GREEN FRAMEWORK TO IMPROVE INDOOR AIR QUALITY IN BUILDINGS: REDUCING THE IMPACT OF SICK BUILDING SYNDROME ON OFFICE WORKERS IN SRI LANKA: A LITERATURE REVIEW

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Abstract

The prevalence of harmful, natural and artificial substances, indoors are combined with poorly ventilated interior and the long period of time staff spend indoors, can lead to various health problems. Poor Indoor Air Quality (IAQ) can lead to such increased incidents of health related symptoms, which in turn can lead to an increase in absenteeism and loss of productivity. Sick Building Syndrome (SBS) is a major health effect faced by occupants in buildings with indoor air problems whilst most of buildings were potential carriers of SBS. SBS due to poor IAQ could affect to the workers who are working in the same premises for long durations. Especially in an office environment, the workers have to work in the same working area with many numbers of hours continually in the same premises. Thus, they are directly faced with the indoor air factors all along the day. Thus, poor IAQ has become a major concern and widely regarded as a significant health, environment and economic hazard. Consequently, certain guidelines are helpful to improve and control the quality of air indoors. Green building concept is gaining momentum in facilitating healthier environment specially by improving IAQ due to its potential impact on building occupants. Accordingly, a green framework of IAQ has been developed through a comprehensive literature review by considering available green strategies including green tools, standards and codes and organizational and national policies and procedures. Thus, those strategies can be applied to control sources of poor IAQ, human activities and IAQ performance as well as to improve the awareness on SBS and green strategies. Further, it is expected that the study will serve a green platform which can be applied by future researchers in order to reduce the impact of SBS on building occupants in Sri Lanka.

Keywords: Indoor Air Quality, Sick Building Syndrome, Office Workers, Green Building Concept, Green Framework

1. Introduction

The prevalence of harmful, natural and artificial substances, indoors are combined with poorly ventilated interior and the long period of time staff spend indoors, can lead to various health problems (Loozor et al., 2001). Poor Indoor Air Quality (IAQ) can lead to such increased incidents of health related symptoms, which in turn can lead to increase absenteeism and loss of productivity (Kim and Dear, 2011). IAQ refers to the nature of conditioned air that circulates throughout the space/area where the people work and live, that is, the air people can breathe during most of our lives. IAQ refers not only to comfort, which is affected by temperature, humidity and odours. According to a study by Mendell (2004 cited Ling et al., 2008), environmental risk to public health due to poor air quality has increased drastically, over the last 20 years. Thus, Poor IAQ is widely regarded as a significant health, environment and economic hazard. 'Sick Building Syndrome (SBS) is a critical health issue in office buildings with indoor air problems, sometimes called sick buildings whilst IAQ affects to the workers who are in office environment. SBS have been affected the people who are working in the same premises for long duration. According to the Nandasena et al. (2010), air pollution is recognized as an emerging public health problem in developing countries. Most of these countries do not have adequate data to evaluate the actual magnitude of the problem. Similarly in Sri Lanka, the situation is same and, does not concentrate on indoor air quality measurements comparing with the overseas countries.

Consequently, certain guidelines are helpful in aiming to improve and control the quality of air indoors of buildings. Green Building (GB) has emerged as a new building philosophy among other concepts for mitigating such impacts on their occupants by encouraging the use of more environmentally friendly materials, the implementation of techniques to improve IAQ etc (Thormark, 2006 cited Lacouture et al., 2008). Therefore, this study is expected to convince about the importance of GB concept in order to reduce the impact of SBS on office workers by improving IAQ of buildings. Hence, this study has developed a green framework through a comprehensive literature review. The green framework can be served as a national green platform applied by future researchers in order to reduce the impact of SBS on building occupants in Sri Lanka.

2. Literature review

2.1 Indoor air quality (IAQ)

A study of Loozor et al. (2001) mentions that the prevalence of harmful natural and artificial substance combined with poorly ventilated interiors lead to various health problems since occupants spend long period of time indoors. IAQ refers not only to comfort, which is affected by temperature, humidity and odours, but, also to harmful biological contaminants and chemicals presented in the conditioned space. Illinois Department of Public Health (IDHP) has consistently ranked indoor air pollution among the top five environmental risks to public health. According to Bholah and Subratty (2002), World Health Organization (WHO) has defined that the poor IAQ leads to an increased incidence of health related symptoms.

Indoor Air Quality (IAQ) refers to the nature of conditioned air that circulates throughout the space/area where the people work and live, that is, the air people can breathe during most of our lives. The definition of indoor air quality can be approached from three points of view: the human, the indoor air of the space and the sources contributing to indoor air pollution (Bluyssen, 2009).

2.2 Effect of poor IAQ

The reality is that indoor air can be up to ten times more polluted than outdoor air. The fact remains that the air we breathe, working or living, 85% of the time in conditioned spaces may be more injurious to health than outdoor air (ASHRAE, 2010 cited Charles et al., 2005). Concerning the possible health effects of indoor air pollution is increasing, with respect to asthma, allergies and non-specific symptoms from eyes, upper airways and facial skin. Such non-specific symptoms are common in the general population (Ling et al., 2008). IAQ can be a cause to many building related health issues especially it highly causes to building related illnesses and sick building syndrome (SBS). According to previous studies, IAQ can be highlighted as a major fact affecting SBS among the other factors; personal factors, psychological factors etc (Fisk et al., 2009; Crock and Burton, 2010).

Sick Building Syndrome (SBS): According to the WHO, SBS originally defines as "a collection of nonspecific symptoms including eye, nose and throat irritation, mental fatigue, headaches, nausea, dizziness and skin irritation, which seem to be linked with occupancy of

certain workplaces" (Hedge and Erickson 1995, p.3). Further, SBS can be defined as a collection of signs and symptoms fitting a recognizable pattern (Morris and Dennison, 1995).

2.3 Impact of sick building syndrome on office environment

According to the WHO (1986 cited (Wong et al., 2009), up to 30% of new and re-modelled buildings worldwide were potential carriers of SBS. Since then, there have been many cases of SBS, predominantly in sealed office buildings. In an office environment the workers have to work in the same working area with many numbers of hours continually with their working life time in the same premises. Because of that they are directly faced with the indoor air factors all along the day. The prevalence of harmful natural and artificial substances, indoors are combined with poorly ventilated interior and the long period of time staff spend indoors, can lead to various health problems (Llozor et al., 2001). A number of studies have attributed to the character of the symptoms of sick building syndrome (SBS) to the physical indoor environment, especially poor indoor air quality. The symptoms usually develop on the first day back at work after a break, often in the same afternoon, and can become severe in the evening and night after the person has left the work (Morris and Dennison, 1995).

Similarly in Sri Lanka, measuring air quality is very difficult task since cost of measurement is very high and few expertise in industry revealed that measurement of indoor air quality is not essential. However, these are evidence that health effects of the occupants are not that much concerned for the industry. .Further, though Sri Lanka is a tropical country, some limited data has suggested that indoor air is more polluted than outdoor air (Nandasena et al., 2010). Some of the researches have been illustrated symptoms resulted by poor IAQ that are affecting as the people who are in the same place which are more related with SBS.

Even though many standards and guidelines were available to meet the quality of indoor air, as experienced by the occupants, is still not acceptable and even unhealthy, causing health and comfort problems. There seems to be a discrepancy between current standards with end-users wishes and demands. Thus, developing new guidelines is vital to improve and control the quality of IAQ of buildings. Hence, key research papers were reviewed in order to identify possible green strategies which can be applied to reduce the impact of SBS on office workers by improving and controlling the quality of air indoors.

2.4 Application of green building concept for IAQ improvements

Impacts of building activities on building occupants due to poor indoor climate become more apparent, a movement called "Green Building (GB)" is gaining momentum (Edwin et al., 2009). Thormark, (2006 cited Lacouture et al., 2008) verified that GB has emerged as a new building philosophy, encouraging the use of more environmentally friendly materials, and implementation of techniques to save resources and specially the improvement of indoor environmental quality including quality of indoor air. Henceforth, GB practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings (Hashim et al., 2011). Green, or sustainable building, is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition (US Green Building Council, 2007; EPA GB, 2008 cited Edwin et al., 2009). It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants' is reduced (Ali et al., 2009 cited Hikmat et al., 2009). Cheng (2007 cited Edwin et al., 2009) mentioned that the concept of GB has applied in most of the countries to reduce the impact of buildings on environment and human health.

2.5 Green strategies for improving IAQ

Many researches state that there are several green tools, standards and codes and organizational policies and procedures available to improve indoor environment of buildings specially for improving IAQ of indoors.

Green assessment tools

According to studies of Westerberg and Glaumann (2002) and McKay (2007), green assessment tools were primarily developed to assess, or measure specific aspects of a building, pertaining to sustainability goals. Once measured, buildings could be more easily compared with current and past building practices and other green buildings. Wallhagen (2010) further verified that the green assessment tools can also be used to produce guidelines, benchmarks, ratings and incentives to construct buildings with low environmental impact and to work as environmental management tools. The most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment

System for Building Environmental Efficiency (CASBEE) and Green Star (Roderick et al., n.d.; Boonstra and Pettersen, 2003; McKay, 2007).

Table 1: IAQ in green tools (Boonstra and Pettersen, 2003; Haapio, 2008; Wallhagen, 2010)

	LEED	*BREEAM*	*Green Star*	*CASBEE*
Indoor Air Quality factors	• *Indoor chemical and pollutant source control* • *Minimum IAQ performance* • *Construction IAQ management plan*	• *Smoking* • *Clean carpets*	• *Air change effectiveness* • *CO_2 and VOC monitoring and control* • *Hazardous materials*	• *Type of A/C* • *CO_2 monitoring* • *Control of smoking*

Table 1 summarized that the application of LEED, BREEAM, CASBEE and Green Star tools for improve and control IAQ of buildings. Indoor chemical and pollutant source control, minimum IAQ performance etc can be identified as IAQ factors mentioned in LEED while smoking is controlled by both BREEAM and CASBEE. Furthermore, air change effectiveness, CO_2 monitoring and controlling are measured by Green Star.

Standards and codes

Internationally the organizations are provided with the IAQ standard to prevent the prevalence of SBS in the organizations. The summary of standards that are published by the IDPH, ASHRAE and OSHA are shown in the following table 2. To maintain a quality air indoor, the following levels of requirements are essential.

Table 2: IAQ standards by Illinois Department of Public Health (Arnold, 2010)

PARAMETER	*IDPH*	*ASHRAE*	*OSHA*
Humidity	*20% - 60 %*	*30% - 60 %*	*N/A*
Temperature	*68 - 75 (winter)*	*68 - 75 (winter)*	*N/A*
	73 – 79 (summer)	*73 - 79 (summer)*	
Carbon Dioxide	*1,000 ppm*	*1,000 ppm*	*5,000 ppm*
	(<800 ppm preferred)		
Carbon Monoxide	*9 ppm*	*9 ppm*	*50 ppm*
Hydrogen Sulfide	*0.01 ppm*	*N/A*	*20 ppm*
Ozone	*0.08 ppm*	*N/A*	*0.1 ppm*
Particulates	*0.15 mg/m 3 (PM 10) (150 µg/m 3) 24-hr 0.065 mg/m 3 (PM 2.5) (65 µg/m 3) 24-hr*	*50 µg/m3, annual average (PM 10)*	*15 mg/m 3 (total)*
			5 mg/m 3 (resp.)
Formaldehyde	*0.1 ppm (office)*	*0.1 ppm (office)*	*0.75 ppm*
	0.03 ppm (home)	*0.04 ppm (home)*	
Nitrogen Dioxide	*0.05 ppm*	*N/A*	*5 ppm*
Pressure relationship with Zones	*N/A*	*Restroom mechanically exhaust with no recirculation*	*N/A*
Outdoor air floor rate	*N/A*	*10 L/s (20 cfm) per person*	*N/A*

Policies and procedures

Even though those standards and guidelines are met, the quality of the indoor air, as experienced by the occupants, is still not acceptable and even unhealthy, causing health and comfort problems. It seems to be a discrepancy between current standards with end-users wishes Hashim et al., 2011). Therefore, ‘‘other or additional’’ recommendations and guidelines are required to improve IAQ. Regulation is the most powerful tool to force people to create a good indoor air quality. From the regulator point of view, one needs a simple way to test

whether an existing building or future building, fulfils certain rules to reach a good indoor air quality. Hence, several ways can be applied to control the sources of poor IAQ by reducing the effect of IAQ and to maintain minimum allowable emission rates of pollutants from a source (Boonstra and Pettersen, 2003). However, policies are required to control the IAQ and human activities as ban of use of certain pollutants in products or in general (for example asbestos, smoking etc), maintaining a minimum required ventilation rate and maximum allowable concentration level (exposure level), applying preventive measures such as design approaches, maintenance activities to prevent growth of Legionella or strict procedures of intended use of a space or product (Bluyssen, 2009).

In order to control the human activities, awareness on IAQ and such green tools, methods to improve the quality of IAQ is utmost important. Educating people via press releases, television spots, leaflets, internet, courses for professionals, introduction at elementary schools, high school programmes of sustainability; specific courses at universities; involvement of professional organisations (stakeholders), etc are ways of awareness which can be applied (Arnold, 2010). Another way of raising awareness is to make it commercially attractive for stakeholders to include indoor air quality in their daily business. Furthermore, the dynamic process of managing the indoor environment and thus the indoor air quality, involves many stakeholders, such as the owner, the end-user, the contractor, but also the persons that maintain the indoor environment. However, It is important to realise that those ways should not be undertaken separately, but integrative and holistically (Bluyssen, 2009).

2.6 Green framework of IAQ

The green framework has been developed by integrating several green strategies which can be applied nationally and organizationally (refer figure 1). It is important to establish a national platform by introducing a national strategy to improve indoor environment of buildings by highlighting IAQ parameters that should be reached through organizational procedures. Thus, the national IAQ strategy can be developed including various IAQ parameters; indoor chemical and pollutant source control, minimum IAQ performance, construction IAQ management plan, CO_2 monitoring, air change effectiveness etc compared with the available green assessment tools namely LEED, BREEAM, CASBEE and Green Star.

In order to reduce the impact of SBS on building occupants, organizations can implement policies and procedures to control and improve air quality of their indoors based on the national strategy.

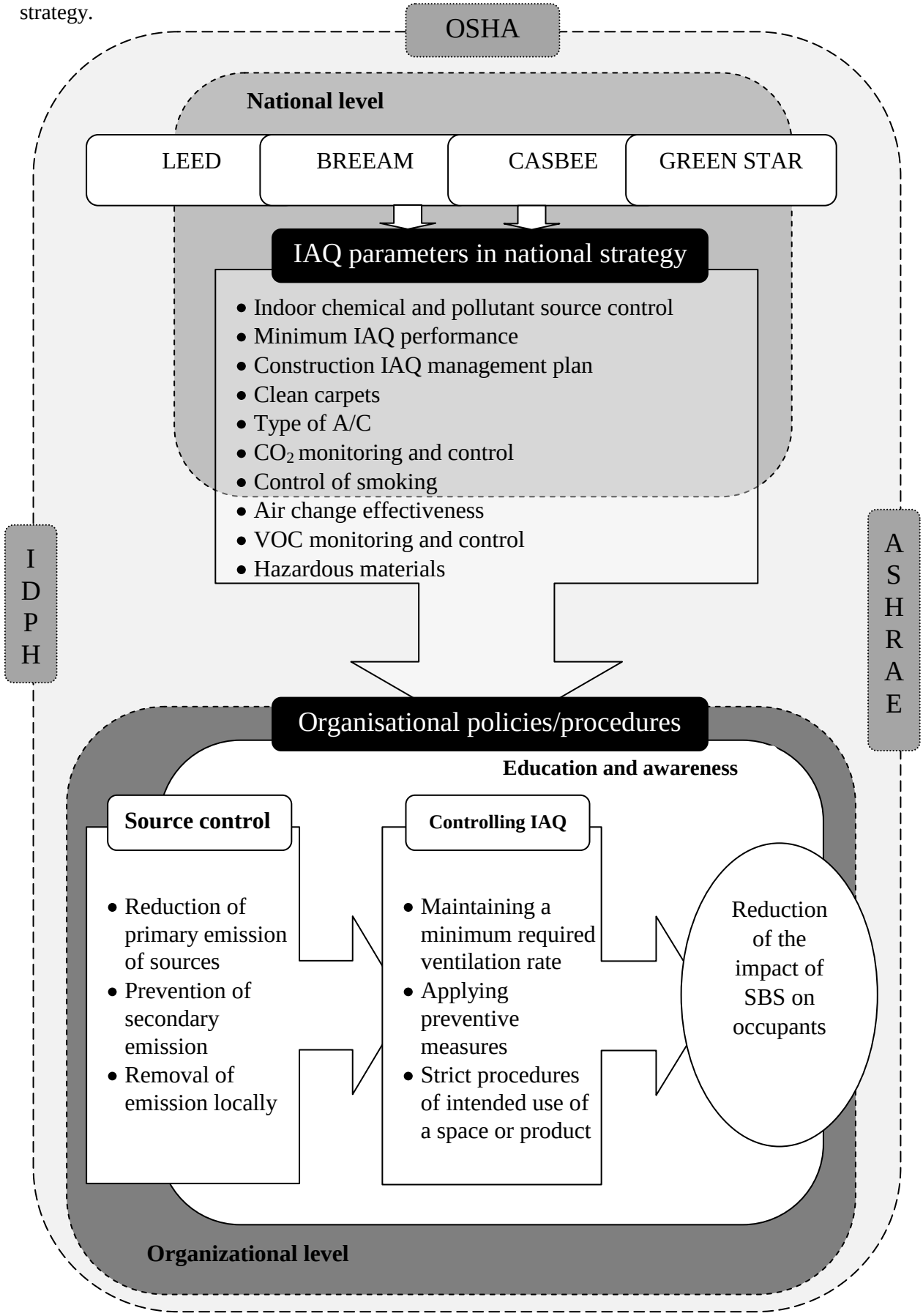

Figure 1: Green framework of IAQ

Organizational policies can be implemented in order to controlling source of poor IAQ, to control quality of air and specially to educate and aware the occupants on impact of SBS and its mitigation. The whole strategy of improving IAQ of buildings can be further assisted by international standards published by the IDPH, ASHRAE and OSHA.

2.7 Application of green framework for office buildings in Sri Lanka

Literature findings prove that the measurement of IAQ is essential to improve productivity of workers. However, some limited data have suggested that indoor air is more polluted than outdoor air in Sri Lanka (Nandasena et al., 2010). According to the previous studies, poor IAQ has been affected on office workers in Sri Lanka which has proved by a study conducted by Wijerathne (2011). As Wijerathne (2011) further illustrated that many of office buildings in Sri Lanka have effected to SBS on their workers. Therefore, the developed green framework (Figure 1) can be applied within Sri Lankan context in order to reduce the impact of SBS on office workers in Sri Lanka by implementing a national green platform towards ensuring high quality air indoors within buildings.

The IAQ policy can be developed nationally with legal binding on every organisation in order to maintain required quality of air indoors in buildings. Thus, every organisation must be implemented an organisational procedure to improve and control the IAQ of buildings. Further, relevant standards and codes can be introduced through the national policy referring to international standards published by the IDPH, ASHRAE and OSHA.

Organisational policy can be established including ways of measuring and improving air quality of the building. Further, the parameters mentioned in the green framework can be employed as indicators for measuring IAQ and thus, the organisational IAQ guideline can be developed as illustrated in table 03.

As table 03 illustrated that, the IAQ guideline can be developed including several major categories namely, IAQ measurement, standards and codes of IAQ, mitigation measures, capacity building and awareness raising and resource allocation. IAQ measurement parameters, required equipments, measurement process and the responsibility should be further clarified

under the IAQ measurement while establishing IAQ standards and codes based on international references. Further, there should be reduction/corrective measures of poor IAQ which can verify according to the national policy and legal requirements. In order to reduce the impact of SBS by maintaining the quality of air indoors, awareness and training is an essential category that should be introduced through the organisational guideline. Awareness can be raised through workshops, presentations, leisure activities etc. Further, there should be a top management commitment for the process of reducing impact of SBS on occupants as it can be highly affected on the productivity of occupants and also on the organisational performance. Therefore, allocation through annual budgets for this process will not be a cost as it can serve as the long term investment for improving organisational performance.

Table 3: Example IAQ guideline

CATEGORIES	*SUBCATEGORIES*
IAQ measurement	• *Parameters, equipments, process, responsible person*
Standards and codes of IAQ	• *Reference to international standards; IDPH, ASHRAE and OSHA*
Mitigation measures	• *Reference to the national policy*
Capacity building and awareness raising	• *Training for employees on IAQ measurement and controlling* • *Awareness programs on building occupants*
Resource allocation	• *Trained employees* • *Measuring equipments* • *Financial allocation through annual Budgets*

Accordingly, organisational procedure can be further assisted by national policy and the international standards, codes and guidelines available so as to reduce the impact of SBS on occupants those who are working in same premises for long durations especially on office workers.

3. SUMMARY

Poor Indoor Air Quality (IAQ) can be lead to increased incidents of health related symptoms, which in turn can lead to an increase in absenteeism and loss of productivity. Thus, Poor IAQ is widely regarded as a significant health, environment and economic hazard. 'Sick Building Syndrome' (SBS) is a critical health issue in office buildings with indoor air problems, sometimes called sick buildings. SBS has been affected the people who are working in the same premises in long duration. Consequently, certain guidelines are helpful in aiming to improve and control the quality of air indoors of buildings. Green Building (GB) has emerged as a new building philosophy among other concepts for mitigating such impacts on their occupants. There are several green tools, standards and codes and organizational policies and procedures available to ensure high quality air indoors of buildings especially by improving and controlling IAQ of buildings.

Accordingly, a green framework of IAQ has been developed by considering available green strategies including green tools, standards, codes, policies and procedures integrating both national and organisational level. National policy can be established to control the quality of indoor environments for reducing the impact of SBS. Organisational policies can be developed based on the national and international policies and a IAQ guideline can be introduced specially highlighting IAQ measurement, standards and codes of IAQ, mitigation measures, capacity building and awareness raising and resource allocation.. Thus, the developed green framework can be applied as a national platform towards ensuring high quality air indoors within buildings by reducing impact of SBS on office workers in Sri Lanka and for other contexts too.

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