Original scientific article

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

Andreja **KUKEC**[1], Mateja **DOVJAK**[2*]

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

Received: 20. 2. 2014
Accepted: 16. 10. 2014

[1] University of Ljubljana,
Faculty of Medicine, Centre of Public Health
Zaloška 4, 1000 Ljubljana, Slovenia

[2] University of Ljubljana,
Faculty of Civil and Geodetic Engineering,
Chair for Buildings and Constructional Complexes
Jamova cesta 2, 1000 Ljubljana, Slovenia

[*] *Corresponding author*
Mateja Dovjak
University of Ljubljana,
Faculty of Civil and Geodetic Engineering,
Chair for Buildings and Constructional Complexes
Jamova cesta 2, 1000 Ljubljana, Slovenia
mdovjak@fgg.uni-lj.si

Article with the title *"Prevention and control of Sick Building Syndrome (SBS). Part I: Identification of risk factors"* 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

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 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.

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-

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.

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.

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.

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].

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. 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.

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-your-self 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.

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.

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.

Women are often employed under less favourable working conditions than men, as it was confirmed in the study by Bullinger et al.

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.

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.

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.

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.

REFERENCES

[1] Evans GW, McCoy JM. When buildings don’t work: The role of architecture in human health. Env Pschy 1998; 18:85-94.

[2] WHO. World Health Organization. Strategic approaches to indoor air policy-making. Bilthoven: WHO European Center for Environment and Health, 1999: http://www.paho.org/tierra/index.php?option=com_multicategories&view=article&id=75 %3Astrategic-approaches-to-indoor-air-policy-making&catid=9 %3A1996-2000&Itemid=136&lang=en (12. 2. 2014).

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

[3] Yassi A, et al. Basic Environmental Health. Oxford: Oxford University Press, 2001: 456.

[4] Eržen I, et al. Zdravje in okolje: izbrana poglavja. Maribor: Univerza v Mariboru, Medicinska fakulteta, 2010: 216.

[5] Dovjak M, Kukec A, Krainer, A. Identification and control of health risks in hospital environment from the aspects of users, buildings and systems. Slovenian Journal of Public Health 2013; 52(4): 304-315.

[6] Dovjak M, Kukec A, Kristl Ž, Košir M, Bilban M, Shukuya M, Krainer A. Integral Control of Health Hazards in Hospital Environment. Indoor Built Environ 2013; 22 (5): 776-795.

[7] Krainer A et al. Passive house versus bioclimatic house. Gradb vestn 2008; 57 (3): 58-6

[8] EPA. US Environmental Protection Agency. Indoor Air Facts No. 4 (revised). Sick Building Syndrome. Air and Radiation (6609J). February 1991,1-4: http://www.epa.gov/iaq/pdfs/sick_building_factsheet.pdf (12. 2. 2014).

[9] ECA. European concerted action indoor air quality & its impact on man. COST Project 61 3. Environment and Quality of Life Report No. 4. Sick Building Syndrome. A Practical Guide. Commission of the European Communities. Directorate General for Science. Research and Development. Joint Research Centre – Institute for the Environment. Commission of the European Communities. Luxembourg, ECA, 1989.

[10] Redlich CA, Sparer J, Cullen MR. Sick-building syndrome. Lancet 1997; 349: 1013-1016.

[11] Burge PS. Sick building syndrome. Occup Environ Med 2004; 61: 185-190.

[12] WHO. World Health Organization. Indoor air pollutants: exposure and health effects. EURO Reports and Studies No. 78, WHO Regional Office for Europe, Copenhagen: WHO, 1983.

[13] Burge S, et al. Sick Building Syndrome: A Study Of 4373 Office Workers. Ann Occup Hyg 1987; 31 (4a): 493-504.

[14] Woods JE, Drewry GM, Morey P. Office worker perceptions of indoor air quality effects on discomfort and performance. In: Proceedings of the 4t international Conference on Indoor Air and Climate, August, 17 – 21 August 1987. Berlin, 1987:464-408.

[15] Bourbeau J, Brisson C, Allaire S. Prevalence of the sick building syndrome symptoms in office workers before and six months and three years after being exposed to a building with an improved ventilation system. Occup Environ Med 1997; 54 (1): 49-53.

[16] Scheel CM, Rosing WC, Farone AL. Possible sources of sick building syndrome in a Tennessee middle school. Arch Environ Health 2001; 56 (5): 413-7.

[17] Engvall K, Norrby C, Norbäck D. Sick building syndrome in relation to building dampness in multi-family residential buildings in Stockholm. Int Arch Occup Environ Health 2001; 74 (4): 270-8.

[18] Takigawa T, et al. A longitudinal study of aldehydes and volatile organic compounds associated with subjective symptoms related to sick building syndrome in new dwellings in Japan. Sci Total Environ 2012; 417-418: 61-67.

[19] Araki A, et al. Relationship between selected indoor volatile organic compounds, so-called microbial VOC, and the prevalence of mucous membrane symptoms in single family homes. Sci Total Environ 2010; 408 (10): 2208-2215.

[20] Sahlberg B, et al. Airborne molds and bacteria, microbial volatile organic compounds (MVOC), plasticizers and formaldehyde in dwellings in three North European cities in relation to sick building syndrome (SBS). Sci Total Environ 2013; 444 (1): 433-440.

[21] Valbjorn O, Kousgaard N. Headache and mucous membrane irritation at home and at work. Report 175. Harsholm: Statens Byggeforsknings Institut (SBI), 1986.

[22] Valbjorn O, Skov P. The Danish Indoor Climate Study Group. Influence of indoor climate on the sick building syndrome prevalence. In: Indoor air '87, Proceedings of the 4th Intern.-Conf. on Indoor Air Quality and Climate, Berlin (West) 17-21 Aug. 1987. Berlin: Inst. fur Wasser-, Boden- und Lufthygiene, 1987; 2: 593-597.

[23] Jaakkola JJK, Heinonen OP, Seppänen O. Sick building syndrome, sensation of dryness and thermal comfort in relation to room temperature in an office building: need for individual control of temperature. Environ Int 1989;15: 163-8.

[24] Nordström K, Norbäck D, Akselsson R. Effect of air humidification on the sick building syndrome and perceived indoor air quality in hospitals: a four month longitudinal study. Occup Environ Med 1994; 51(10): 683-688.

[25] Andersen I, et al. Human response to 78-hour exposure to dry air. Arch Environm Health 1974; 29(6):319-24.

[26] Li CS, Hsu CW, Lu CH. Dampness and respiratory symptoms among workers in day-care centers in a subtropical climate. Arch Environ Health 1997; 52:68-71.

[27] Barna E, Bánhidi L. Combined effect of two local discomfort parameters studied with a thermal manikin and human subjects. Energy and Buildings 2012; 51:234-241.

[28] Seppänen OA, Fisk WJ, Mendell MJ. Association of ventilation rates and CO2 concentrations with health and other responses in commercial and industrial buildings. Indoor Air 1999; 9: 226-52.

[29] Seppänen O, Fisk WJ. Association of ventilation system type with SBS symptoms in office workers. Indoor Air 2002; 12: 98-112.

[30] Costa MF, Brickus LS. Effects of ventilation systems on prevalence of symptoms associated with sick buildings in Brazilian commercial establishments. Arch Environ Health 2000; 55: 279-83.

[31] WHO. World Health Organisation. Environment and Health, 2013: http://www.euro.who.int/en/health-topics/environment-and-health/noise (12.2.2014).

[32] Wonga SK. Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong. Habitat International 2009, 33 (4): 463-471.

[33] Hodgson M.J., et al. Vibrations as a cause of "tight-building syndrome" symptoms. ibid. 1987; 2:449-453.

[34] Boubekri M. Daylighting, architecture and health: Building design strategies. Oxford: Elsevier, 2008: 144.

[35] Bommel WJM. Non-visual biological effect of lighting and the practical meaning of lighting for work. Elsevier. Appl Ergon 2006; 37 (4): 461-66.

[36] Veitch JA. Lighting for health: time to light up your life? Ottawa: National Research Council of Canada, Institute for Research in Construction, 2008.

[37] Abdel-Hamid MA, et al. Prevalence and risk factors of sick building syndrome among office workers. J Egypt Public Health Assoc 2013; 88 (2): 109-14.

[38] WHO. World Health Organisation. Electromagnetic fields and public health , 2014: http://www.who.int/peh-emf/publications/facts/fs322/en/ (12.2.2014).

[39] Eriksson NM, Stenberg BGT. Baseline prevalence of symptoms related to indoor environment. Scand J Public Health 2006, 34: 387-396.

[40] ILO. International Labour Organization. Indoor air ionization, 2011: http://www.ilo.org/oshenc/part-vi/indoor-environmental-control/item/261-indoor-air-ionization (12.2.2014).

[41] Reilly T, Stevenson IC. An investigation of the effects of negative air ions on responses to submaximal exercise at different times of day. J Hum Ergol (Tokyo) 1993; 22(1):1-9.

[42] Jokl MV. Microenvironment, The Theory and Practice of Indoor Climate. Illinois: Thomas, 1989.

[43] Sulman FG. The Effect of Air Ionization, Electric Fields, Atmospherics and Other Electric Phenomena On Man and Animal, Illinois: Thomas, 1980.

[44] Sulman FG. Migraine and headache due to weather and allied causes and its specific treatment. Ups J Med Sci Suppl 1980; 31:41-4.

[45] Hedge A., Erickson WA. Sick building syndrome and office ergonomics: a targeted work environment analysis Human Factors Laboratory, Dept. of Design & Environmental Analysis, College of Human Ecology, Cornell University, Technology & Engineering, 1998: 54.

[46] Dovjak M, Kristl Ž. Development of the Leonardo da Vinci Accessible World for all Respecting Differences – AWARD project. Int J San Eng Res 2009; 2, 3: 35-49.

[47] Simmons LH., Richard JL. Building Materials: Dangerous Properties of Products. River Street: Wiley, 1997: 421.

[48] Dovjak M, Kristl Ž. Health concerns of PVC materials in the built environment. Int J San Eng Res 2011; 5 (1): 4-26.

[49] Šestan P, Kristl Ž, Dovjak M. Formaldehyde in the built environment and its potential impact on human health. Gradb vestn 2013; 62: 191-203.

[50] NIPH. Nacionalni inštitut za varovanje zdravja RS, Osvežilci zraka, 2009: http://www.ivz.si/Mp.aspx?ni=78&pi=6&_6_id=286&_6_PageIndex=0&_6_groupId=-2&_6_newsCategory=IVZ+kategorija&_6_action=ShowNewsFull&pl=78-6.0 (12. 11. 2013).

[51] Zock, J., et al., The Use of Household Cleaning Sprays and Adult Asthma. Am J Respir Crit Care Med 2007; 176 (8): 735-741.

[52] Cohen A, Janssen S, Solomon G, 2012. Hidden Hazards of Air Fresheners. Natural Resources Defense Council. Clearing the Air, NRDC Issue Paper 2007; September 2007: 1-16: https://www.nrdc.org/health/home/airfresheners/airfresheners.pdf (12. 2. 2014).

[53] Blondel A., Plaisance H. Screening of formaldehyde indoor sources and quantification of their emission using a passive sampler. Build Environ 2011; 46 (6): 1284-1291.

[54] Sakai K, et al. A comparison of indoor air pollutants in Japan and Sweden: formaldehyde, nitrogen dioxide, and chlorinated volatile organic compounds. Environ Res 2004; 94 (1): 75-85.

[55] ARB. Air Resources Board, Indoor air quality guideline, 2012: http://www.arb.ca.gov/research/indoor/formaldGL08-04.pdf (12. 2. 2014).

[56] Hendrick DJ, Lane DJ. Occupational fornnalin asthma. Brit J Industr Med 1977; 34: 11-18.

[57] Salthammer T, Mentese S, Marutzky R. Formaldehyde in the Indoor Environment. Chem Rev 2010; 110 (4): 2536-2572.

[58] Heudorf U, et al. Phthalates: toxicology and exposure. Int J Hyg Environ Health 2007; 210: 623-634.

[59] Jaakkola JJK, et al. Surface materials in the home and development of bronchial obstruction in young children in Oslo, Norway. Am J Public Health 1999; 84(2): 188-192.

[60] Bornehag CG, et al. The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case–control study. Environ Health Perspect 2004; 112: 1393-1397.

[61] Jaakkola JJK., Knight TL. The Role of Exposure to Phthalates from Polyvinyl Chloride Products in the Development of Asthma and Allergies: A Systematic Review and Meta-analysis. Environ Health Perspect 2008; 116, 7:845-853.

[62] Xu Y, et al. Predicting residential exposure to phthalate plasticizer emitted from vinyl flooring: a mechanistic analysis. Environ Sci Technol 2009, 43 (7): 2374-80.

[63] IARC. International Agency for Research on Cancer. Monographs on the evaluation of carcinogenic risks to humans, Man-Made Vitrous Fibres 2002; 81, Lyon: IARC Press.

[64] EC. European Commission. Recommendation from the Scientific Committee on Occupational Exposure Limits for man made-mineral fibres (MMMF) with no indication for carcinogenicity and not specified elsewhere, 2012.

[65] Nielsen O. Man-made mineral fibers in the indoor climate caused by ceilings of man-made mineral wool. In: Seifert B, Esdorn H, Fisher M, Riiden H, Wegner J, ed. Indoor air '87: Proceedings of the 4th international conference on indoor air quality and climate; vol 1. Berlin: Institute for Water, Soil and Air Hygiene, 1987:580-3.

[66] Wolkoff P. Sampling of VOC under conditions of high time resolution. INDOOR AIR '87, Proceedings of the 4th Intern. Conf. on Indoor Air Quality and Climate, Berlin (West). 17-2 I Aug. I987 Inst. fur Wasser-, Boden- und Lufthygiene, Berlin, 1987; 1: 126-129.

[67] Takigawa T, et al. A longitudinal study of environmental risk factors for subjective symptoms associated with sick building syndrome in new dwellings. Sci Total Environ 2009, 407 (19): 5223-5228.

[68] Nakaoka H, et al. Correlating the symptoms of sick-building syndrome to indoor VOCs concentration levels and odour. Ind Built Environ 2013, 0(0): 1–10. doi: 10.1177/1420326X13500975.

[69] Molhave L. Organic compounds as indicators of air pollution. Indoor Air 2003; 13 (Suppl 6): 12-19.

[70] Wang S, Ang HM and Tade MO. Volatile organic compounds in indoor environment and photocatalytic oxidation: state of the art. Environ In 2007; 33: 694-705.

[71] Hodgson M. Indoor environmental exposures and symptoms. Environ Health Persp 2002; 110: 663-667.

[72] Logue JM, et al. Hazard assessment of chemical air contaminants measured in residences. Indoor Air 2011; 21: 92–109.

[73] Schneider T, et al. Airborne particles in the indoor environment. A European interdisciplinary review of scientific evidence on associations between exposure to particles in buildings and health effects. Indoor Air 2003; 13: 38-48.

[74] Yu CWF, Kim JT. Long-term impact of formaldehyde and VOC emissions from wood-based products on indoor environments and issues with recycled products. Indoor Built Environ 2012; 21: 137-149.

[75] CDC. Centers for Disease Control and Prevention Indoor environmental quality, 2013: http://www.cdc.gov/niosh/topics/indoorenv/chemicalsodors.html (12.2.2014)

[76] Wang J, et al. Odors and sensations of humidity and dryness in relation to sick building syndrome and home environment in Chongqing, China. PLoS One 2013; 8(8): e72385.

[77] CCOHS. Canadian Centre for Occupational Health and Safety, 2011: Environmental Tobacco Smoke (ETS): General Information and Health Effects http://www.ccohs.ca/oshanswers/psychosocial/ets_health.html (12.2.2014).

[78] Hodgson MJ. Environmental tobacco smoke and the sick building syndrome. Occup Med 1989; 4(4): 735-40.

[79] Robertson AS, et al. Relation between passive cigarette smoking exposure and "building sickness". Thorax 1988; 43J, 2638.

[80] Mizoue T, Reijula K, Andersson K. Environmental tobacco smoke exposure and overtime work as risk factors for sick building syndrome in Japan. Am J Epidemiol 2001; 1, 154(9): 803-8.

[81] NIOSH. National Institute for Occupational Safety and Health. Criteria for a Recommended Standard, Occupational Exposure to Carbon Dioxide, 1976: http://www.cdc.gov/niosh/docs/1970/76-194.html (12. 2. 2014).

[82] Rules on the ventilation and air-conditioning of buildings (O.J. RS, No. 42/2002, 105/2002).

[83] Bakó-Biró Z,et al. Ventilation rates in schools and learning performance. In: Finnish Association of HVAC Societies. Proceedings of the 9th REHVA World Congress: Clima 2007 wellbeing indoors; Helsinki, 10–14 June 2007. Helsinki: Finnish Association of HVAC Societies, 2007.

[84] Erdmann CA, Steiner KC, Apte MG. Indoor Carbon Dioxide Concentrations And Sick Building Syndrome Symptoms In The Base Study Revisited: Analyses Of The 100 Building Dataset Proceedings: Indoor Air 2002: 443-448.

[85] Apte MG, Fisk WJ, Daisey JM. Associations between indoor CO2 concentrations and sick building syndrome symptoms in U.S. office buildings: An analysis of the 1994-1996 BASE study data. Indoor Air 2000, 10: 246-257.

[86] Tsai DH, Lin JS, Chan CC. Office workers' sick building syndrome and indoor carbon dioxide concentrations. J Occup Environ Hyg. 2012; 9(5): 345-51.

[87] EPA. Environmental Protection Agency. Biological contaminants, 2012: http://www.epa.gov/iaq/biologic.html (12.2.2014).

[88] WHO. World Health Organization, 2009: Dampness and mould, 2009: http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf (12.2.2014).

[89] Straus DC. Molds, mycotoxins, and sick building syndrome. Toxicol Ind Health 2009; 25 (9-10): 617-35.

[90] Zhang, X et al. Dampness and moulds in workplace buildings: Associations with incidence and remission of sick building syndrome (SBS) and biomarkers of inflammation in a 10 year follow-up study. Sci Total Environ 2012; 430: 75-81.

[91] Sahlberg B., et al. Airborne molds and bacteria, microbial volatile organic compounds (MVOC), plasticizers and formaldehyde in dwellings in three North European cities in relation to sick building syndrome (SBS). Sci Total Environ 2013, 444: 433-440.

[92] Sun Y. et al. Effects of gender and dormitory environment on sick building syndrome symptoms among college students in Tianjin, China Building and Environment 2013; 68:134-139.

[93] Zhang X. et al. A longitudinal study of sick building syndrome among pupils in relation to microbial components in dust in schools in China. Sci Total Environ 2011; 409 (24): 5253-5259.

[94] Teeuw KB, Vandenbroucke-Grauls CM, Verhoef J. Airborne gram-negative bacteria and endotoxin in sick building syndrome. A study in Dutch governmental office buildings. Arch Intern Med 1994; 154 (20): 2339-45.

[95] Ammann HM. Microbial Volatile Organic Compounds. In: Bioaerosols: Assessment and Control, Macher J.M. etal.al., Cincinnati, UH: ACGIH, 1988: 26-1-26-17.

[96] Yu B., et al. Review of research on air-conditioning systems and indoor air quality control for human health. Int J Refrig 2009; 32 (1): 3-20.

[97] Hess-Kosa K. Indoor Air Quality: The Latest Sampling and Analytical Methods, Second Edition. CRC Press, 2002: 397.

[98] Burge PS, Jones P, Robertson AS. Sick building syndrome; environmental comparisons of sick and healthy buildings. Indoor Air 1990;1: 479–83.

[99] Nexo E, et al. 1983. Extreme fatique and malaise syndrome caused by badly-cleaned wall-to-wall carpes? Ecol. Dis., 1983; 2: 415-418.

[100] Kishi R, et al. Phthalate in house dust and its relation to sick building syndrome and allergic symptoms. 30th International Congress on Occupational Health organized in Cancun from March 18th to March 23rd, 2012. Mexico: ICOH, 2012.

[101] Mølhave L, Kjærgaard SK, Attermann J. Sensory and other neurogenic effects of exposures to airborne office dust. Atmospheric Environment 2000, 34 (28): 4755-4766.

[102] Stenberg B, et al. The sick building syndrome (SBS) in office workers. A case-referent study of personal, psychosocial and building related risk indicators. Int J Epidemiol 1994; 23: 1190-7.

[103] Engvall K. Development of a multiple regression model to identify multi-family residential buildings with a high prevalence of sick building syndrome (SBS). Indoor Air 2000; 10: 101-110.

[104] Lenvik K. Smoking habits, atopy, and prevalence of sick building syndrome symptoms among office workers in Norway. Environment International 1993; 19 (4): 333-340.

[105] Bullinger M et al. The Sick-Building-Syndrome – Do women suffer more? Zentralblatt für Hygiene und Umweltmedizin 1999; 202 (2-4): 235-241.

[106] Norbäck D. An Update on Sick Building Syndrome: Personal Risk Factors for Sick Building Syndrome. Medscape, 2009: http://www.medscape.org/viewarticle/701739_7 (21.11.2013)

[107] Norlen U, Andersson K. An indoor climate survey of the Swedish housing stock (the ELIB study). In: Proceedings of Indoor Air'93, 6th International Conference on Indoor Air Quality and Climate, Helsinki, 1993; 1: 743-748.

[108] Bickford M., Stress in the Workplace: A General Overview of the Causes, the Effects, and the Solutions. Canadian Mental Health Association Newfoundland and Labrador Division, 2005.

[109] Morris L, Hawkins L. The role of stress in the sick building syndrome. In: Indoor air '87, Proceedings of the 4th Intern. Conf. on Indoor Air Quality and Climate, Berlin (West) 17-21 Aug. 1987 Berlin: Inst. fur Wasser-, Boden- und Lufthygiene, 1987; 2: 566-571.

[110] Hedge A, et al. Indoor air quality investigation as a psychological stressor. Indoor air '87, Proceedings of the 4th Intern. Conf. on Indoor Air Quality and Climate, Berlin (West) 17-21 Aug. 1987 Berlin: Inst. fur Wasser-, Boden- und Lufthygiene, 1987; 2: 552-556.

[111] Crawford JO, Bolas SM. Sick building syndrome, work factors and occupational stress. Scand J Work Environ Health 1996; 22(4): 243-50.

[112] Ooi PL, Goh KT. Sick building syndrome: an emerging stress-related disorder? Int J Epidemiol. 1997 Dec;26(6):1243-9.

[113] Lu CY, et al. Oxidative stress associated with indoor air pollution and sick building syndrome-related symptoms among office workers in Taiwan. Inhal Toxicol 2007; 19(1): 57-65.

[114] NDSC. National Guidelines for the Prevention of Nosocomial Invasive Aspergillosis During Construction/Renovation Activities. Dublin: National Disease Surveillance Centre, 2002: 40.

[115] Regulation EU 305/2011 of the European Parliament and of the Council of 9 March 2011 Laying Down Harmonized Conditions for the Marketing of Construction Products and Repealing Council Directive 89/106/EEC.

[116] Occupational Health and Safety Act (O.J. RS, No. 56/1999, 64/2001, 43/2011).

[117] Rules on requirements for ensuring safety and health of workers at workplaces (O.J.RS, No 89/1999, 39/2005, 43/2011).

[118] SIST ISO 7726: 1998. Ergonomics of the thermal environment–Instruments for measuring physical quantities.

[119] EN CR 1752:1999. Ventilation for buildings – Design criteria for the indoor environment.

[120] ANSI/ASHRAE/ASHE Standard 62.I-2010: Ventilation for Acceptable Indoor Air Quality. Atlanta, GA, American Society for Heating, Refrigerating and Air-Conditioning Engineers Inc, 2010.

[121] ANSI/ASHRAE Standard 55-2010. Thermal Environmental Conditions for Human Occupancy. Atlanta, GA, American Society for Heating, Refrigerating and Air-Conditioning Engineers Inc, 2010.

[122] Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

[123] Rules on protection against noise in buildings (O.J. RS, No. 10/2012).

[124] TSG-1-005: 2012. Technical guidelines on protection against noise in buildings. Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, 2012.

[125] Rules on the protection of workers from the risks related to exposure to noise at work (O.J.RS, No. 17/2006, 18/2006, 43/2011)

[126] Directive 98/24/EC – risks related to chemical agents at work of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work.

[127] Rules on the protection of workers from the risks related to exposure to chemical substances at work (O.J.RS, No. 100/2001, 39/2005, 53/2007, 102/2010, 43/2011)

[128] Directive 2000/54/EC – biological agents at work of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work.

[129] Rules on the protection of workers from risks related to exposure to biological agents at work (O.J.RS, No. 4/2002, 39/2005, 43/ 2011).