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Content

Original scientific article

Effects of ozone on consultations for asthma in children in Koper municipality: A time trend study

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ABSTRACT

Aiming at assessing the feasibility of linkage of existing health and environmental data in Slovenia in the case of the Koper Municipality in identifying the grounded need for public health action, the objective of the study was to assess the association between consultations on the primary health care level due to asthma and daily ozone concentrations. An ecological time-trend study with a single day as a unit of observation was performed in 2012. Periods from April 1 through October 31 were observed in 2010 and 2011. The study population was children, aged 0-12 years, who visited the Community Health Centre Koper for asthma. Logistic regression was used in analysis. The results showed statistically significant association between daily occurrence of at least one consultation for asthma and ozone daily maximum 8-hr average concentration 70 $\mu g/m^3$ or exceeded, lag 4 days (OR=4.77; p=0.042). There is an evidence of association between increased ozone levels and daily occurrence of any consultation for asthma in Koper Municipality. The study opened many challenges for future research. If they are resolved, evidence-based approach to public health activities in the field of environmental health in the region and in Slovenia would be strongly improved on this basis thereof.

Key words: ozone, asthma, ecological time-trend study, logistic regression, Koper Municipality

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INTRODUCTION

Exposure to air pollution has been proven to be associated with a variety of adverse health effects. There is a strong evidence that especially increased air pollution with particulate matter (PM_{10} and $PM_{2.5}$), and ozone (O_3), precipitates respiratory symptoms [1-5], and consequently emergency room visits and hospital admissions due to these symptoms [6-10]. Among the most susceptible population subgroups are children [3, 7, 11-17].

In Slovenia the highest O_3 concentrations occur in the western part, especially in the situations when the wind blows from the south or south-west direction, what reflects the transfer of O_3 across the border from Italy [18, 19]. Koper Municipality (KM) is a part of this region. It is located in the south-west (Figure 1a).

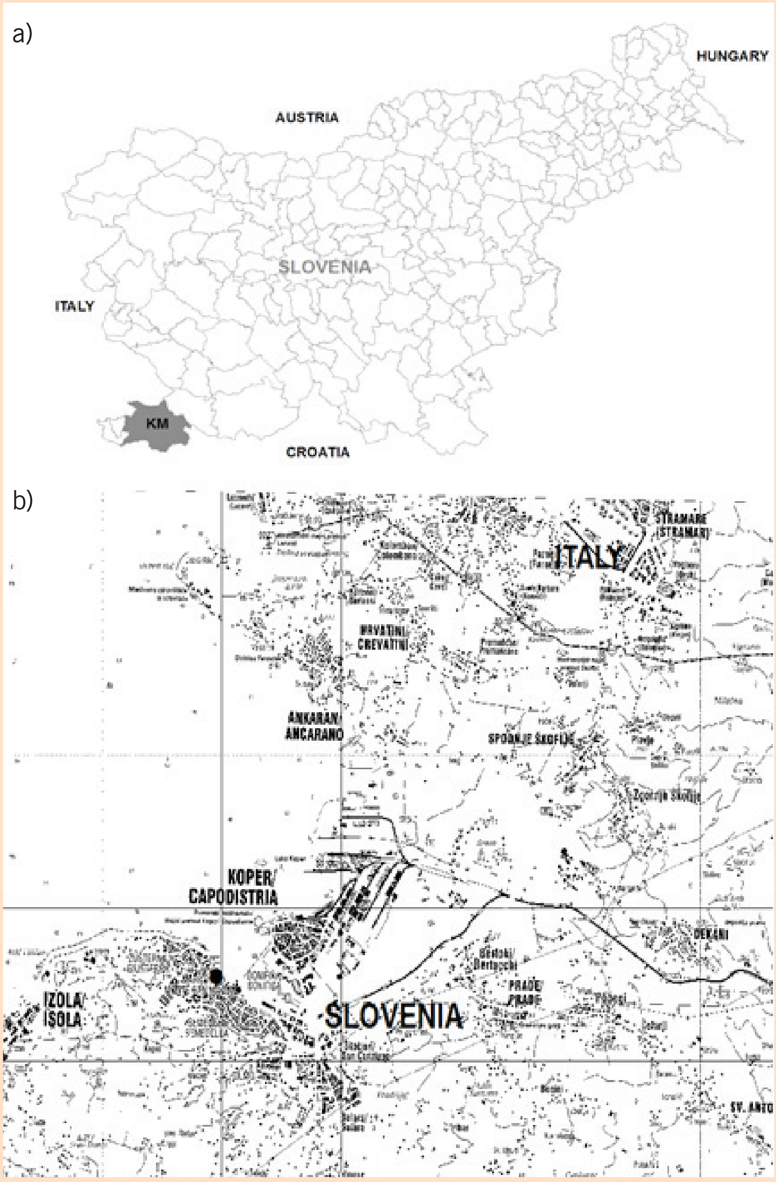

Figure 1:
The location of the Koper Municipality (KM) within Slovenia (a). Location of the Environment Agency of the Republic of Slovenia measuring station Markovec in the Koper Municipality (●) (b).

Source of shape files: DMNV25, GURS.

The results of outdoor air quality measurements in the KM in the past have shown that the burdening through O_3 is considerable [20-22]. On the other side, in the recent years the evidence on the relationship between respiratory diseases in children and air pollution in the KM accumulate [23, 24]. However, none of these studies has tried to link routine environmental and routine health data. There exist only one study which tried to link mortality data of the total population and air pollution with O_3 in the region [22].

Aiming at identifying the possibilities for targeted public health action, the objective of the study was to assess the association between consultations at the Community Health Centre Koper (CHCK) due to asthma symptoms and daily O_3 concentrations in children from the KM.

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MATERIALS AND METHODS

Study characteristics

The ecological time-trend study was conducted in 2012. The study population was children, aged 0–12 years, residing permanently (July 1, 2010: 5,965; July 1, 2011: 6,163) [25], or temporarily (as tourists) in the KM in the observed periods, who visited the CHCK for asthma symptoms. The data for the years 2010 and 2011 were analysed. Observation time was limited to the periods April 1 to October 31, when O_3 concentrations in the observed area are the highest. The unit of observation was a single day. Altogether, 428 days were observed. The study protocol was approved by the Ethical Committee of the Republic of Slovenia in 2012.

Origin of data

Health data were obtained from health information systems of the CHCK. The information gathered was the number of children aged 0–12 years who for the first time visited CHCK due to asthma (including acute exacerbation of this chronic disease) by day in the observed periods.

Data on the concentration of air pollutants in the smallest possible time interval were obtained from the measuring station in Koper/Markovec (Figure 1b), which is part of the fixed stations of the national automated network for monitoring air quality of the Republic of Slovenia, operated by the Slovenian Environment Agency (SEA). The information on O_3, PM_{10} and nitrogen dioxide (NO_2) concentrations (for all three 1-hr average in $\mu g/m^3$), air temperature (in °C) and relative humidity (as %) was obtained (Figure 1b).

Data analysis

Observed outcome was basically the daily number of first consultations for asthma, which was later transformed to a binary indicator as to whether or not any first consultation for asthma occurred in a day, since the number of daily consultations was low.

As the explanatory factor only O_3 was considered, expressed as a daily maximum 8-hr average concentration. The 8-hr running averaged value for each hour was calculated as the average of the values for that hour and the 7 foregoing hours. The daily maximum value for a given calendar day was afterwards determined as the highest of the 24 possible 8-hour averages computed for that day. For the purposes of analysis additionally a binary indicator as to whether or not daily maximum 8-hr average achieved or exceeded the according to WHO 8-hour average baseline level for maximum 8-hour average of 70 $\mu g/m^3$ (the estimated background O_3 level) [26] was calculated. Lags of 0-5 days from exposure to the consultation day were examined to determine the amount of time between exposure and effect.

Some important covariates were considered as proposed in the literature [27]. Firstly, data on PM_{10} and nitrogen dioxide (NO_2) were considered. Both were expressed as the average of the 24 hourly values covering the period from the midnight of the day-1 to the midnight of the day n. Lags of 0–5 days from exposure to consultation day were examined. Secondly, temperature and humidity were considered. Both were expressed as the average of the 24 hourly values covering the period from the midnight of the day-1 to the midnight of the day n. Finally, the seasonal factors were considered: the year of data collection, and the day of the week (workday or weekend day) and holiday indicators (yes, no). Meteorological and seasonal factors were used in analysis as background covariates [27].

Univariate relationship analysis was performed only as simple univariate correlation analysis between explanatory (O_3) and other pollution factors. The analysis was performed by using Pearson correlation method. Results are presented as a part of description of data.

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For statistical analyses SPSS for Windows, Version 18.0 (IBM Corporation, Armonk, NY, USA) was used.

The relationship between observed outcomes and explanatory factor adjusted to potential confounders was analysed by using logistic regression model [28, 29]. The modelling procedure was performed in two steps. In the first step, single pollutant models were defined by adding the single exposure variable (both indicators on O_3, and indicators on PM_{10}, and NO_2) to a set of background covariates (temperature, relative humidity, year of data collection, workday or weekend day, and holiday or not). These models were determined in order to obtain the best lag of exposure variable and covariates to be potentially included in the multi-pollutant model. In the process of determination, biological plausibility, e.g. the direction of relationship between the outcome and explanatory variable or covariate (only positive association was considered as plausible and acceptable), as well as statistical significance of this relationship, were considered. A p-value ≤ 0.05 was considered as statistically significant, and a p-value ≤ 0.250 was considered acceptable for entering a variable into the multi-pollutant model [28]. In the second step, a model that included best lags of all pollutants considered in the study (O_3, PM_{10}, NO_2), and a set of background covariates was defined. A stepwise method of selecting the variables to enter the final model was used [28].

RESULTS

Data description

Data on observed outcome were available for all 428 days of observation. In the year 2010 there were in total 163/214 (76.2 %) days with no consultations for asthma-related symptoms and 51/214 with any consultation, while in the year 2011 there were in total 187/214 (87.4 %) days with no consultations for asthma symptoms and 27/214 with any consultation. Maximal daily number of consultations was 3. Altogether there were 93 visits for asthma symptoms in the observed period (63 in 2010 and 30 in 2011).

O_3 daily maximum 8-hr average concentration ($\mu g/m^3$) was possible to calculate for total 423, PM_{10} 24-hr average concentration ($\mu g/m^3$) for total 411, NO_2 24-hr average concentration ($\mu g/m^3$) for total 411, 24-hr temperature average (˚C) for total 426, and 24-hr relative humidity average (%) for total 426 days of observation. Selected characteristics for these indicators are presented in Table 1.

Table 1:
Selected characteristics of the distribution of selected pollutants and meteorological factors in the Koper Municipality, Slovenia, from April 1 to October 31, in the years 2010 and 2011.

Covariate	Year	N[1]	Mean	SD	Min	Max
O_3 daily maximum 8-hr average concentration ($\mu g/m^3$)	2010	209	103.5	24.7	52.2	161.6
	2011	214	108.6	23.3	32.6	173.2
PM_{10} 24-hr average concentration ($\mu g/m^3$)	2010	203	21.8	9.1	7.1	67.8
	2011	208	21.1	7.7	5.7	48.3
NO_2 24-hr average concentration ($\mu g/m^3$)	2010	203	17.7	6.1	1.9	41.6
	2011	211	16.3	6.4	2.8	46.7
Daily temperature average (˚C)	2010	212	19.8	4.9	9	31
	2011	214	20.8	4.9	5	30
Daily humidity average (%)	2010	212	61.8	11.4	24	87
	2011	214	58.0	11.8	21	89

Source: Authors

Regarding the seasonal indicators, in each of observed years, there were in total 152/214 (71.0 %) workdays and 62/214 (29.0 %) weekend days in the observed period. In each of observed years, 2010 and 2011, there were in total 74/214 (34.6 %) holidays days and 140/214 (65.4 %) non-holidays days in the observed period. Additionally, in the year 2010 there were in total 188/209 (90.0 %) days in the observed period on which 8-hr average achieved or exceeded the WHO 8-hour average baseline level of 70 $\mu g/m^3$, while in 2011 there were 195/214 (91.1 %) such days.

Correlation analysis between daily 24-hr average concentration of O_3 ($\mu g/m^3$) and PM_{10} 24-hr average concentrations ($\mu g/m^3$) showed only weak positive correlation ($r=0.246$; $p\leq0.001$). Correlation analysis between daily 24-hr average concentration of O_3 ($\mu g/m^3$) and NO_2 24-hr average concentrations ($\mu g/m^3$) showed only weak negative correlation ($r=-0.234$; $p\leq0.001$). Correlation analysis between PM_{10} 24-hr average concentrations (μg/m³) and NO_2 24-hr average concentrations (μg/m³) showed moderate positive correlation (r=0.444; p≤0.001).

Results of uni-pollutant relationship analysis

The results of association between daily occurrence of any consultation for asthma symptoms and O_3 daily maximum 8-hr average concentration showed that in the lags 1, 3 and 4 that the higher O_3 daily maximum 8-hr average concentrations could be associated with a higher probability for daily occurrence of any consultation for asthma symptoms. However, in none of these lags the association was statistically significant (Table 2). Consequently, none of the lags was chosen to enter the multi-pollutant model, and no multi-pollutant model was defined at all. On the other side the results of association between daily occurrence of any consultation for asthma symptoms and O_3 daily maximum 8-hr average ≥70 μg/m³ showed a bit stronger association in the lag 4, since in this lag the association was borderline statistically significant (Table 2). Consequently, this lag was chosen to enter the multi-pollutant model.

Table 2:
Summary results of the logistic regression analysis of association between daily occurrence of any consultation for asthma symptoms and two ozone indicators for uni-pollutant models for lags 0-5.

Explanatory factor/covariate		N[1]	OR[2]	95 % C.I.[3] limits for OR		*p*-value
				Lower	Upper	
O_3 daily maximum 8-hr average concentration, lag 0		423	0.999	0.985	1.013	0.906
O_3 daily maximum 8-hr average concentration, lag 1		420	1.005	0.991	1.019	0.459
O_3 daily maximum 8-hr average concentration, lag 2		417	0.998	0.984	1.011	0.741
O_3 daily maximum 8-hr average concentration, lag 3		415	1.003	0.990	1.016	0.670
O_3 daily maximum 8-hr average concentration, lag 4		413	1.001	0.988	1.015	0.846
O_3 daily maximum 8-hr average concentration, lag 5		411	0.988	0.975	1.002	0.095
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 0	No	423	1.000			
	Yes		0.687	0.262	1.797	0.444
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 1	No	420	1.000			
	Yes		1.857	0.581	5.940	0.297
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 2	No	417	1.000			
	Yes		1.211	0.408	3.596	0.730
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 3	No	415	1.000			
	Yes		1.931	0.604	6.177	0.267
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 4	No	413	1.000			
	Yes		3.571	0.775	16.447	0.102
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 5	No	411	1.000			
	Yes		0.625	0.213	1.833	0.392

Source: Authors

The results of association between daily occurrence of any consultation for asthma symptoms and PM_{10} 24-hr average concentration showed that in lags 0-3 higher PM_{10} concentrations were associated with a higher probability for daily occurrence of any consultation for asthma symptoms. In lags 0 and 2 it was statistically significant (Table 3). The

Table 3:
Summary results of the logistic regression analysis of association between daily occurrence of any consultation for asthma symptoms and selected pollutants for uni-pollutant models for lags 0-5.

Explanatory factor/covariate	N[1]	OR[2]	95 % C.I.[3] limits for OR		p-value
			lower	upper	
PM_{10} 24-hr average concentration, lag 0	424	1.031	1.001	1.063	0.045
PM_{10} 24-hr average concentration, lag 1	421	1.031	0.999	1.064	0.056
PM_{10} 24-hr average concentration, lag 2	418	1.033	1.002	1.065	0.038
PM_{10} 24-hr average concentration, lag 3	416	1.005	0.975	1.036	0.749
PM_{10} 24-hr average concentration, lag 4	414	0.997	0.966	1.029	0.851
PM_{10} 24-hr average concentration, lag 5	412	0.997	0.966	1.028	0.830
NO_2 24-hr average concentration, lag 0	414	1.033	0.990	1.077	0.139
NO_2 24-hr average concentration, lag 1	412	1.030	0.986	1.075	0.185
NO_2 24-hr average concentration, lag 2	410	1.022	0.980	1.064	0.309
NO_2 24-hr average concentration, lag 3	409	1.006	0.964	1.050	0.783
NO_2 24-hr average concentration, lag 4	408	0.996	0.955	1.038	0.838
NO_2 24-hr average concentration, lag 5	407	1.023	0.981	1.066	0.288

Source: Authors

association was slightly stronger in lag 2. However, since this difference was not big, and biologically more plausible is lag 0, this lag was chosen to enter the multi-pollutant model. The results of association between daily occurrence of any consultation for asthma symptoms and NO_2 24-hr average concentration showed that in all lags except in the lag 4 higher NO_2 concentrations could be associated with a higher probability for daily occurrence of any consultation for asthma symptoms. However, only in lags 0 and 1 the association was borderline statistically significant (Table 3). It was slightly stronger in lag 0. Consequently, this lag was chosen to enter the multi-pollutant model.

Results of multi-pollutant relationship analysis

The results of multi-pollutant relationship analysis are presented in the Table 4. In the model, in which all statistically non-significant variables were omitted by the procedure itself, the association between daily occurrence of any consultation for asthma symptoms and O_3 daily maximum 8-hr average concentration 70 $\mu g/m^3$ or exceeded, lag 4, was statistically significant. The results indicated that on the days on which O_3 daily maximum 8-hr average was ≥ 70 $\mu g/m^3$ the odds for any consultation for asthma symptoms were 4.77-times higher than on other days. In PM_{10} 24-hr average, lag 0, the association was also statistically significant (Table 4).

Table 4:
Results of the logistic regression analysis (stepwise method) of association between daily occurrence of any consultation for asthma symptoms and ozone concentration, controlled for selected covariates (N=388).

Explanatory factor/covariate		OR[1]	95 % C.I. limits for OR		p-value
			lower	upper	
O_3 daily maximum 8-hr average concentration ≥70 μg/m³, lag 4	No	1.000			
	Yes	4.769	1.057	21.520	0.042
PM_{10} 24-hr average concentration, lag 0		1.036	1.005	1.068	0.024
Year	2010	1.000			
	2011	0.412	0.236	0.719	0.002
Work day	No	1.000			
	Yes	5.021	2.075	12.150	<0.001
Holiday	No	1.000			
	Yes	0.485	0.258	0.910	0.024

Source: Authors

DISCUSSION

The most important results of our study showed that the association between increased O_3 concentrations and daily occurrence of any consultation for asthma symptoms in KM can be confirmed. They are comparable to the results of the study of Myers et al. [7], which is one of the studies most similar to our study in terms of the methodology employed (logistic regression was employed for modelling of the daily occurrence of any consultation for asthma symptoms). The results were also similar – O_3 (lagged two days) was statistically significantly associated with increased odds of at least one asthma medical visit per day. Our results are also similar to the results of a study performed by Ji et al. [10]. In their meta-analysis was reported that it was evident that number of consultations for asthma in children in emergency department was statistically significantly associated with O_3 levels. The results of our study indicate that problems in children with asthma in the KM occurred already when daily maximum 8-hr average was ≥ 70 μg/m³. This is consistent with WHO Air quality guidelines [26] and indicates that the attention we should be paid to adverse effects of O_3 in lower concentrations than are actual threshold values (8-hr average target value of 120 μg/m³).

There are several reasons that may account for these findings. Firstly, patients with respiratory diseases as well as mothers of children with chronic respiratory diseases in Slovenia are well-informed as to how to react in relation to their disease. A 4-day delay after exposure to high O_3 levels to the observed effect could be due to the fact that mothers of asthmatic children, particularly those who have been experiencing the disease of their child for some time, are able to manage their child's disease on their own. Only when the condition fails to improve they decide to consult a doctor. Since preventive notification of the population on the air pollution in Slovenia is also well-managed, as daily air pollu-

The results of our study indicate that problems in children with asthma in the KM occurred already when daily maximum 8-hr average was ≥ 70 μg/m³.

tion levels are daily monitored by SEA, which promptly notifies the public, the mothers have additional information enabling them to react accordingly. Secondly, the children with a chronic respiratory disease have been already prescribed a therapy and the effects of air pollution with O_3 are less expressed. Thirdly, the Regional Institute of Public Health Koper (RIPHK) constantly provides information on adverse effects of the air pollution with O_3 in the region. The final reason could be the exposure misclassification since there is only one measuring station for monitoring air quality located in the region.

Our study has some limitations. Firstly, in the entire coastal region only one fixed air pollution measuring station is located, making detection of any differences between individual areas in the KM impossible. However, the air pollution may vary considerably between micro-locations [21]. The solution would be to evaluate exposure to polluted air by mathematical modelling [30, 31], and the study upgraded with a geographical analysis taking into account places of residence of children who sought medical attention for asthma or other respiratory diseases in the observation period. Secondly, we were able to use only the health data starting from 2010 because before 2010 the CHCK had used the old software which did not allow for a display of information needed for the analysis in our study. Consequently, we were limited to a very short observation period. Together with a small population this meant a relatively low frequency of the endpoint. However, the general problem in Slovenia with health data for the use in ecological research is the lack of uniform software for recording health data [32]. The final limitation might be that children without permanent residence in the KM coming to the doctor due to current health aggravation were included in the analysis. Particularly during summer months, there are many tourists staying in the KM, including many children. However, we established that 70% of children seeking medical assistance in CHCK came from the KM. We decided for this inclusion during the study, as the number of consultations for asthma was small from the aspect of analytical methods. On the other side, the study has also several strengths. Firstly, the results of the study themselves, which already in such a short time-series indicated positive association between observed phenomena, are the most important strength. Secondly, the present study provides important information for further work in the field of health promotion in the region. Finally, all methodological issues arisen during the study represent a new challenge for further work, particularly in the field of studying the association between environmental and health data on a population level, since the results and particularly the process itself provide information as to what should be improved if such studies are to be carried out in Slovenia in the future.

The present study brought several challenges for future research in the field, the most important being how to evaluate exposure more geographically precisely.

The present study brought several challenges for future research in the field, the most important being how to evaluate exposure more geographically precisely. This could be done only by mathematical modelling. Definite challenge would be to develop the methodology for studying the relationship between atmospheric pollution by O_3 and health phenomena in population on the level of small spatial units on such a complex terrain as is in the coastal area of Slovenia (mountainous region, coastal meteorology and weak winds that maintain sustainable high O_3 concentrations). Development of such a methodology would be of a huge importance for the planning and implementation of public health activities aimed at areas where there is a high concentration of vulnerable population. In doing so, attention should be paid to both, local residents and tourists. Swedish Environmental Research Institute has drawn attention to the problem of O_3 pollution in the southern Europe where the most serious problems occurred in densely-populated areas, often near the coasts, already over a decade ago [33]. The highest concentrations happened to occur in the most attractive tourist areas. This was especially the case in Athens and its surroundings, in parts of the coast of eastern Spain, and the Po valley in northern Italy [33], which is located in the immediate vicinity of Slovenija. Erlih and Eržen [23] concluded in their survey that transfer of O_3 air pollution from the industrial north of Italy seems to be the main cause of pollution with O_3 in the KM. The fact is that the highest O_3 concentrations occur in the coastal region in the summer when this region is on the western outskirts area of higher air pressure. In such situations the prevailing winds are weak west and south-west winds [18]. This hypothesis is supported by the results of other studies in Slovenia [34] and Italy [35]. In KM, such an area with a high concentration of vulnerable population (children and adolescents under 15), is the area of Debeli rtič Health Resort. More than 10,000 children are accommodated there in a season, among them a lot with chronic respiratory disease.

We can conclude that an increased number of consultations for asthma in children in the KM is associated with increased concentrations of O_3. Yet these conclusions must be evaluated in the light of the limitations of the study. Despite these limitations, we believe that this study brings new insights on how to manage the problem of O_3 in the coastal area of Slovenia. Our study also opened new challenges for future research. If they are resolved, evidence-based approach to public health activities in the field of environmental health in Slovenia would be strongly improved on this basis thereof.

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Original scientific article

Prevention and control of Sick Building Syndrome (SBS). Part 1: Identification of risk factors

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ABSTRACT

Problem: People in the developed countries spend around 90 % of their time indoors, so the design of healthy and comfortable buildings presents a key fundament. Construction of energy-efficient buildings with increased air tightness of the building envelope and poorly maintained ventilation systems often results in unhealthy and uncomfortable indoor conditions as well as in Sick Building Syndrome (SBS). In Part 1, risk factors for SBS are identified. In Part 2, an interactive influences among risk factors are detected and a preventive and control strategy to lower the occurrence of SBS is designed. **Purpose:** The purpose of this study is to identify and classify risk factors for SBS, as well as to define relevant parameters for the occurrence of SBS. **Method:** In the period of January to February 2014, *comprehensive literature review was carried out studying* risk factors for SBS. *We searched* two bibliographic databases (Pub Med and Science Direct) for peer-reviewed publications from 1974 to 2014. **Results and discussion:** *Based on the results of the comprehensive literature review, the risk factors for SBS can be classified into six major groups, i.e. physical, chemical, biological, psychosocial, personal and others.* **Conclusions:** Identification of risk factors presents *a first step towards integral prevention and control of SBS. The identified and classified risk factors and their parameters are used for the design of a preventive strategy to lower the occurrence of SBS (Part 2).*

Key words: Sick Building Syndrome, risk factors, identification

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INTRODUCTION

People in the developed countries spend around 90 % of their time indoors and around 20 % in working environments [1, 2]. During that time we are exposed to numerous health hazards that can be classified into biological, chemical, physical, biomechanical and psychosocial [3, 4]. Exposure to these hazards could affect human health. The extent of the effects is dependent on their exposure dose, exposure time and individual characteristics [3, 4]. On the other side, design of healthy and comfortable built environment is fundamental for the prevention and control of health hazards [5, 6].

Current design of energy-efficient buildings is mainly focused on the solving of energy problems. Solutions are defined in the direction of improved thermal insulation, increased air tightness of the building envelope as well as in the installation of energy-efficient ventilation systems [7]. Such partial solutions often results in unhealthy and uncomfortable conditions and may be related to the occurrence of a Sick Building Syndrome (SBS). US Environmental Protection Agency [8] describes SBS as situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be widespread throughout the building. The characteristic symptoms of SBS that may occur singly or in combination with each other are headache, eye, nose, or throat irritation, dry cough, dry or itchy skin, dizziness and nausea, difficulty in concentrating, fatigue and sensitivity to odours [9-11]. In contrast, the term Building Related Illness (BRI) is used when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants [8].

The World Health Organization [12] estimated that up to 30 % of new and renovated buildings worldwide may be related to SBS. Comprehensive study [13] performed in the UK on 4373 office workers in 42 public buildings revealed that 29 % of those studied experienced five or more of the characteristic SBS symptoms. An investigation carried out by Woods et al. [14] on 600 office workers in the USA concluded that 20 % of the employees experience SBS symptoms and most of them were convinced that this reduces their working efficiency. Additionally, a study on 1390 workers in 5 public buildings in Quebec, Canada [15] showed that 50 % of workers experienced SBS symptoms. SBS may also occur in other environments such as schools, kindergartens and residential buildings [16-20]. In studies on residential buildings [18-20] from 12 % to 30.8 % of occupants were identified as having SBS.

Identification of risk factors, main parameters and their interactions are important for integral prevention and control of SBS. The purpose of this study is to identify risk factors for SBS and their main parameters. Identification of risk factors presents a first step towards integral prevention and control of SBS. The identified and classified risk factors will be used for the detection of interactive influences among risk factors and their parameters as well as for the design of a preventive and con-

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trol strategy to lower the occurrence of SBS. The interactions among risk factors and their parameters, and the designed strategy are presented in Part 2.

METHODS

Comprehensive literature review was carried out studying risk factors for SBS. In the period of January to February 2014 we searched two bibliographic databases (Pub Med and Science Direct) for peer-reviewed publications from 1974 to 2014. The key-words were written in English: "sick building syndrome", together with "air temperature", "surface temperature", "relative humidity", "air velocity", "heating", "cooling", "ventilation", air-conditioning", "noise", "vibrations", "daylight", "indoor air quality", "air pollutants", "volatile organic compounds", "construction products", "household products", "phthalates", "formaldehyde", "tobacco smoke", "odours", "bacteria", "mould", "dust", "gender", "age", "stress", "social status". Titles, abstracts or both, of all articles, were reviewed to assess their relevance.

We reviewed reports, guidelines, legislative and other documents of the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), Health Protection Agency (HPA), Occupational Safety and Health Administration (OSHA), International Labour Organization (ILO), National Institute for Occupational Safety and Health (NIOSH), American Institute of Architects (AIA), Canadian Centre for Occupational Health and Safety (CCOHS), International Agency for Research on Cancer (IARC), National Institute of Public Health of the Republic of Slovenia (NIPH), European Commission (EC), Eurostat, Official Journal of RS, EUR-Lex, Ministry of Health of the Republic of Slovenia (MZ GOV SI); ISO standards; manuals and handbooks of the American Society for Heating, Refrigerating, and Air–Conditioning Engineers (ASHRAE).

On the basis of the literature review, the risk factors were identified, classified and their main parameters were defined. In the presented study, 96 various sources of literature were analysed according to researched risk factors (Table 1). Literature review included all sources of literature addressing the scientific question of association between specific risk factor and its impact on SBS. The detection of interactive influences among risk factors and the design of preventive and control strategy to lower the occurrence of SBS are presented in Part 2.

Table 1:
Number of recorded literature sources according to research fields/risk factors from 1974 to 2014.

Research fields/risk factors	Number of recorded reference sources
Physical risk factors for SBS	25
Chemical risk factors for SBS	47
Biological risk factors for SBS	9
Psychosocial, personal and others risk factors for SBS	15

Abbreviations: SBS – Sick Building Syndrome

RESULTS

Classified risk factors and their key parameters are presented in Figure 1. The main findings of literature review are presented hereinafter.

Figure 1:
Classified risk factors for SBS with their main parameters.

Source: Own source summarised from [1-129]

Risk factors of SBS					
Physical	**Chemical**	**Biological**	**Psychosocial**	**Personal**	**Others**
• Environmental parameters of thermal comfort • Parameters related to building ventilation • Noise, vibrations • Daylight • Electromagnetic fields • Ions • Ergonomy • Universal design	• Constructional and household products • Formaldehyde • Phthalates • Man-made mineral fibres • Volatile organic compounds • Odours • Environmental tobacco smoke • Other indoor air pollutants	• Moulds • Bacteria • Microbes volatile organic compounds • House dust	• Occupational stress • Social status • Lonliness, helplesness • Work organisation, communication, supervision	• Gender • Individual characteristics, health status	• Location, geopatogenic zones building characteristics • Building characteristics • Owership • Presence of insects, rodents, use of desinsection, deratization, desinfection products

Physical risk factors for SBS

The most relevant parameters in the group of physical risk factors are environmental parameters of thermal comfort, parameters of building ventilation, noise, vibrations, daylight, electromagnetic fields, ions as well as ergonomic issues and universal design.

Environmental parameters of thermal comfort

Indoor air temperature (T_{ai}) and relative humidity (RH_{in}) present two of the environmental parameters of thermal comfort. Studies show that general dissatisfaction with the T_{ai} and RH_{in} may be related with the increase of SBS symptoms [21, 22]. Jaakkola et al. [23] carried out a study in a modern eight floor office building in Finland (N=2150 workers) and found out a linear correlation between the amount of SBS symptoms, sensation of dryness, and a rise in T_{ai} above 22 °C. SBS symptoms increased both when the T_{ai} was considered to be too cold and too warm.

Nordström et al. [24] performed a study in new and well ventilated geriatric hospital units in southern Sweden (N=104 employees). It was stated that in Scandinavia, the indoor relative humidity (RH_{in}) in well

The experiment showed that very low RH_{in} (less than 20 %) can cause, in some individuals, drying of the mucous membranes and of the skin.

ventilated buildings was usually in the range 10-35 % in winter that results in increased number of dissatisfied persons. It was concluded that air humidification during the heating season in colder climates can decrease symptoms of SBS and perception of dry air among employees. Andersen et al. [25] performed an experiment in a climate chamber, where eight young healthy men were exposed to clean dry air with T_{ai} 23 °C. The experiment showed that very low RH_{in} (less than 20 %) can cause, in some individuals, drying of the mucous membranes and of the skin [25].

High RH_{in} usually appears in the buildings that are located in a hot-humid climate. However, higher RH_{in} (more that 80 %) may also occur in other buildings, especially due to incorrectly designed building envelopes, systems and installations, processes of increased steam production, water damage and flooding. These conditions may lead to dampness, stuffy odour, visible mould and adverse health effects. Dampness may be a strong predictor of SBS symptoms. Li et al. [26] evaluated the association between measures of dampness in 56 day care centres in the Taipei area and symptoms of respiratory illness in 612 employees. Dampness was found in 75.3 % of the centres, visible mould in 25.8 %, stuffy odour in 50.0 %, water damage in 49.3 %, and flooding in 57.2 %. Furthermore, prevalence of SBS symptoms in the day care workers was statistically significant among those who worked in centres that had mould or dampness.

Beside air temperature and humidity, surface temperatures also have to be considered due to their large influence on perceived temperature. Additionally, lower surface temperatures may result in local discomfort, radiative asymmetry and water condensation. Studies [27] showed that low surface temperatures often result in thermally uncomfortable conditions and higher prevalence of SBS symptoms.

Parameters related to building ventilation

The main causes for SBS symptoms related to building ventilation and defined by studies were inadequate functioning, obsolete and unmaintained HVAC system, decreased number of air changes and decreased volume of clean air [9]. Literature review of 41 studies [28] showed that ventilation rates below 10 L/s per person in office buildings were associated with statistically significant worsening in one or more health or perceived air quality outcomes. Some studies determined that increases in ventilation rates up to approximately 20 L/s per person, were associated with further significant decreases in the prevalence of SBS symptoms or with further significant improvements in perceived air quality. The reviewed studies reported relative risks of 1.5-2 for respiratory illnesses and 1.1-6 for SBS symptoms for low compared to high ventilation rates.

Numerous researchers examined the prevalence of SBS symptoms in naturally ventilated buildings and air-conditioned buildings. Literature review on office buildings [29] indicated that occupants of naturally ventilated offices had fewer SBS symptoms than occupants of air-conditioned offices. Similar study was performed by Costa and Brickus [30] in a central-air-conditioned dropping centre and in natural-ventilation commercial shops in Rio de Janeiro, Brazil. Air-conditioned building [30] were associated with increased SBS symptoms.

Noise and vibrations

Excessive noise seriously harms human health and interferes with people's daily activities [31]. It can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour [31]. From engineering point of view, noise control in buildings includes protection against outside noise, direct sound transmission through structures, equipment noise and reverberation sound.

Wonga [32] studied the prevalence of SBS among apartment residents of 748 households in Hong Kong. The major indoor environmental quality problem perceived by residents was the noise. Beside excessive noise, low frequency noise (20-100 Hz) which is found in buildings with industrial machines or ventilation machinery, may also cause health problems. Certain body organs (specifically the eyes), have characteristics resonance frequencies in the range 1-20 Hz [9]. Hodgson et al. [33] observed that irritability and dizziness experienced by a group of secretaries working in new offices correlated significantly with the vibrations measured on their desks. The vibrations were caused by an adjacent pump-room.

Daylight

Daylight (DL) has an important benefit on well-being, including visual, psychological and non-visual effects. Non-visual effects of DL are related to the regulation of circadian rhythms (i.e. hormone secretion, body temperature, heart frequency and arterial pressure), non-circadian effects (i.e. mood, alertness, concentration) and synthesis of vitamin D [34-36]. Abdel-Hamid et al. [37] carried out a cross-sectional study at the Faculty of Medicine, Ain Shams University, Cairo, Egypt. Results of self-administered questionnaire on 826 workers showed that fatigue and headache were the most prevalent symptoms related to SBS (76.9 and 74.7 %). Poor lighting, lack of sunlight and absence of air currents were associated statistically with SBS symptoms, besides other parameters (poor ventilation, high noise, temperature, humidity, environmental tobacco smoke, use of photocopiers and inadequate office cleaning).

Electromagnetic fields

In the area of adverse health effects of exposure to electromagnetic (EM) fields many articles have been published over the years. Based on a recent in-depth review of the scientific literature, WHO [38] concluded that current evidence did not confirm the existence of any health consequences from exposure to low level EM fields. Exposures to higher levels that might be harmful are restricted by national and international guidelines. However, a number of epidemiological studies [38]

The main causes for SBS symptoms related to building ventilation and defined by studies were inadequate functioning, obsolete and unmaintained HVAC system.

suggest small increases in risk of childhood leukemia with exposure to low frequency magnetic fields in the home. Some individuals reported “hypersensitivity” to electric or magnetic fields. Eriksson and Stenberg [39] investigated the prevalence of general, mucosal, and skin symptoms in the Swedish population (N=3,000, age 18-64). The survey addressed 25 symptoms, principally general, mucosal and skin symptoms. SBS symptoms, skin symptoms and symptoms similar to those reported by individuals with “electric hypersensitivity” were significantly more prevalent among employees with extensive display screen equipment usage.

Ions

In general, air contains negative and positive ions that can be produced naturally or artificially [40]. Concentrations of ions in the air vary with environmental and meteorological conditions [40]. Researchers [40, 41] support the view that negative ions have a net positive effect on health, including improved mood, stabilized catecholamine regulation and circadian rhythm, enhanced recovery from physical exertion and protection from positive ion-related stress and exhaustion disorders. The acceptable minimum concentration of negative ions for indoor air is 200–300 ions per cm^3. The optimal level is 1000–1500 negative ions per cm^3 [42]. The lack of negative ions in the air may be responsible for SBS [9].

All sources of fire [43, 44], and especially cigarette smoking [42], electrical radiators and air-conditioners increase the concentration of positive ions considerably. Contrary, positive ions may be related to SBS. According to Sulman [43, 44], the reported physiological effects of positive ions include inhibition of growth of tissue cell cultures, increased respiratory rate, increased basal metabolism, increased blood pressure, produced headache, fatigue, nausea, produced nasal obstructions, sore throat, dizziness, increased skin temperatures. The researchers found that the electrical charges (positive ionization) engendered by every incoming weather front produce the release of serotonin and weather sensitivity reactions (irritation syndrome, exhaustion syndrome; hyperthyroidism) [43, 44].

Hedge et al. [45] define that worker ergonomics (designing the work / environment / process / equipment to fit the worker, instead of forcing the worker to fit the work / environment / process / equipment) and issues of universal design (barrier free environment for all groups of functional disabilities) [46] also present important physical risk factors that have to be considered for prevention of SBS.

Chemical risk factors for SBS

The most important parameters for SBS among chemical risk factors are used constructional and household products and emitted pollutants, especially formaldehyde, phthalates, volatile organic compounds, odours, environmental tobacco smoke, biocides, and others.

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Constructional and household products

According Simmons and Richard [47] many construction products used for waterproofing, insulating, fireproofing, roofing, painting, plastering, building and treating of floors, as well as surface coating contain toxic chemicals. Constructional products may emit harmful substances in the surrounding environment during their whole life cycle [48, 49].

In addition to constructional products, also household products have to be considered from the aspects of indoor environment quality. For example, use of air-fresheners may be related with poor indoor air quality and may lead to SBS symptoms [50-52]. Studies [50-52] proved that air-fresheners may have adverse health effects. Within the follow-up of the European Community Respiratory Health Survey in 10 countries, Zock et al. [51] identified 3,503 persons doing the cleaning in their homes and who were free of asthma at baseline. The results showed that the use of cleaning sprays at least weekly (42 % of participants) was associated with the incidence of asthma symptoms or medication and wheeze. The incidence of physician-diagnosed asthma was higher among those using sprays at least 4 days per week. Dose-response relationships were apparent for the frequency of use and the number of different sprays.

Moreover, due to low air humidity in buildings, humidifiers are often used. Humidifiers in the ventilation circuit provide a place for microbes to flourish, and also provide a reason for adding biocides to humidified water. Many of these biocides are irritants or allergens [11]. These products are highly irritant in concentrated form; when dispersed in the indoor atmosphere, at low concentrations, they may cause mucous membrane irritation in susceptible individuals [11].

Formaldehyde

Constructional products and wooden furniture (i.e. plywood, particleboard, fibreboard, OSB, panel boards, urea-formaldehyde foam, etc.), paints, adhesives, varnishes, floor finishes, disinfectants, cleaning agents and other household products emit formaldehyde (HCHO) [49].

The results of several studies of indoor / outdoor ratios of formaldehyde in buildings are approximately from 3 to 18 [53-55]. Formaldehyde may be the cause of SBS since it irritates both the eyes and the upper or lower respiratory tract. It may also be responsible for allergic disorders including asthma [56]. Šestan et al. [49] reviewed 11 epidemiological studies (9 studies-residential buildings and 2 studies-public buildings) and found out that measured concentrations of formaldehyde were from 0.0016 ppm (2 $\mu g/m^3$) to 0.109 ppm (134 $\mu g/m^3$). Measured concentrations from the reviewed studies may cause irritation of the upper respiratory tract in the exposed individuals. An examination of studies carried out in 2005 or after [57] indicated that the average exposure of the population to formaldehyde seems to lie between 0.0163 ppm (20 $\mu g/m^3$) and 0.0326 ppm (40 $\mu g/m^3$) under normal living conditions. Salthammer et al. [57] emphasised that new buildings with changed microclimate conditions may be related to higher average and maximum concentrations, which may lead to the increased exposures and health risks, particularly in the group of sensitive individuals.

Constructional products may emit harmful substances in the surrounding environment during their whole life cycle.

In addition to constructional products, also household products have to be considered from the aspects of indoor environment quality.

Phthalates

Polyvinyl chloride (PVC) constructional products usually contain plasticisers, phthalate esters that may be emitted from PVC during the whole life cycle of the product. PVC materials are problematic during normal use of the building or during emergency situations (i.e. a case of fire). Comprehensive literature review [48] indicated that the use of PVC constructional products in indoor environment may have adverse health effects. Phthalates are thought to be responsible for low testosterone level, declining sperm counts and quality, genital malformations, retarded sexual development or even reproductive abnormalities and increased incidences of certain types of cancer [58]. Epidemiologic studies at children [59, 60] evidence that the presence of PVC flooring and walls is related to asthma, rhinitis, wheeze, cough, phlegm, nasal congestion, nasal excretion and eczema. These findings underline the need to consider the health aspects of materials used in indoor environment. Systematic review and meta-analysis on 14 laboratory toxicology studies in adults (1950 to May 2007) assessed the relationship between PVC-related occupational exposure (meat wrappers, hospital and office workers, fire fighters, PVC processors) and the risk of asthma, allergies, or related respiratory effects [61]. During emergency situations (i.e. a case of fire) it forms hazardous products such as carbon monoxide, carbon dioxide, hydrogen chloride, hydrochloric acid, dioxins, smoke/soot, etc. [48].

Comprehensive literature review indicated that the use of PVC constructional products in indoor environment may have adverse health effects.

Phthalates can be adsorbed onto indoor surfaces (carpet, wood, and skin) and re-emitted in the indoor air [62].

Man-made mineral fibres

Man-made mineral fibre (MMMF) is a generic name used to describe an inorganic fibrous material manufactured primarily from glass, rock, minerals, slag and processed inorganic oxides. According to IARC [63] MMMF is classified into five categories: continuous glass filament, glass wool (insulation wool and special purpose wool), rock wool, slag wool, refractory ceramic and other. According to results from epidemiological studies, MMMF have adverse health effects [64]. Acoustic ceilings may contain MMMF that may be transferred from such surfaces to skin and eyes, normally by direct hand contact. However, MMMF may be transferred via air transmission modes. Nielsen [65] proved that especially high concentrations were found in the rooms with uncovered ceilings, but also where the fibres were bound by a water-soluble glue and exposed to water damage. Unsealed fibreglass and other insulation material lining the ventilation ducts can release particulate material into the air. Such material can also become wet, creating an ideal and often concealed site for the growth of microorganisms [10].

Volatile organic compounds

Volatile organic compounds (VOCs) are suspected to be one of the major causes of SBS [66-74]. Sources of VOCs in indoor environments are constructional products, furniture, household products (waxes, detergent, insecticides), products of personal hygiene (cosmetics), do-it-yourself goods (resins), office materials (photocopier ink) or environmental tobacco smoke (ETS). Wolkoff [66] found out that concentrations of volatile organic compounds (VOC) depend on the type of the room, activity and time. VOCs may affect human health and also sometimes are source of odours [9]. Takigawa et al. [67] conducted a study in residential buildings in Okayama, Japan (N=86 men, 84 women). The results showed that aldehyde levels increased frequently and markedly in the newly diseased and ongoing SBS groups. About 10 % of the subjects suffered from SBS in both years. Similar findings were made by Takigawa et al. [12]. Takigawa et al. [12] studied 871 people living in 260 single-family houses in 2004 and 2005. Approximately 14 % and 12 % of subjects were identified as having SBS in the first and second year, respectively. Elevated levels of indoor aldehydes and aliphatic hydrocarbons increased the possible risk of SBS in residents living in new houses.

Odours

Odours are organic or inorganic compounds that originate from within the building, or they can be drawn into a building from the outdoors as well. Indoor sources of odours are usually associated with constructional products, household products, furnishings, office equipment, insufficient ventilation, problems with mould, bioeffluents, etc. Odours are an important source of indoor environmental quality problems in buildings [75]. According to the Report of European Commission on SBS [9], the hidden olfs from materials and systems are claimed to be the major reason for the SBS.

According to the Report of European Commission on SBS, the hidden olfs from materials and systems are claimed to be the major reason for the SBS.

Nakaoka et al. [68] examined the correlation between the sum of VOCs, total odour threshold ratio and SBS symptoms. The findings indicated that the total odour threshold ratio and the concentration level of VOCs were correlated with SBS symptoms among sensitive people. Wang et al. [76] studied the prevalence of perceptions of odours and sensations of air humidity and SBS symptoms in domestic environments. Parents of 4530 1–8 year old children from randomly selected kindergartens in Chongqing, China participated. Stuffy odours, unpleasant odour, pungent odour, mould odour, tobacco smoke odour, humid air and dry air in the last three months (weekly or sometimes) was reported by 31.4 %, 26.5 %, 16.1 %, 10.6 %, 33.0 %, 32.1 % and 37.2 % of the parents, respectively. The prevalence of parents' SBS symptoms were: 78.7 % for general symptoms, 74.3 % for mucosal symptoms and 47.5 % for skin symptoms. Multi-nominal regression analyses for associations between odours/sensations of air humidity and SBS symptoms showed that the odds ratio for "weekly" SBS symptoms was consistently higher than for "sometimes" SBS symptoms.

Environmental tobacco smoke

Environmental tobacco smoke (ETS) is composed of both mainstream and side-stream smoke. ETS usually contains more than 4,000 different chemicals. Undiluted side-stream smoke contains higher concentrations of several chemicals than the mainstream smoke inhaled by the smoker. These chemicals include 2-naphthylamine, N-nitrosodimethylamine, 4-aminobiphenyl, and carbon monoxide [77]. The side-stream smoke may even be more irritant than the mainstream [9].

ETS presents one of the main causes for SBS symptoms [78]. The studies on examination of the relations between ETS exposure and SBS showed that SBS was statistically more pronounced in smokers than in non-smokers [22] and there was an excess of symptoms in non-smokers and ex-smokers exposed to ETS compared with the same non exposed categories [79]. Mizoue et al. [80] analysed the data from a 1998 cross-sectional survey of 1,281 municipal employees who worked in a variety of buildings in a Japanese city. Among non-smokers, the odds ratio for the association between SBS and 4 hours of ETS exposure per day was 2.7, and for most symptom categories, odds ratios increased with increasing hours of ETS exposure. Working overtime for 30 or more hours per month was also associated with SBS symptoms, but the crude odds ratio of 3.0 for SBS was reduced by 21 % after adjustment for variables associated with overtime work and by 49 % after further adjustment for perceived work overload.

ETS presents one of the main causes for SBS symptoms.

Working overtime for 30 or more hours per month was also associated with SBS symptoms.

Other indoor air pollutants

One of the most important indicators for indoor air quality and adequacy of building ventilation is CO_2. The main indoor source of CO_2 in most buildings is human metabolic activity. In terms of worker safety, Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) for CO_2 of 5,000 parts per million (ppm) over an 8 hour work day. Similarly, the American Conference of Governmental Industrial Hygienists (ACGIH) TLV (threshold limit value) is 5,000 ppm for an 8-hour workday, with a ceiling exposure limit of 30,000 ppm for a 10-minute period based on acute inhalation data [81]. According to national Rules on the ventilation and air-conditioning of buildings [82], the permissible value of CO_2 in indoor air is 3000 mg/m^3 (1667 ppm). However, also lower levels than those recommended or regulated may lead to occupant dissatisfaction and decreased productivity [83]. For example, a concentration higher than 1000 ppm was associated with an increased percentage of dissatisfied occupants [9].

Seppänen et al. [28] reviewed 41 studies with over 60,000 subjects on the associations of ventilation rates and CO_2 concentrations in non-residential and non-industrial buildings (primarily offices) with health outcomes. The risk of SBS symptoms continued to decrease significantly with decreasing CO_2 concentrations below 800 ppm. Similar conclusion was presented in the study by Erdmann et al. [84], Apte et al. [85] and Tsai et al. [86]. Erdmann et al. [84] found out that higher dCO_2 (workday time-averaged indoor minus outdoor CO_2 concentrations) was associated with increased prevalence of certain mucous membrane and lower respiratory SBS syndrome symptoms. Even at peak dCO_2 concentrations it was below 1,000 ppm. Apte et al. [85] evaluated relationship between indoor CO_2 concentrations and SBS symptoms in occupants from 41 U.S. office buildings. Results showed that dose response relationship with odds ratios per 100 ppm dCO_2 ranged from 1.2 to 1.5 for sore throat, nose/sinus, tight chest, and wheezing. Tsai et al. [86] evaluated the SBS symptoms among 111 office workers in August and November 2003. The most prevalent symptoms of the five SBS groups were eye irritation and nonspecific and upper respiratory symptoms. Tsai et al. [86] proved that workers exposed to indoor CO_2 levels greater than 800 ppm were likely to report more eye irritation or upper respiratory symptoms.

Biological risk factors for SBS

Biological contaminants present in indoor air include bacteria, moulds, mildew, viruses, animal dander and cat saliva, house dust, mites, cockroaches, and pollen [87]. There are many indoor or outdoor sources of these pollutants (i.e. people, animals, and soil and plant debris). Microbial pollution involves hundreds of species of bacteria and fungi that grow indoors when sufficient moisture is available. Exposure to microbial contaminants is associated with respiratory symptoms, allergies, asthma and immunological reactions [88].

Moulds

The study by Straus [89] emphasised the importance of moulds and their mycotoxins in the phenomenon of SBS. Zhang et al. [90] studied the associations between dampness and indoor moulds in workplace buildings and selected biomarkers as well as incidence and remission of SBS. The study was based on a ten-year prospective study (1992–2002) in a random sample of adults (N=429) from the Uppsala part of the European Community Respiratory Health Survey. Dampness was associated with increased incidence and decreased remission of SBS. Dampness and moulds increased bronchial responsiveness and eosinophilic inflammation. Similar study was performed by Sahlberg et al. [91] in 159 homes of the participants in three EU cities (Reykjavik, Uppsala, Tartu). The associations between SBS, MVOC, and reports on dampness and mould were examined. The results showed that the indoor levels of some MVOCs were positively associated with SBS. Levels of airborne moulds and bacteria and some MVOCs were higher in dwellings with a history of dampness and moulds. The problems with dampness exist also in other environments, such as dorm rooms and schools. Sun et al. [92] carried out a study in 1569 dorm rooms in Tianjin, China (2006–2007; N=3712 students). A “mouldy odour” or “dry air” was perceived by occupants in 31 % dorm rooms. The adjusted odds ratio (AOR) of perceived mouldy odour for general SBS symptoms was 2.4, for mucosal symptoms 2.2, and for skin symptoms 2.0. Local mouldy odour around room corners or under radiators was reported by inspectors in 26 % dorm rooms. The study concluded that local mouldy odour perceived by inspectors was a significant risk factor for nose irritation (AOR 2.8).

Zhang et al. [93] analysed the relationship between the concentration of allergens and microbial compounds and new onset of SBS. The study was based on a two-year prospective analysis in pupils (N=1143) in a random sample of schools in China. The prevalence of mucosal and general symptoms was 33 % and 28 %, respectively, at baseline, and it increased during follow-up. At baseline, 27 % reported at least one symptom that improved when away from school (school-related symptoms). The authors concluded that fungal exposure could increase the incidence of school-related symptoms.

Bacteria

Teeuw et al. [94] carried out a survey of SBS among 1355 employees working in 19 governmental office buildings in the Netherlands. Physical, chemical, and microbiological characteristics between mechanically ventilated and naturally ventilated buildings were examined. Mechanically ventilated buildings were grouped as "healthy" or "sick" based on symptom prevalence (mean symptom prevalence < 15 % or > or = 15 %). The authors found no differences in physical characteristics. However, the concentration of airborne endotoxin and gram-negative rods were found in higher numbers in the "sick" mechanically ventilated buildings than in the "healthy" mechanically ventilated buildings and naturally ventilated buildings. The study concluded that airborne microbial contamination, in particular with gram-negative rods and perhaps with endotoxin, may have a role in the causation of SBS.

Microbes volatile organic compounds

Microbes volatile organic compounds (MVOCs) are products of the microbes' primary and secondary metabolism. They are associated with mould and bacterial growth and responsible for the odorous smells [95]. Araki et al. [19] measured indoor MVOC levels in single family homes and evaluated the relationship between exposure to them and SBS. The most frequently detected MVOC was 1-pentanol. Among 620 participants, 19.4 % reported one or more mucous symptoms; irritation of the eyes, nose, airway, or coughing every week (weekly symptoms), and 4.8 % reported that the symptoms were home-related. Weekly symptoms were not associated with any of MVOC, whereas significant associations between home-related mucous symptoms and 1-octen-3-ol and 2-pentanol were obtained. Additionally, Sahlberg et al. [91] examined whether MVOCs, and airborne levels of bacteria, moulds, formaldehyde, and two plasticizers in dwellings were associated with the prevalence of SBS, and studied associations between MVOCs and reports on dampness and mould. A total of 159 adults (57 % females) participated (19 % from Reykjavik, 40 % from Uppsala, and 41 % from Tartu). The results showed that MVOCs such as 1-octen-3-ol, formaldehyde and the plasticizer Texanol, may be a risk factor for sick building syndrome. Moreover, concentrations of airborne moulds, bacteria and some other MVOCs were slightly higher in homes with reported dampness and mould. Some MVOCs may have adverse effects on respiratory, nervous and circulatory system and may have carcinogenic effects [96].

House dust

Dust in homes, offices, and other built environments contains various organic and inorganic matter [97]. Quantity and composition of house dust varies greatly with seasonal and environmental factors and also depends upon the HVAC system, cleaning habits, occupant activities, etc. Poor building service maintenance, poor cleaning or cleanability increased the prevalence of SBS [98]. Nexo et al. [99] demonstrated a correlation between the organic dust content of carpets (predominantly skin scales, bacteria and moulds) and the symptoms of SBS. Among 12 employees, 5 employees had symptoms related to the work place.

Dust often contains substances that are emitted from constructional products (i.e. phthalate esters and other plasticisers emitted from PVC constructional products). Many emitted substances may have important health concerns. Kishi et al. [100] performed a study in which dust samples were collected from the living room of 182 single family dwellings in 6 cities in Japan. The prevalence of SBS, asthma, atopic dermatitis, allergic rhinitis and conjunctivitis was 6.5 %, 4.7 %, 10.3 %, 7.6 % and 14.9 %, respectively. Significant associations between the medical treatment of asthma and floor bis(2-ethylhexyl) adipate (DEHA) and multi-surface di-n-butyl phthalate (DnBP), dermatitis and floor BBzP and DEHA, conjunctivitis and floor Bis(2-ethylhexyl) phthalate (DEHP) were obtained after adjustment.

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Office buildings normally present very low concentrations of mites, because they do not provide appropriate conditions for the growth of such microorganisms. Mites are, however, relatively abundant in household dust. Mites can be destroyed keeping absolute humidity below 7 g/kg of air (about 45 %) during the winter time [ECA, 1989]. Airborne house dust frequently causes allergic symptoms. However, house dust may also be problematic for healthy subjects without hypersensitivity reactions, as it was presented by Mølhave et al. [101]. This Danish Office Dust Experiment [101] investigated the response of 24 healthy non-sensitive adult subjects to exposure to normal office dust in the air. The responses were both subjective sensory reactions and other neurogenic effects even at exposure levels within the range found in normal buildings. Some of the effects appeared acutely and decreased through adaptation while others increased during prolonged exposure and remained for more than 17 h after the exposure ended. The threshold level for the dose–response relationships was below 140 $\mu g/m^3$.

Psychosocial, personal and other risk factors

Psychosocial, personal and other risk factors for SBS are gender, individual characteristics, health condition, stress, feelings of loneliness and helplessness, working position, social status, others.

Gender, working position, health characteristics

A screening questionnaire study of 4943 office workers and a case-referent study of SBS in 464 subjects were completed by Stenberg et al. [102]. Females reported SBS more often than males [102]. The same conclusions were found in the studies by Sun et al. [92] in dorm environment in Tianjin, China (2006–2007) and Engvall et al. [103] in multi-family buildings in Stockholm. Additionally, the importance of gender to the prevalence of the SBS symptoms was investigated on 590 employees of three office buildings in Norway [104]. The results showed that greater percentage of females than males reported having SBS symptoms.

Women are often employed under less favourable working conditions than men, as it was confirmed in the study by Bullinger et al. [105]. Questionnaire results from 2517 female employees in Germany (as compared to 2079 male employees) showed that women report higher scores in sensory irritation, higher bodily complaint rate and more negative evaluation of the indoor climate. In addition, most psychosocial variables showed less favourable scores for women as compared to men.

The relative influence of gender, atopy, smoking habits and age on reported SBS symptoms among office workers was investigated through questionnaire studies among 1293 employees in 10 nonindustrial buildings [104]. The occurrence of atopy among the office workers was not found to be different from that of the general population. The prevalence of symptoms was higher among atopic individuals than among nonatopics, and higher among females than among males. While gender was found to be important for some symptoms, atopy was important for all of them. The results indicated interrelations between smoking and atopy, with enhanced prevalence of some symptoms. Age of the persons was also included in the present analyses. Different ways of grouping age indicated different trends in associations between age and the prevalence of symptoms, but the study did not show any unambiguous associations between the age and the prevalence of symptoms. The same conclusion was made in the literature review by Norbäck [106]. Norbäck [106] showed that there was no consistent association between age and SBS.

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Symptoms are generally more common and more problematical in the stressed, the unloved, and in individuals who feel powerless to change their situation. There is a strong association between lack of control of the office environment and symptoms [11]. There is an association between lower social status and SBS symptoms [11]. Norlen and Andersson [107] showed that residents in single-family houses reported less SBS than those in multifamily houses, although measurements suggest a less favourable indoor environment in single-family houses.

Stress

Occupational stress has been shown to have a detrimental effect on the health and wellbeing of employees, as well as a negative impact on workplace productivity and profits [108]. Some researchers [109, 110] have investigated the possible links between SBS symptoms and occupational stress. Occupational stress has been found to be correlated with symptoms of the SBS, but much of the research has been of a cross-sectional nature, and it does not indicate whether stress is an active element or an outcome [111]. However, Ooi and Goh [112] examined the role of work-related psychosocial stress among 2160 subjects in 67 offices in the aetiology of SBS. Ooi and Goh [112] found an incremental trend in the prevalence of SBS among office workers who reported high levels of physical and mental stress, and decreasing climate of co-operation.

Lu et al. [113] investigated whether SBS complaints and indoor air pollution for 389 office workers in 87 government offices of 8 high-rise buildings in Taipei city are associated with oxidative stress. Oxidative stress was indicated by urinary 8-hydroxydeoxyguanosine (8-OHdG). The results showed that urinary 8-OHdG had significant associations with VOC and CO2 in offices, and with urinary cotinine levels. The mean urinary 8-OHdG level was also significantly higher in participants with SBS symptoms than in those without such complaints. The mean 8-OHdG increased as the number of SBS symptoms increased. This study indicated that the 8-OHdG level was significantly associated with SBS complaints after controlling for air pollution and smoking.

Other factors

Wang et al. [76] performed a study in domestic environments in Chongqing, China and confirmed that living near a main road or highway, redecoration, and new furniture were risk factors for perceptions of odours and sensations of humid air and dry air. The presence of cockroaches, rats, and mosquitoes/flies, use of mosquito-repellent incense and other incenses were all risk factors. The analyses of 609 multi-family buildings with 14,235 dwellings in Stockholm [103] showed that subjects owning building reported less SBS, but the relationship between ownership and building age was strong. According to the model, 5 % of all buildings built before 1961, 13 % of those built in the period 1976–1984, and 15 % of those built in the period 1985–1990 would have significantly more SBS than expected. Another issue that has to be investigated in relation to SBS are geopatogenic zones.

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DISCUSION

Based on our comprehensive literature review the risk factors for SBS were classified into six main groups: physical, chemical, biological, psychosocial, personal an others. Studies where risk factors for SBS are systematically identified are for the moment scarce. Moreover, there are no appropriate methods for the identification of all risk factors for SBS. However, identification of risk factors for SBS and their relevant parameters present an important step towards effective prevention and control of SBS symptoms.

The most important findings of the literature review show that many studies have examined the correlation between SBS symptoms and physical risk factors as well as the correlation between SBS symptoms and chemical risk factors, while the studies on the correlation between

SBS symptoms and biological, psychological, personal and other risk factors are for the moment scarce. From the chronological point of view, the first studies appeared in the 1970s, where physical risk factors were primarily examined. The main reasons might be related to the introduction of thermal insulated building envelopes, synthetic materials and the application of mechanical systems. Solutions for lowering the energy use were party defined on the level of thermally improved materials and mechanical systems. In the 1980s, beside physical risk factors a number of studies examined the biological risk factors. In the 1990s the researchers realized that the SBS was influenced also by psychosocial, personal and other risk factors. Nevertheless, psychosocial, personal and other risk factors still present neglected research areas.

Among physical risk factors, a number of studies examine the correlations between T_{ai}, RH_{in} and ventilation parameters. Additionally, other parameters of physical risk factors were examined (i.e. noise, DL, EM and ions) in our study; they were studied in a small number of studies. Studies on chemical risk factors are mainly focused on the links between SBS symptoms exposure to different emission sources, such as construction product, furniture and household products. They revealed the possible adverse health effects of constructional products on building occupants, during normal use of the building or during emergency situations (i.e. a case of fire). Despite those issues, many of construction and household products on the market may present potential health concerns. Composition of construction and household products in relation to the content of harmful substances is often questionable, legislation and inspection are incomplete.

Composition of construction and household products in relation to the content of harmful substances is often questionable, legislation and inspection are incomplete.

Studies in the field of biological risk factors examine the association between the presence of many biological agents in the indoor environment in relation to dampness related problems (mould spots, damp stains, water damage and condensation) as well as inadequate ventilation. Studies on the exposure to other biological risk factors and SBS occurrence are for the moment scarce, mainly due to the fact that beside SBS also BRI presents a common result of exposure to biological agents (i.e. asperigillosis) [8, 114].

The most important step in planning the strategies for prevention and control of SBS is risk assessment. Identification and classification of risk factors for SBS presents a crucial part of risk assessment. Qualitative and/or quantitative determination of the parameters of risk factors is defined in international and national legislation, standards, guidelines and recommendations. Legal requirements for physical risk factors, i.e. the parameters for thermal comfort, ventilation and air-conditioning of buildings (i.e. T_{ai}, RH_{in}, mean radiant temperature, etc.), are hierarchically defined in international and national legal acts [115-117, 82], standards and recommendations [118-121]. The protection against noise and vibrations in buildings is also well defined [115, 122-125]. However, legal requirements are mainly related to the working environment, while the living environment is often neglected. The qualitative and quantitative characteristics of DL (especially parameters important for non-visual biological effects of daylight on wellbeing), ions and EM fields in built environment are partly defined or even not defined, nor supervised.

The protection of workers from risks related to exposure to biological and chemical agents at work is well regulated [82, 119, 120, 126-129]. However, the requirements for biological and chemical risk factors are mainly defined for working environments [126-129]. For other environments, the requirements for chemical risk factors are defined only for the indoor air quality, where limit values for key indoor air pollutant are required [82, 119, 120]. There even exist EU legislative documents for health and environment safety of constructional products [115], while the composition and emission rates of harmful substances from constructional and household products are not monitored and supervised.

Methods of identification are defined just for some parameters of risk factors. Ignored or disregarded legal requirements at the stage of building design, construction, usage and maintenance as well as lack of legislation present problematic fields that have to be confronted in the future. Consequently, this may be one of the main cause for SBS [5]. At the moment, there are no standardized methods for the sampling and identification of risk factors for SBS in working and living environment. At the stage of preparation of standardized methods, the interdisciplinary cooperation of all subjects that are involved in the stage of design, construction, usage, maintenance and control of building is necessary.

The most important step in planning the strategies for prevention and control of SBS is risk assessment.

CONCLUSIONS

Identification of risk factors for SBS and their relevant parameters presents an important step towards effective prevention and control of SBS symptoms. Based on the comprehensive literature review the risk factors for SBS were classified into the six main groups: physical, chemical, biological, psychosocial, personal an others. The physical, chemical and biological risk factors in relation to SBS are well researched topics. However, psychosocial, personal and other risk factors are poorly investigated. For integral prevention and control of risk factors of SBS, additional research is needed. Future research should be focused on defining standardized methods for identifying risk factors with sampling procedures and analysis. This should be based on interdisciplinary cooperation of various experts. The occurrence of SBS symptoms may be a result of *interactive influences* among risk factors and their parameters. The interactions among risk factors and their parameters on the occurrence of SBS and strategy of prevention and control are presented in Part 2.

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Future research should be focused on defining standardized methods for identifying risk factors with sampling procedures and analysis.

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Original scientific article

Prevention and control of Sick Building Syndrome (SBS). Part 2: Design of a preventive and control strategy to lower the occurrence of SBS

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ABSTRACT

Problem: Current design of energy-efficient buildings is mainly focused on the solving of energy problems. Solutions are party defined, which may result in unhealthy conditions, Sick Building Syndrome (SBS) or even Building Related Illness (BRI). For the design of healthy and energy-efficient buildings a strategic approach for integral prevention and control of SBS is mandatory. **Purpose:** The purpose of this study is to design a preventive and control strategy to lower the occurrence of SBS. **Method:** On the basis of the results of Part 1, the *interactive influences among risk factors and their parameters were detected and a preventive and control strategy* to lower the occurrence of SBS was designed. **Results and discussion:** Interactive influences were detected among all groups of risk factors, especially on chemical-chemical, chemical-physical and multifactorial interactions. *Designed strategy includes* integral measures specific for the prevention and control of SBS. It includes step-by-step actions for the prevention of physical, chemical, biological, psychosocial, personal and other risk factors and their influences. **Conclusions:** The designed strategy is *necessary* for the planning of healthy and comfortable buildings *and is a basis for successful renovations.*

Key words: Sick Building Syndrome, risk factors, interactions, prevention, control, strategy.

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Article with the title *"Prevention and control of Sick Building Syndrome (SBS). Part 2: Design of a preventive and control strategy to lower the occurrence of SBS"* presents an original work. It has not been sent to any other publisher. All authors have read the article and agreed with its content.

INTRODUCTION

According to EU directives [1-4], a large part of building fond must be renovated. Directive 2012/27/EU on the energy efficiency [2] defines that each Member State shall ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year. Beside energy-efficiency, health and comfort issues have to be well considered [3]. In such way overall building-efficiency has to be attained [5, 6].

In conflict with the EU requirements, current design of energy-efficient buildings is mainly focused on the solving of energy problems [7]. Solutions are party defined, which may result in unhealthy conditions, Sick Building Syndrome (SBS) or even Building Related Illness (BRI). Approximately 30 % of new and renovated buildings worldwide may be related to SBS [8]. SBS symptoms may occur in residential and public buildings [9-13]. In the studies on residential buildings [11-13] from 12 % to 30.8 % of occupants were identified as having SBS symptoms. Moreover, in the studies on public buildings [14-16] from 20 % to 50 % of workers experienced SBS symptoms. Among public buildings, health-care facilities, schools and kindergartens present priority environments [9-13] due to highly sensitive population with increased health risks. Consequently, design of healthy and comfortable built environment is fundamental for the prevention and control of health hazards.

Identification of risk factors and definition of interactive influences among parameters present a first step towards integral prevention and control of SBS.

Identification of risk factors and definition of interactive influences among parameters present a first step towards integral prevention and control of SBS. Part 1 presents results of the comprehensive literature review, on which risk factors were identified. On the basis of the results of Part 1, the purpose of this study was to design a preventive and control strategy to lower the occurrence of SBS (Part 2).

METHODS

Interactive influences among risk factors were detected according to the results presented in Part 1 (a-c) of the study:

a) Results of the comprehensive literature review of 113 sources of literature published from 1973 to 2014.

b) Results of the classified risk factors for SBS into physical, chemical, biological, psychosocial, personal and others.

c) Results on the defined main parameters of classified groups of risk factors.

Based on the results of comprehensive literature review, interactive influences among impact factors were detected. Altogether 130 various sources of literature were analysed. Interactive influences included detected interactions between parameters of each group of risk factors, i.e. chemical-chemical, chemical-physical, chemical-biological, biological-biological, biological-physical, physical-physical, personal-physical, personal-chemical and multifactorial interactions. A preventive strategy to lower the occurrence of SBS was designed and includes integral measures for the prevention of physical, chemical, biological, psychosocial, personal and other risk factors as well as their interactive influences.

RESULTS

Interactive influences among parameters

Based on the comprehensive literature review all possible interactive influences among risk factors and their parameters were detected and are presented in Table 1. The main findings are presented hereinafter.

Chemical-chemical interactions: detected chemical-chemical interactions present interactive influences among the parameters of the group of chemical risk factors (constructional products, household products, furniture, equipment, formaldehyde, volatile organic compounds (VOCs), phthalates, odours, man-made mineral fibre (MMMF), environmental tobacco smoke (ETS), other indoor pollutants). Constructional products, household products, furniture and other equipment may emit harmful substances in the surrounding environment during their whole life cycle [17, 18]. For example, wooden constructional products and furniture (i.e. plywood, particleboard, fibreboard, oriented strand board (OSB), panel boards, urea-formaldehyde foam, etc.), paints, adhesives, varnishes, floor finishes, disinfectants, cleaning agents and other household products emit formaldehyde [18]. Polyvinyl chloride (PVC) constructional products, personal-care products, medical devices, detergents and surfactants, packaging, children's toys, modelling clay, waxes, paints, printing inks and coatings, pharmaceuticals, food products, and textiles contain phthalates. Phthalates are easily released into the environment because there is no covalent bond between the phthalates and plastics [17]. Sources of VOCs in indoor environments are constructional products, furniture, household products (waxes, detergent, insecticides), products of personal hygiene (cosmetics), do-it-yourself goods (resins), office materials (photocopier ink) or ETS [19]. Inefficient ventilation system, incomplete combustion processes, unvented heating, gas cooking, tobacco smoking may result in higher concentrations of other indoor air quality (IAQ) pollutants (i.e. CO_2, CO, NO_x, SO_x) [19]. IAQ pollutants may present an important source of odours [19, 20].

Chemical-physical interactions: detected chemical-physical interactions present interactive influences among parameters of the group of chemical risk factors and parameters of the group of physical risk factors (environmental parameters of thermal comfort, parameters related to building ventilation system, noise, vibrations, daylight, electromagnetic (EM) fields, ions, ergonomic issues, universal design). The emission rates of harmful substances from the constructional products, household products, furniture and other indoor sources are influenced by the environmental conditions such as air temperature (T_{ai}), surface temperatures, relative humidity of indoor air (RH_{in}), air change rate and surface air velocity [19, 21- 28]. Sakai et al. [22] performed a comparative study in urban dwellings in Japan and Sweden and proved that indoor concentrations of formaldehyde were increased at

Phthalates are easily released into the environment because there is no covalent bond between the phthalates and plastics.

Table 1:
Matrix of detected interactive influences among risk factors and their parameters.

			1	2	3	4	5	6	7	8	9
Chemical	1	Products, furniture, equipment	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9
	2	HCHO	2-1	2-2			2-5	2-6			
	3	VOCs	3-1		3-3		3-5	3-6			
	4	Phthalates	4-1			4-4					
	5	Odours	5-1	5-2	5-3		5-5	5-6			5-9
	6	ETS	6-1	6-2	6-3		6-5	6-6			6-9
	7	MMMF	7-1						7-7		
	8	Biocides	8-1							8-8	
	9	Other pollutants	9-1				9-5	9-6			9-9
Physical	10	$T_{ai,}$ T_{surf}	10-1	10-2	10-3	10-4	10-5			10-8	10-9
	11	RH_{in}	11-1	11-2	11-3	11-4	11-5			11-8	11-9
	12	Ventilation parameters	12-1	12-2	12-3	12-4	12-5	12-6	12-7	12-8	12-9
	13	Noise, vibrations	13-1								
	14	Daylight	14-1								
	15	EM fileds, ions	15-1								
	16	Ergonomy, universal design									
Biological	17	Moulds	17-1				17-5			17-8	17-9
	18	Bacteria	18-1				18-5			18-8	
	19	MVOC	19-1				19-5			19-8	
	20	House dust	20-1			20-4					20-9
Psychological, personal, other	21	Gender, working position									
	22	Social status									
	23	Other									
			1	2	3	4	5	6	7	8	9
			Products, furniture, equipment	HCHO	VOCs	Phthalates	Odours	ETS	MMMF	Biocides	Other pollutants
			Chemical								

Abbreviations: VOCs – volatile organic compounds, ETS – environmental tobacco smoke, MMMF – man-made mineral fibre, T_{ai} – *air* temperature, T_{surf} – surface temperature, RH_{in} – relative humidity of indoor air, EM – electromagnetic fields, MVOC – microbes volatile organic compounds.

Source: [1-59]

higher T_{ai} and RH_{in}. The same findings were reported in the study by Järnström et al. [23] for new residential buildings in Finland and in the study by Blondel and Plaisance [24] for students rooms in France. Järnström et al. [23] measured higher concentrations of formaldehyde in summer, at higher T_{ai} and RH_{in}. And vice versa, lower concentrations were measures in winter, at lower T_{ai} and drier air. Blondel in Plaisance [24] concluded that the rise of formaldehyde emissions from indoor materials correlated with T_{ai}. These findings were confirmed by an experimental study in a test chamber [29], where the increase of

1-10	1-11	1-12	1-13	1-14	1-15	1-16	1-17	1-18	1-19	1-20			
2-10	2-11	2-12											
3-10	3-11	3-12											
4-10	4-11	4-12								4-20			
5-10	5-11	5-12					5-17	5-18	5-19				
		6-12									6-21	6-22	
		7-12											
	8-11	8-12					8-17	8-18					
9-10	9-11	9-12											
10-10	10-11	10-12		10-14		10-16	10-17	10-18					
11-10	11-11	11-12		11-14	11-15	11-16	11-17	11-18	11-19	11-20			
12-10	12-11	12-12	12-13	12-14	11-15	12-16	12-17	12-18	12-19	12-20	12-21		
		13-12	13-13										
14-10					14-15	14-16							
	13-11	13-12											
16-10	16-11	16-12	16-13	16-14	16-15	16-16					16-21	16-22	
17-10	17-11	17-12					17-17	17-18	17—19	17-20	17-21	17-22	17-23
18-10	18-11	18-12					18-17	18-18	18-19	18-20			
							19-17	19-18	19-19				
20-10	20-11	20-12					20-17	20-18		20-20			
		21-12									21-21	21-22	21-23
											22-21	22-22	22-23
											23-21	23-22	23-23
10	11	12	13	14	15	16	17	18	19	20	21	22	23
T_{ai}	RH_{in}	Ventilation parameters	Noise, vibrations	Daylight	EM, ions	Ergonomy, universal design	Moulds	Bacteria	MVOC	House dust	Gender, age, working position	Social status	Other
Physical							**Biological**				**Psychological, personal, other**		

T_{ai} resulted in higher emission rate of formaldehyde from analysed materials.

Beside on formaldehyde emissions, T_{ai} and RH_{in} have a significant effect on the emissions of phthalates, VOCs and odours. Clasuen et al. [25] analysed the influences of T_{ai} and RH_{in} on the emission of di-(2-ethylhexyl) phthalate (DEHP) from PVC flooring. The study concluded that DEHP concentrations increased greatly with increasing T_{ai}, and were independent on the RH_{in}. Similarly, the study by Nimmermark and Gustafsson [28] showed that odour emission increased significantly with T_{ai}

at similar ventilation rate. Comprehensive literature review by Haghighat et al. [21] noted that emission rates of total volatile organic compounds (TVOCs) increased by T_{ai} for both the paint and varnish. However, the individual compounds did not necessarily follow the same trend established by the TVOC; they showed greater emission rates at lower T_{ai}. The effects of RH_{in} on the emissions of TVOC differed between paint and varnish. Individual compounds showed higher emission rates for lower humidities and vice versa.

Beside T_{ai} and RH_{in}, VOC emissions are also influenced by surface temperatures. Kim et al. [26] measured VOC emissions from building materials in residential buildings in Korea with radiant floor heating systems. The results showed that the VOC emissions from flooring materials increased as the floor temperature rises. In particular, increased temperatures may accelerate chemical reactions within the material, leading to additional VOC emissions [26]. Emitted pollutants can be adsorbed onto indoor surfaces (carpet, wood, skin) and re-emit in the indoor air [27] or they may react with each other and form secondary pollutants.

High RH_{in} in combination with room temperatures often results in dampness and odours. Dampness related problems (i.e. mould spots, damp stains, water damage and condensation) present risk factors for the perceptions of odours and sensations of humid air and dry air, as it was proven by Wang et al. [30] in domestic environments in Chongqing, China and Zang et al. [31] in workplace buildings in Uppsala.

Additionally, ventilation system itself can be a source of air pollutants. Unsealed fibreglass and other insulation material lining the ventilation ducts can release particulate material into the air. Such material can also become wet, creating an ideal and often concealed site for the growth of microorganisms.

The type of building ventilation system (i.e. natural-ventilation vs. mechanical systems) was related to IAQ and SBS as it was presented in the comparative study by Costa and Brickus [32] in Niteroi, Rio de Janeiro, Brazil. Occupants in naturally ventilated offices have fewer SBS symptoms than occupants of air-conditioned offices [32, 33].

Inadequate functioning, obsolete and unmaintained HVAC system, decreased number of air changes, decreased volume of clean air may lead to increased concentrations of indoor air pollutants and may result in the occurrence of SBS symptoms [19, 34-36]. Moreover, ventilation rates strongly influence the emission rates from indoor sources, such as DEHP emission rate from PVC flooring. Similar findings were reported in the study by Hodgson et al. [37] in houses in Florida, where VOCs emission rates at the low and high ventilation rates decreased with decreasing compound volatility. Additionally, ventilation system itself can be a source of air pollutants. Unsealed fibreglass and other insulation material lining the ventilation ducts can release particulate material into the air. Such material can also become wet, creating an ideal and often concealed site for the growth of microorganisms [34].

Chemical-biological interactions: Chemical-biological interactions present interactive influences among parameters of the group of chemical risk factors and parameters of the group of biological risk factors (moulds, bacteria, MVOCs, house dust). For example, house dust often contains substances that are emitted from constructional products, i.e. phthalate esters and other plasticisers emitted from PVC constructional products [38].

Biological-biological interactions: Biological-biological interactions present interactive influences among parameters of the group of biological risk factors. The association between MVOCs, dampness and mould was reported in the study by Assimakopoulos and Helmis [35] in the public building in the centre of Athens and in the study by Sahlberg et al. [39] in 159 homes in Reykjavik, Uppsala and Tartu.

Biological-physical interactions: detected biological-physical interactions present interactive influences among parameters of the group of biological risk factors and parameters of the group of physical risk factors. High RH_{in} in combination with T_{ai} may lead to the occurrence of condensation on surfaces, material damages, dampness and toxic mould growth [19], as it was presented in the study by Zhang et al. [31] in office buildings and Sahlberg et al. [39] in homes in three EU cities. Sahlberg et al. [39] found out that levels of airborne moulds and bacteria and some MVOCs were higher in dwellings with a history of dampness and moulds.

Additionally, mites as important biological agents are related to RH_{in}. They can be destroyed by keeping absolute humidity below 7 g/kg of air (about 45 %) during the winter time [19]. If RH_{in} is too low, which usually happens during heating season, humidifiers are introduced. Humidifiers provide an optimal place for microbes to flourish. Beside humidifiers also dehumidifiers, cooling devices, indoor A/C units are problematic for the growth of microorganisms [19]. Moreover, man-made water systems (e.g., hot water systems, ventilation systems, cooling towers, humidifiers, whirlpool spas) are common sources of outbreaks of *Legionella* infection [40].

Physical-physical interactions: detected physical-physical interactions present interactive influences among parameters of the group of physical risk factors. Indirect effects of low RH_{in} include static electricity and consequent electric discharges and variation of the respirable suspended particulate matter [19]. Industrial machines, ventilation machinery and other mechanical systems may produce low frequency noise and vibrations. Hodgson et al. [41] showed that an adjacent pump-room caused vibrations which resulted in the occurrence of SBS symptoms among the group of secretaries.

Personal-physical interactions: detected physical-personal interactions present interactive influences among parameters of the group of physical risk factors and parameters of the group personal risk factors (gender, health status, individual differences). Literature survey on how different factors influence human comfort in indoor environments [42] showed that thermal comfort was influenced by the level of education, the relationship with superiors and colleagues and time pressure, but not by gender, age, body build, fitness, health, self-estimated environmental sensitivity, menstruation cycle, pattern of smoking and coffee drinking, job stress or hours worked per week.

Personal-chemical interactions: detected personal-chemical interactions present interactive influences among parameters of the group of personal risk factors and parameters of the group of chemical risk factors. Many studies have focused on the adverse health effect of the indoor air pollutants among highly sensitive groups of individuals, such as children, elderly and occupational groups [43, 44]. The positive correlation between oxidative stress, indoor air pollution (VOC, CO2) and SBS complaints was proved in the study by Lu et al. [45] among 389 office workers in 87 government offices of 8 high-rise buildings in Taipei city.

Multifactorial interactions: detected multifactorial interactions present interactive influences among parameters of different groups of risk factors. A lot of studies have analysed the association between various risk factors for SBS. Burge [46] found out that there was an association between increasing T_{ai}, overcrowding, and inadequate ventilation and the occurrence of SBS. Skov et al. [47] performed a multivariate logistic regression analyses on 2369 office workers in 14 building in Copenhagen, Denmark, in which the influence of various factors, such as the concentration of macromolecular organic floor dust, the floor covering, the number of workplaces in the office, the age of the building, the type of ventilation, shelf factor and fleece factor on SBS symptoms was investigated. The effect of physical, chemical, and microbiological characteristics of 19 governmental office buildings in the Netherlands and SBS were analysed by Teeuw et al. [48].

Preventive strategy to lower the occurrence of SBS

A preventive strategy was designed and it *includes* integral measures specific to the prevention and control of SBS. Integral measures include step-by-step actions for the prevention of physical, chemical, biological, psychosocial, personal and other risk factors, and their interactive influences (Table 2).

Table 2:
Stages of preventive strategy to lower the occurrence of SBS.

Stage	Measure
Integral measures for prevention of physical risk factors	
Legislation	**Implementation of Regulation EU 305/2011** [3] and its basic requirements No. 3 (Hygiene, health and the environment), No. 6 (Energy economy and heat retention) and No. 7 (Sustainable use of natural resources) into national legislation. **Implementation of national requirements** in the field of building, systems, constructional products; definition of **specific requirements** for individual users.
Building design	**Building design:** based on the concept of bioclimatic design, starting on the specific location; optimal orientation, arrangement of active spaces, according to the purpose, health and energetic issues. **Building envelope:** thermally and sound well insulated, optimal position and surface area of transparent/non-transparent parts to assure enough daylight; effective prevention against overcooling, overheating problems. **Constructional complexes:** optimal thermal conductivity, minimised impact of thermal bridges, active regulation of surface temperatures, protection against mould growth, control of building air tightness; control and prevention against outside noise, direct sound transmission through structures, equipment noise and reverberation sound. The selection of materials with good sound absorption. **Transparent parts of building envelope:** optimization between thermal conductivity and visible transmittance. Implementation of principles of **universal design and ergonomic issues**. **Constructional products:** selection of materials that are health and environmental friendly.
Active space design	**Optimal orientation** of building according to the purpose of active spaces, attaining **overall comfort, health and energetic issues**.
HVAC systems design	**Overall efficiency of HVAC systems** that supports health as well as thermal comfort of individual users, application of low-temperature heating, high-temperature cooling systems. **Individual control and regulation** of microclimate parameters for individual user. Energy efficiency of all systems. More **functional central control systems**: monitoring, reporting errors, and optimizing performance. To assure **natural ventilation** or effective mechanical ventilation. Easily accessible, periodical maintenance, inspection of HVAC systems and replacement of old systems.

Stage	Measure
Devices	Protection against electromagnetic radiation.
Staff	**Education and training** of all employees.
Integral measures for prevention of chemical risk factors	
2.1. Complete elimination or minimization of the causes of chemical pollution	**Risk assessment** and **risk management** are recommended: Selection of materials and products that are health and environmental friendly.
2.2. Control and prevention of outdoor air pollution	Adoption and implementation of **national and international regulations** and standards. Complete **supervision and control** of production–consumption cycle of products. Actions to prevent the source of pollution.
2.3. Prevention against entering of exterior pollutants	**Green barriers and building orientation**. **Good air tightness** of building envelope. **Efficient filtration system** on windows (i.e. window integrated controlled ventilation system). Attention on taking decisions about **ventilation type** for specific part of building: natural ventilation primarily or highly–efficient mechanical ventilation secondly.
2.4. Healthy and environment friendly construction products and materials	Compliance with Regulation EU 305/2011 and basic requirement No. 3, Hygiene, health and environment [3]. **Life cycle analysis** (LCA) has to be carried out. Selection of **health and environment friendly** constructional product/household products, supervision. VOC-free, zero-emission, low pollutant materials.
2.5. Effective heating, ventilating and air–conditioning (HVAC) systems	Design of **natural ventilation or highly–efficient mechanical ventilation**. To assure the control of indoor environment quality, and to secure healthy, safe and appropriate indoor air quality for occupants. Proper design considering national and international regulations and standards. **Periodical control of operating** conditions of HVAC equipment. **Maintenance** of ventilation system; renovation of old systems; a ventilation system that is designed for building has to take into consideration the specifics of such environment, and the type and concentrations of indoor pollutants.
2.6. Prevention against potential sources of contamination	Establishment of a **hazard communication program**. Training of workers. Available material safety data sheets for hazard materials. Development, supervision of a monitoring program. Elimination of potential hazard materials (biocides, household products), introduce safer alternatives/procedures.
Integral measures for prevention of biological risk factors	
3.1. Prevention of airborne transmission	Efficient **source control**. Appropriate **engineering design and maintenance** of HVAC installations. Fulfilment of ventilation parameters for the type of activity spaces, i.e. recommended air changes per hour. Elimination of dust deposition, closed systems, point dust extraction.
3.2. Elimination of contact	Against **direct contact** the most important actions are: personal hygiene (hand and clothes hygiene), personal protective equipment, doctrine of cleaning and disinfection procedures, sterilization, food hygiene. Use of surfaces and materials that enable **easily cleaning and disinfection.** Smooth and fluid resistant wall coverings and furnishings, tightly sealed pipe penetrations and joints. Preparation of a plan and evidence for cleaning and disinfection with responsible persons. Enhanced cleaning/disinfection of environmental surfaces, ventilation grills.
3.3. Elimination of vehicle transmission mode	Establishment of **Hazard Analysis of Critical Control Point System** (HACCP system) that enables complete control of food from cradle–to–grave.
Integral measures for prevention of psychosocial, personal and other risk factors	
4.1. Stress	**Work ergonomics** with organisation of work time/ work environment / process / equipment; good relations among employees, effective communication. Provide a **stress management training**, a stress prevention programs, an employee assistance programs to improve the ability of workers to cope with difficult work situations. Balance between work and family or personal life. A relaxed and positive outlook [49].
4.2. Supervision	Planning and implementation of **internal supervision** of the work environment with trained persons, specialists. Self-awareness and integration of self and role, encouraging teamwork and work towards conflict resolution, creating and maintaining a respectful workplace, resource and budget management, goal setting, practicing risk management, implement internal control of work environment guidelines [50].

Source: [1-59]

DISCUSSION

Based on the results of identified interactions, problems are revealed and strategy for the prevention and control of SBS was designed. Detected interactive influences among parameters presented problematic fields that have to be eliminated or minimised. The designed strategy includes step-by-step activities at the level of physical, chemical, biological, psychosocial, personal and other groups of risk factors and their interactive influences. At the level of physical risk factors, important actions include measures at the level of legislation, design of building and systems, actions on installations and education and training of all employees. Measures related to chemical risk factors include activities for complete elimination or minimization of the causes of chemical pollution, control and prevention of outdoor air pollution, prevention against entering of exterior pollutants, healthy and environment friendly building materials, effective ventilation systems, prevention against potential sources of contamination. Implementation of work ergonomics, stress prevention program and internal supervision of the work environment present the priority actions for the prevention and control of psychosocial and personal risk factors.

Implementation of work ergonomics, stress prevention program and internal supervision of the work environment present the priority actions for the prevention and control of psychosocial and personal risk factors.

Any improvement of indoor environments with the prevention and control of SBS significantly increases health and productivity and results in great economic benefits. The potential financial benefits of improving indoor environments exceed costs by factors of 9 and 14 [51]. Fisk et al. [51] estimated for the U.S. that potential annual savings and productivity gained in 1996 dollars of $ 6 to $ 14 billion from reduced respiratory disease; $ 2 to $ 4 billion from reduced allergies and asthma, $ 15 to $ 40 billion from reduced symptoms of SBS, and $ 20 to $ 200 billion from direct improvements in worker performance unrelated to health. Similar findings were recorded in the studies by Dutton et al [52] and Wargocki [53]. Dutton et al. [52] assessed the impact of natural ventilation retrofit of 10 % of California's office stock on the prevalence of SBS symptoms and associated costs. 10 % of California's 5 million office workers resulted in 22,000–56,000 fewer people reporting symptoms in a given week. Wargocki [53] showed that crude estimates suggest that 2 million healthy life years can be saved in Europe by avoiding exposures to indoors air pollutants in non-industrial buildings. Similar estimates have been made for the U.S. as regards exposures to air pollutants in residential buildings. The potential annual savings and productivity gains have been estimated to be as high as $ 168 billion in the U.S. (1997 estimate as no newer data are available). A saving of $ 400 per employee per year (2000 estimate) was estimated due to reduced absenteeism being the result of improved indoor air quality. In Europe, the annual productivity benefits were estimated to be at the level of about € 330 per worker (2000 estimate as no newer data are available) [53].

Several studies make the same conclusions that due to multifactorial effects it is difficult to pinpoint the causative factor for SBS. The study in an air conditioned building in Niteroi, Rio de Janeiro, Brazil, Costa and

Brickus [32] concluded that poor individual control of temperature and lighting are associated with increased symptoms. Univariate analysis, performed by Abdel-Hamid et al. [54] at the Faculty of Medicine, Ain Shams University, Cairo, Egypt showed that poor lighting, poor ventilation, lack of sunlight, absence of air currents, high noise, temperature, humidity, environmental tobacco smoke, use of photocopiers and inadequate office cleaning were statistically associated with SBS symptoms. Building characteristics, such as year of construction, effect indoor emissions and lead to SBS. New houses and new furniture result in higher emissions [55]. The strong relationship between ownership and building age was proved by Engvall et al. [56] in Stockholm, 609 multi-family buildings with 14,235 dwellings. Subjects owning their own building reported less SBS, but 5 % of all buildings built before 1961, 13 % of those built 1976-1984, and 15 % of those built 1985-1990 would have significantly more SBS than expected. Mizoue et al. [57] examined these relations using data from a 1998 cross-sectional survey of 1,281 municipal employees who worked in a variety of buildings in a Japanese city. Working overtime for 30 or more hours per month was also associated with SBS symptoms. Additional factor presents personal lifestyles. The association between personal and psychosocial factors was confirmed in the study by Ooi and Goh [58]. The authors found an incremental trend in prevalence of SBS among office workers who reported high levels of physical and mental stress, and decreasing climate of co-operation. Similar findings were reported in the study by Burge et al. [46], where SBS symptoms were generally more common and more problematic in the stressed, the unloved, and in individuals who feel powerless to change their situation [46]. Important issue is also the possibility of individual regulation and control of indoor environmental parameters. Poor individual control of temperature and lighting are associated with increased symptoms [59]. The study by Burge et al. [46] proved a strong association between lack of control of the office environment and symptoms.

With the implementation of design strategy, healthy and comfortable conditions are expected, as well as increased productivity and decreased health costs with economic benefits, as it was shown in studies [51-53]. Moreover, an overall efficiency of buildings will be achieved [5]. For healthy buildings and effective prevention and control of SBS a multidisciplinary approach is necessary.

With the implementation of design strategy, healthy and comfortable conditions are expected, as well as increased productivity and decreased health costs with economic benefits, as it was shown in studies. For healthy buildings and effective prevention and control of SBS a multidisciplinary approach is necessary.

CONCLUSIONS

Identification of risk factors for SBS and their parameters is crucial step for effective prevention and control of SBS. Additionally, it is important to detect all interactive influences among factors and their parameters. The presented designed strategy is necessary for the future planning of healthy and comfortable buildings and is a basis for successful renovations. For this reason, it is important to implement the strategy at the first step of design, at the planning stage.

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Conference report

UFIREG – "Ultrafini delci – prispevek k razvoju regionalne in evropske okoljske in zdravstvene politike"

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ABSTRACT

The air that we breathe is a very important natural source. Its quality can have significant effect on human health. It is suspected that especially ultrafine particles could have an influence on human health. However the knowledge on health effects of ultrafine particles is still limited. The main aim of the EU founded project UFIREG is to investigate the short-term effects of ultrafine particles on mortality and morbidity. Until the end of 2014 environmental and medical experts from four European countries will work together to make a contribution to the environmental policy in Europe and so help to reduce air pollution, improve air quality and consequently help saving people's health in Europe.

Key words: Central European Projects, ultrafine particles, measurements, health effects

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UFIREG je mednarodni raziskovalni projekt financiran s strani Evropske unije. Namen projekta je ponuditi nove odgovore o vplivu ultrafinih delcev (ultra fine particles – UFP) v zraku na zdravje in umrljivost ljudi. S pridobljenimi rezultati želi projekt prispevati k evropski okoljski politiki, tako imenovanemu programu Čist zrak za Evropo (Clean Air Plan for Europe) in s tem k izboljšanju kakovosti zraka v Evropi. Projekt, ki traja od julija 2011 do decembra 2014, vodi Tehnična univerza Dresden, kot projektni partner za Slovenijo pa je vključen Zavod za zdravstveno varstvo Celje.

V okviru projekta se raziskovalci in strokovnjaki s področja varstva okolja in javnega zdravja v Nemčiji, na Češkem, v Ukrajini in v Sloveniji osredotočajo na merjenje ultrafinih delcev v zraku in preučevanje vpliva le teh na zdravje ljudi, še posebej na razvoj kradiovaskularnih in respiratornih bolezni. Merjenja se izvajajo v petih evropskih mestih in sicer v Dresdnu in Augsbugu (oboje Nemčija), Pragi (Češka), Černivcih (Ukrajina) ter v Ljubljani (Slovenija).

ULTRAFINI DELCI

Ultrafini delci (v nadaljevanju UFD) so del našega vsakdana, saj jih vsak dan vdihavamo skupaj z zrakom. Delci s prostim očesom niso vidni, kljub temu pa lahko njihova pristnost v pljučih pomembno vpliva na zdravje ljudi. Obravnavanje problematike ultrafinih delcev bo prispevalo nova spoznanja, pomembna za življenje ljudi.

Koncentracija števila delcev se v odvisnosti od intenzitete emisij in vremenskih razmer spreminja tekom dneva, tedna in leta. Na urbanih področjih se UFD sproščajo v okolje predvsem z emisijami iz prometa, iz drobnih kurišč, drugih kotlovnic za ogrevane, industrijskih kotlovnic in iz tehnoloških procesov v industriji. Glavnino UFD največkrat predstavljajo saje. Ker imajo v primerjavi z večjimi delci ultrafini delci večjo površino glede na maso, največkrat delujejo tudi kot nosilci za druga onesnaževala kot so npr. organske spojine in kovine. Nekatere epidemiološke raziskave zato navajajo, da imajo lahko ultrafini delci bolj škodljive vplive na zdravje ljudi kot pa večji delci.

UFD lahko zaradi svoje majhnosti prodrejo do najglobljih delov pljuč v pljučne mešičke in skozi sluznico pljuč v krvni obtok ter na ta način lahko povzročajo bolezni dihal in nekaterih notranjih organov (npr. bolezni srca in ožilja). Povzročijo lahko tudi imunski odziv, kar pomeni zgostitev krvi in s tem povečano tveganje za srčno ali možgansko kap. Še posebno tveganje predstavljajo ultrafini delci za starejše ljudi in ljudi z obstoječimi boleznimi srca in ožilja ter ljudi s sladkorno boleznijo.

UFD lahko zaradi svoje majhnosti prodrejo do najglobljih delov pljuč v pljučne mešičke in skozi sluznico pljuč v krvni obtok ter na ta način lahko povzročajo bolezni dihal in nekaterih notranjih organov (npr. bolezni srca in ožilja).

Kljub velikemu tveganju, ki ga za zdravje lahko predstavljajo ultrafini delci, pa je na področju poznavanja vplivov njihovega vpliva na zdravje ljudi še vedno veliko neznanega in neraziskanega. Obstaja torej velika potreba po dodatnih raziskavah in razvoju ter uporabi ustreznih merilnih naprav, ki bi jih lahko uporabili v omrežjih za redno spremljanje kakovosti zraka.

MERITVE ULTRAFINIH DELCEV

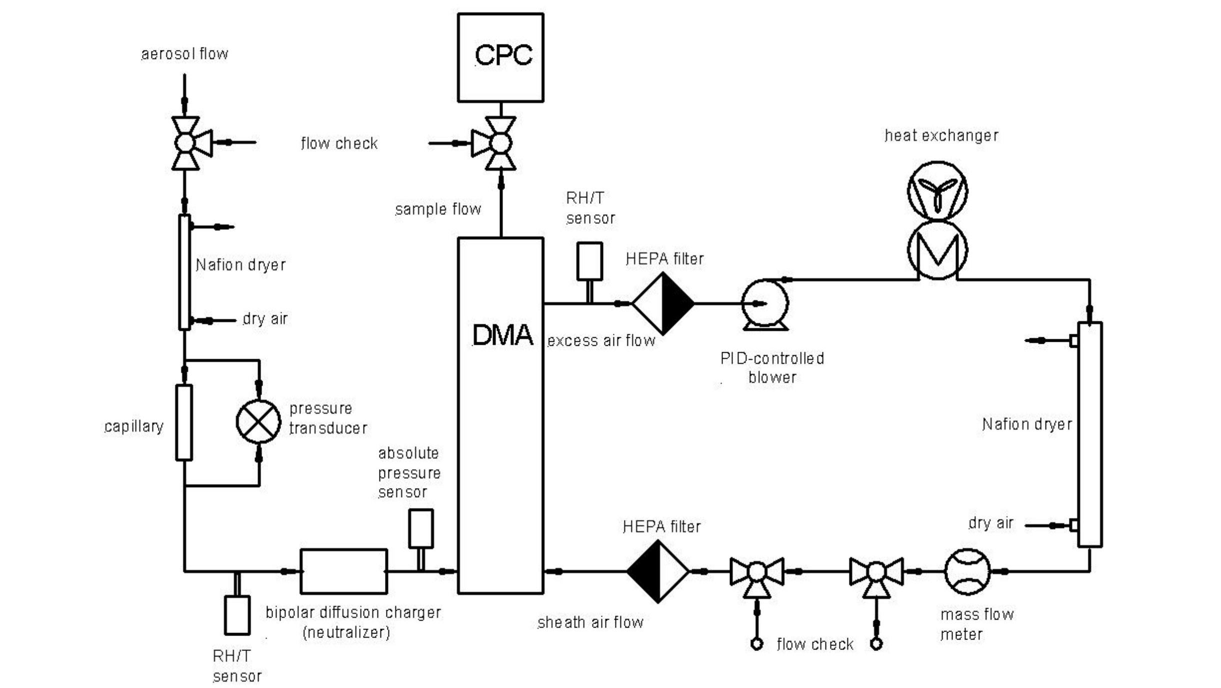
V Evropski uniji trenutno še ni zakonskih predpisov, ki bi opredeljevali način merjenja ultrafinih delcev, zato je v okviru projekta UFIREG ob ugotavljanju vpliva UFD na zdravje posebna pozornost namenjena tudi merilnim pristopom in inštrumentom ter možnosti njihove uporabe v omrežjih za spremljanje kakovosti zraka.

Dokazano je, da gravimetrične metode, ki se sicer uporabljajo za merjenje koncentracije trdnih delcev v zraku, za merjenje koncentracije UFD niso primerne. UFD so namreč izjemno majhni in imajo nizko maso. Njihov aerodinamični premer je 0,1 mikrometer ali manj in so približno enake velikosti kot virusi ter veliko manjši od bakterij. Njihova masa je skoraj neizmerljivo majhna. Zanimiva je primerjava, da so približno 1000-krat manjši od premera človeškega lasu.

Primernejša metoda za merjenje izpostavljenosti ultrafinim delcem v zunanjem zraku bi bila določitev koncentracije števila delcev na enoto količine zraka. Na tržišču so že prisotne določene naprave, s katerimi je mogoče določiti razporeditev števila delcev glede na velikost. Te naprave, ki se imenujejo spektrometri, nam omogočajo določitev števila delcev določene velikosti v določenem času v enem kubičnem centimetru zraka.

Spektrometri za določanje številčne porazdelitve delcev glede na velikost se uporabljajo tudi v projektu UFIREG. Vsi v projektu uporabljeni spektometri so bili pred začetkom izvajanja meritev v Svetovnem kalibracijskem centru za fiziko aerosolov (World Calibration Center for Aerosol Physics – WCCAP) v Leipzigu umerjeni z referenčnim spektrometrom. Zaradi zagotavljanja kakovosti meritev WCCAP z referenčnim spektrometrom na terenu občasno preverja delovanja merilnikov in ocenjuje kakovost podatkov.

Slika 1: Zgradba spektrometra



Slika 1 prikazuje zgradbo spektrometra. Vidimo lahko, da merilna naprava vsebuje sušilec za zmanjšanje relativne vlažnosti vzorca zraka, kar je v skladu z mednarodnim dogovorom, da se meritve opravljajo pri relativni vlažnosti zraka manj kot 40 %. Zaradi primerljivosti podatkov je bil ta kriterij upoštevan tudi v projektu UFIREG. Med izvajanjem meritev posebni senzorji kontinuirano beležijo pretok aerosolov, relativno vlažnost in temperaturo vzorca, prav tako pa tudi tlak na vstopu v merilni sistem. Meritev števila delcev sicer temelji na različni mobilnosti električno nabitih aerosolov v električnem polju (električni mobilnosti). Pri konstantnem pretoku zraka je mobilnost delca v električnem polju odvisna od njegove velikosti in s tem povezane velikosti njegovega električnega naboja.

MERILNA MESTA

Meritve UFD ter zbiranje podatkov o rezultatih sočasnih meritev onesnaženosti zraka in meteoroloških podatkov se izvaja v petih evropskih mestih: Dresdnu in Augsburgu v Nemčiji, Pragi na Češkem, Černivcih v Ukrajini ter v Ljubljani v Sloveniji. Vse merilne postaje so locirane v urbanem okolju tako, da so rezultati meritev reprezentativni za takšno kakovost zraka, ki ga diha velik del mestnega prebivalstva. V Augsburgu in Pragi sta nameščeni po dve merilni napravi zato bo možno med sabo primerjati tudi rezultate meritev pridobljene na dveh različnih lokacijah znotraj ene mestne aglomeracije.

Ob meritvah ultrafinih delcev se na merilnih postajah izvajajo tudi meritve drugih onesnaževal (žveplov dioksid, ogljikov monoksid in dušikov dioksid) ter meritve meteoroloških parametrov (temperatura zraka, relativna vlažnost, zračni tlak). Rezultati teh meritev so pomembni, ker ti dejavniki lahko vplivajo na nastanek ultrafinih delcev, pomembni pa bodo tudi pri ugotavljanju vplivov UFD na zdravje ljudi.

Slika 2:
Merilna postaja projekta UFIREG v Ljubljani, Slovenija

Glede na to, da je področje ultrafinih delcev še precej neraziskano, namenja projekt veliko pozornosti tudi širjenju informacij o samih UFD in o njihovih vplivih na zdravje.

Slika 2 prikazuje merilno postajo v Ljubljani, kjer so se meritve UFD pričele aprila 2012. Postaja je locirana na območju Kmetijskega inštituta Slovenije. Merilno mesto izpolnjuje zahtevane kriterije za reprezentativnost kakovosti zraka: zelo dobro predstavlja razmere na pretežno stanovanjskih predelih Ljubljane Meritve ostalih parametrov (ostala onesnaževala, meteorološki parametri) potekajo na merilni postaji na lokaciji Agencije Republike Slovenije za okolje (ARSO) in je od merilne postaje za UFD oddaljena približno 650 m.

UGOTAVLJANJE VPLIVA ULTRAFINIH DELCEV NA ZDRAVJE LJUDI

Drugi ključni sestavni del projekta UFIREG so raziskave vplivov UPF na zdravje in umrljivost ljudi. Raziskovalci bodo v ta namen uporabili uradne zdravstvene epidemiološke in sociodemografske statistične podatke, ki jih bodo primerjali s podatki o onesnaženostjo zraka z UFD in drugimi onesnaževali.

Glavni vir podatkov za pridobitev informacij o vzrokih obolevnosti in smrtnosti sta statististični bazi podatkov o hospitalizacijah in smrtih. Ti podatki so na voljo s približno osem mesečnim zamikom, kar pomeni, da bodo podatki za leto 2012 za analize na voljo šele proti koncu leta 2013. Za pridobitev podatkov o glavni diagnozi oz. vzroku smrti pa bo uporabljena Mednarodna klasifikacija bolezni in zdravstvenih problemov (MKB-10).

Projektni partnerji bodo vsak za svojo državo v obdelavo posredovali podatke o hospitalizacijah, ki bodo vsebovali informacije o spolu, starosti in glavno diagnozo bolnika. Pri prenosu in sami obdelavi podatkov bo v skladu z evropsko zakonodajo strogo upoštevano varstvo osebnih podatkov.

Pomembno je, da bodo raziskani vsi nespecifični vzroki hospitalizacij in smrti, analizirani pa bodo tudi vsi podatki o hospitalizacijah in primerih smrti zaradi kardiovaskularnih in respiratornih obolenj. Glede na obseg podatkov, ki bo pridobljen, bo morda možno izvesti tudi stratificirano statistično analizo z upoštevanjem dejavnikov kot so starost, spol in regija.

ŠIRJENJE INFORMACIJ O ULTRAFINIH DELCIH

Glede na to, da je področje ultrafinih delcev še precej neraziskano, namenja projekt veliko pozornosti tudi širjenju informacij o samih UFD in o njihovih vplivih na zdravje.

Projektni partnerji in zunanji sodelavci pri projektu so do sedaj projekt predstavili že na mnogih nacionalnih in mednarodnih konferencah. Prav tako je bilo mogoče informacije o projektu zaslediti že v mnogih tiskanih medijih.

Pomembno mesto pri poteku projekta in pri širjenju informacij ima tudi interesna skupina, ki združuje posameznike in organizacije (okoljske agencije, zdravstvene organizacije, javne uprave, univerze etc.), na katere posredno in/ali neposredno rezultati projekta lahko vplivajo. Člani interesne skupine lahko s svojim prispevkom tudi sami vplivajo na potek projekta, čeprav niso vključeni v vsakodnevno delo na projektu.

Trenutno v projektu sodeluje 22 članov interesne skupine iz Nemčije, Češke, Ukrajine, Slovenije in Italije. Prednosti, ki jih imajo kot člani interesne skupine so predvsem prejemanje podrobnejših informacij o poteku projekta, možnost aktivnega sodelovanja v projektu ter prejemanje informacij o rezultatih meritev in o aktualnih znanstvenih ugotovitvah Člani interesne skupine s podajanjem ocen in zunanjim nadzorom nad potekom projekta, z udeležbo na sestankih članov interesne skupine ter s podporo projektnim partnerjem pri širjenju informacij o projektu tudi sami aktivno prispevajo k poteku in razvoju projekta.

Interes za projekt se skuša povečati tudi s pridobivanjem partnerskih mest, ki v projektu sodelujejo. To niso mesta, kjer se izvajajo meritve ali kjer ima katerikoli partner projekta svoj sedež temveč mesta, za katera je značilno, da so prav tako obremenjena z onesnaženostjo zraka in domnevno visoko koncentracijo ultrafinih delcev.

Trenutno so v projekt vključena partnerska mesta iz Nemčije (Hamburg, Ulm, Leipzig), Češke (Pardubice, Choltice) in Slovenije (Zagorje ob Savi). Projektni partnerji skušajo z organiziranjem problemsko-predstavitvenih konferenc in z drugimi aktivnostmi v teh partnerskih mestih povečevati zanimanje za projekt in samo tematiko ultrafinih delcev, kakor tudi povečati izmenjavo strokovnih znanj. Do sedaj so bile tovrstne konference že organizirane v Leipzigu (Nemčija), Zagorju ob Savi (Slovenija) in Ulmu (Nemčija).

NADALJNJI KORAKI

Projekt se bo z meritvami UFD in zbiranjem epidemioloških ter sociodemografskih podatkov nadaljeval tudi v naslednjem letu. Prav tako pa se bodo pričele izvajati analize in primerjave zbranih podatkov, katerih rezultat bo boljše poznavanje problematike ultrafinih delcev in novi podatki kot pomoč pri oblikovanju okoljske politike v Evropi. Projektni partnerji bodo z medsebojnim sodelovanjem in udeležbo na sestankih zagotavljali, da bo cilj projekta – raziskati vpliv ultrafinih delcev na zdravje ljudi, uspešno dosežen. Nadaljevalo se bo tudi širjenje informacij in znanj o tem, kako ultrafini delci različnih velikosti vplivajo na smrtnost in obolevnost prebivalcev. Projekt se bo s končno konferenco v Dresdnu novembra 2014 zaključil, meritve ultrafinih delcev pa se bodo na naštetih lokacijah izvajale še vsaj pet let po zaključku projekta. Več informacij o samem projektu lahko najdete na spletni strani projekta www.ufireg-central.eu.

INSTRUCTIONS FOR AUTHORS

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Sanitarno Inženirstvo/International Journal of Sanitary Engineering Research presents broad interdisciplinary information on the practice and status of research in environmental, food and occupational hygiene, epidemiology, the environmental engineering science, systems engineering, and sanitation. Papers focus on design, development of health engineering methods, management, governmental policies, and societal impacts of drink water, wastewater collection and treatment; the fate and transport of contaminants on watersheds, in surface waters, in groundwater, in the soil, and in the atmosphere; environmental biology, microbiology, chemistry, fluid mechanics, and physical processes that control natural concentrations and dispersion of wastes in the air, water, and soil; non-point source pollution on water-sheds, in streams, in groundwater, in lakes, and in estuaries and coastal areas; treatment, management, and control of hazardous wastes; control and monitoring of air pollution and acid deposition; air-shed management; and design and management of solid waste professional obligations facilities; food technology, management of food quality and food safety. A balanced contribution from consultants, sanitary engineers, and researchers is sought on engineering solutions and responsibilities.

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Inštitut za sanitarno inženirstvo
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4. Mailing address of the corresponding author (address, phone and fax number, e-mail).
5. A statement that the article is original, the manuscript or any part of it (except abstract) has not been sent to any other publisher or it is not in consideration for publication anywhere in any language.
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Technical and reviews articles should have a similar structure, abstracts should not exceed 150 words. All articles should be in English, except news, reviews and reports what can be in Slovenian, Croatian or Serbian. Chapters should be arranged according to the standards ISO 2145 and ISO 690. Abbreviations must be explained at the first mention in the text.

First page of the article should contain the title of the article (max. 10 words), author(s)' name(s), institution and address. The corresponding author should be identified with an asterisk and footnote (the text in the footnote: to whom all correspondence should be addressed and added tel. and fax numbers, and e-mail). Second page should contain the abstract and keywords. An abstract of approximately 100 words should have the following structure: aims, scope and conclusions of the article.

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[1] Bhatt Siddharta M. Energy audit case studies II - Air conditioning (cooling) systems. Appl Th Eng. 2000; 20: 297-307.

[2] American college of physicians. Clinical Ecology. An Int Med 1989; 111:168-78.

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