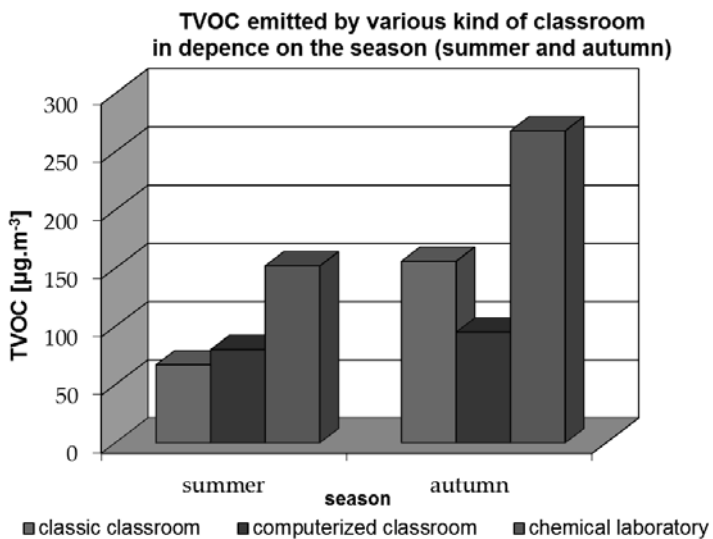


Figure 3: TVOC emitted by various kind of classroom in dependence on the season (summer and autumn)

b) The comparison emission VOCs emitted by classic classroom in dependence on locality

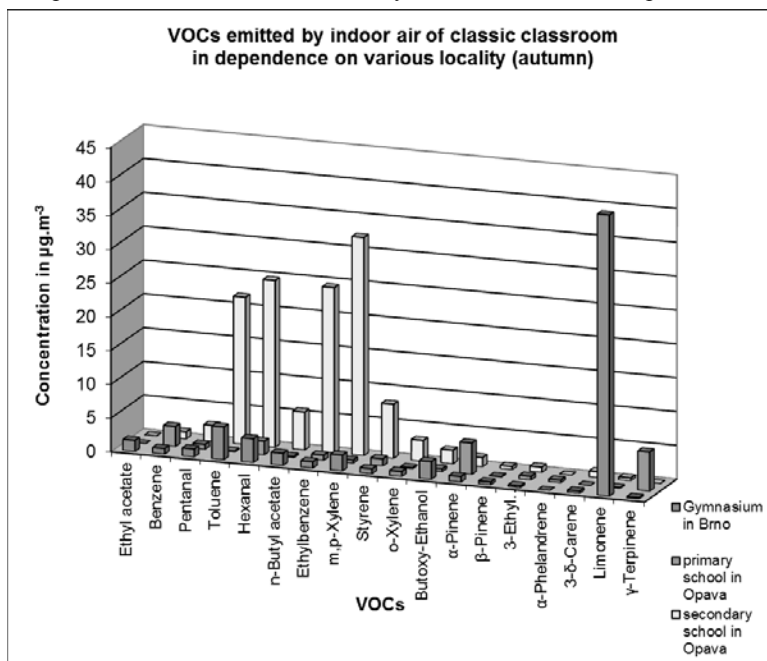


Figure 4: VOCs emitted by indoor air of classic classroom in dependence on various locality (autumn)

Figure 4 shows quantitative and qualitative composition of emission VOCs from indoor air of classic education classrooms, which they are located in two localities (Brno and Opava). The measuring quality indoor air of classic classroom was performed in the autumn. The measuring of emission VOCs There were measured small amounts of compounds as Benzene, Pentanal, Hexanal, Styrene, Butoxy-Ethanol, α and β -Pinene, 3-Ethyl-Toluene, α -Phelandrene, 3- δ -Carene or γ -Terpinene, namely in all tested classroom. The most emission VOCs emitted classic classroom in secondary school in Opava, namely first volume of Toluene, Hexanal and Ethylbenzene (over $20 \mu\text{g}\cdot\text{m}^{-3}$), and even Σ m,p,o-Xylene (over $30 \mu\text{g}\cdot\text{m}^{-3}$). The highest of value was measured at Limonene from classis classroom of gymnasium in Brno (over $40 \mu\text{g}\cdot\text{m}^{-3}$), which we are rationalizing by using cosmetics.

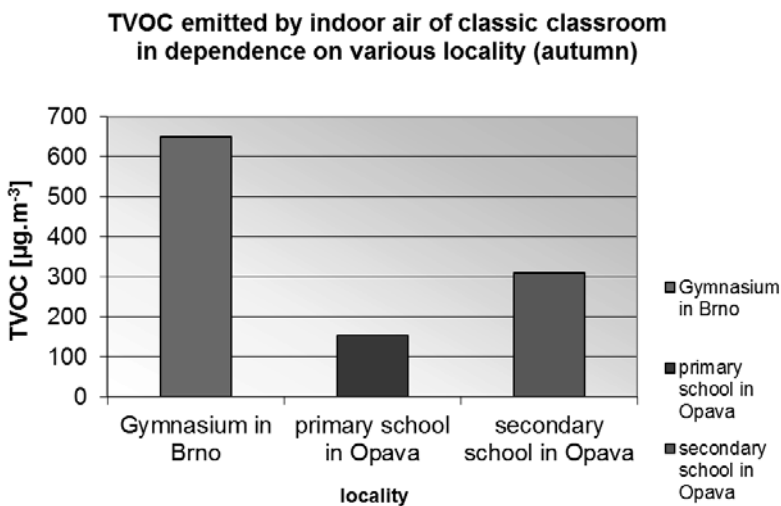


Figure 5: TVOC emitted by indoor air of classic classroom in dependence on the various locality (autumn)

- a) The comparison emission VOCs emitted by classic education classroom and school joinery workshop localized in the same building

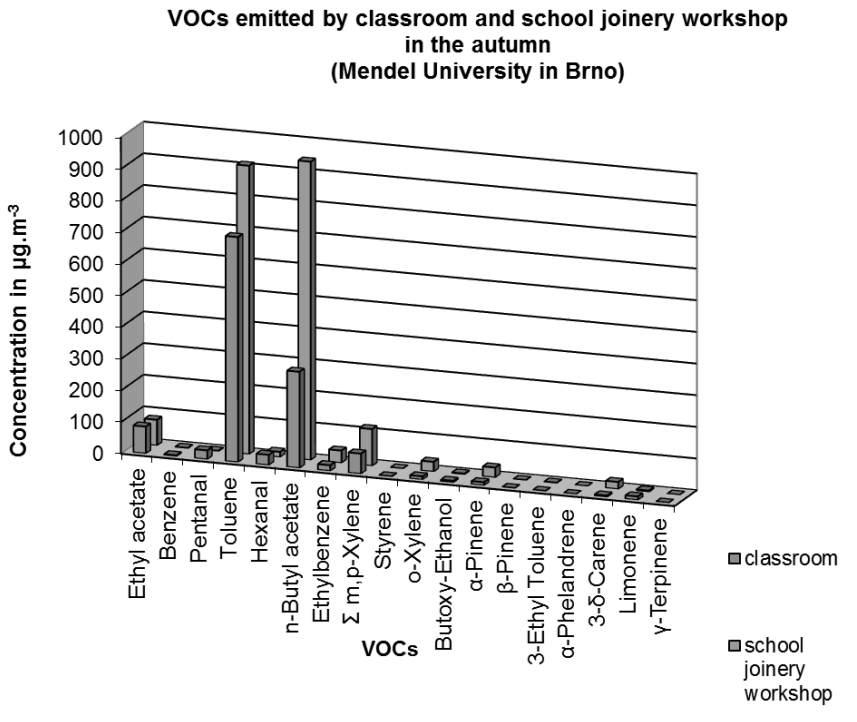


Figure 6: VOC emitted into air of the classic classroom and school joinery workshop in autumn (Mendel University in Brno)

Figure 6 shows the comparison loaded of emission VOCs emitted by classic classroom and school joinery workshop, which are located in the same building (Mendel University in Brno), whereas the measuring was performed in the autumn. The measuring suggests that school joinery workshop has marked impact on quality indoor air of education classroom. This fact is perceptible especially at volatile organic compounds as Ethyl acetate, Toluene and n-Butyl acetate, which they are emitted by school joinery workshop in considerable. The classic education classroom emitted volume of Toluene over 700 µg.m⁻³, which it is value twice higher than hygienic limit 300 µg.m⁻³. Also value at n-Butyl acetate was measured over 300 µg.m⁻³ (hygienic limit is not defined).

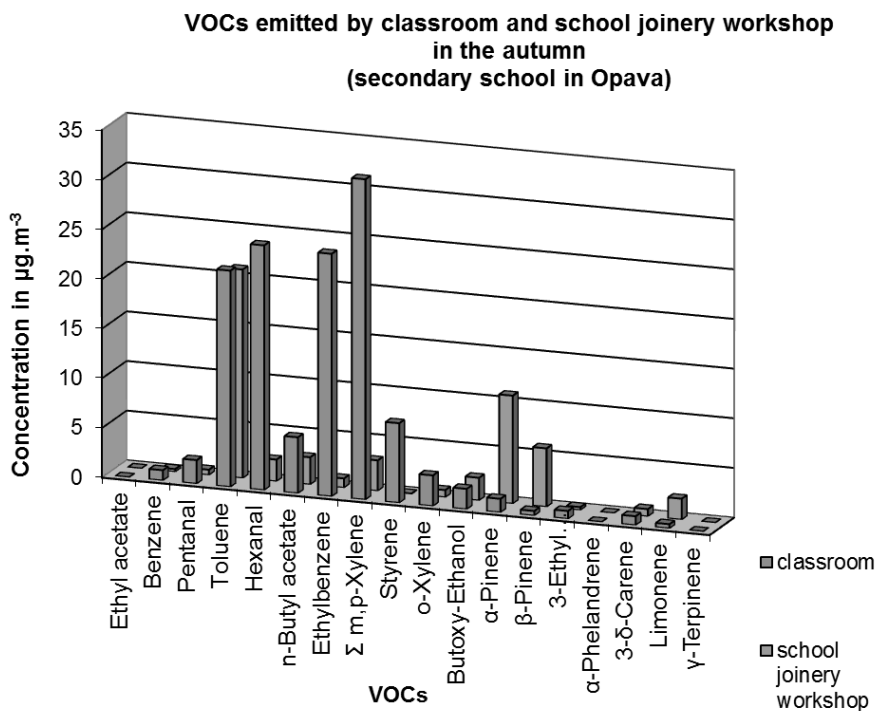


Figure 7: VOC emitted into air of the classic classroom and school joinery workshop in autumn (secondary school in Opava)

Figure 7 shows the comparison loaded of emission VOCs emitted by classic classroom and school joinery workshop, which are located in the same building (secondary school in Opava), whereas the measuring was performed in the autumn. The results proved, that school joinery workshop has not marked impact on quality indoor air of education classroom. The classic education classroom emitted some of VOCs at higher volume than school joinery workshop (Pentanal, Hexanal, Ethylbenzene, Σ m,p,o-Xylene, Styrene). The measured values introduced compounds are below value 36 µg.m⁻³, which it is expressively under hygienic limit.

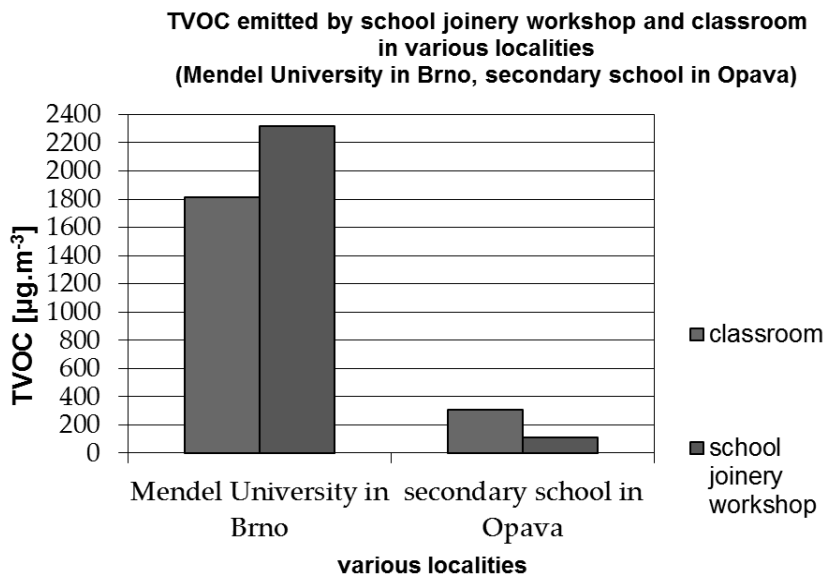


Figure 8: TVOC emitted classic education classroom and school joinery workshop in various localities (Brno and Opava)

Conclusion

Achieved of results predicate about it, that expressive influence on quality indoor air of classrooms has:

- purpose of classroom (classic education, computerized classroom, school joinery workshop, specialized chemical laboratory)
- intensity ventilation of room (year season)
- work in classroom (laboratory for tested organic coating and adhesives)
- siting of room (proximity of classroom and school joinery workshop)

The volumes of Toluene contain in the tested indoor air exceeded the permissible exposure limits of these compounds from the point of the regulation 6/2003 MZČR (classic education classroom and school joinery workshop in the same building, locality-Mendel University in Brno. Other volatile organic compounds determinate in the measured of the indoor airs from the point of MZČR regulation were sufficiently under the limits.

Literature

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KVALITA VNITŘNÍHO PROSTŘEDÍ UČEBEN

Abstrakt: Příspěvek řeší problematiku emisí organických těkavých látek tzv. VOC (Volatile Organic Compounds) těkajících do pracovního a pobytového prostředí. Práce stanovuje závislost kvalitativního a kvantitativního složení emisí VOC, jež ovlivňují obytné či pobytové prostředí nacházející se v bezprostřední blízkosti prostředí pracovnímu u školních truhlářských dílen v rámci jedné budovy v dlouhodobém rozsahu měření, dále porovnává jednotlivé typy učeben navzájem a rovněž řeší i závislost na ročním období či lokalitě, přičemž byly zvoleny dvě lokality (Brno a Opava). Za posuzované objekty byla zvolena Mendelova univerzita v Brně, gymnázium v Brně, základní škola v Opavě a střední odborná škola v Opavě.

Výsledkem práce je stanovení kvalitativního a kvantitativního složení emisí VOC emitované pracovními, či pobytovými místnostmi, včetně stanovení celkového zatížení emisemi VOC tzv. TVOC (total volatile organic compounds).

Klíčová slova: VOC, plynová chromatografie, učebna, vnitřní prostředí, TVOC