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].

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

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

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

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.

REFERENCES

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