

# Indoor Carbon Dioxide Concentrations and Sick Building Syndrome Symptoms in Office Workers of Petroleum Industry Health Organization

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## Abstract

**Aims:** High prevalence of sick building syndrome (SBS) owing to the work is one of the popular discomforts. High prevalence of sick building syndrome (SBS) owing to the work is one of the popular discomforts and Work-related absenteeism between office workers. The aims of this study were to assess the association of indoor carbon dioxide (CO<sub>2</sub>) concentrations with SBS prevalence among employees in two office buildings of Petroleum Industry Health Organization in Tehran city. **Materials and Methods:** In this analytical-descriptive study, 170 employees of the two office buildings of Petroleum Industry Health Organization in Tehran city have been selected. HSE questionnaire was combined with Skov's questionnaire as data collection tools. Questionnaire data analysis has also carried out using SPSS and Chi-square independent sample *t*-test. CO<sub>2</sub> concentrations were measured using calibrated instruments. **Results:** The results suggested that the CO<sub>2</sub> concentration in both buildings is higher than the threshold limit. CO<sub>2</sub> concentration was significantly associated with some symptoms such as dry throat ( $P = 0.028$ ), shortness of breath ( $P = 0.028$ ), nasal irritation ( $P = 0.008$ ), dizziness ( $P = 0.0312$ ), headache ( $P = 0.0315$ ), nausea ( $P = 0.049$ ), and sickness ( $P = 0.023$ ). **Conclusion:** The prevalence of syndrome symptoms in women was higher than men. Some of SBS symptoms were exacerbated by increasing CO<sub>2</sub> concentrations among the employee.

**Keywords:** Indoor carbon dioxide, office buildings, sick building syndrome

## INTRODUCTION

The 1973 World Energy Crisis has been introduced as the starting point for the sick building syndrome (SBS) phenomenon. The consequences of this crisis include the effort to maintain energy through the installation of UPVC windows, reducing the number of building air changes, partitioning rooms, and removing the natural ventilation by introducing ventilation systems based on air recirculation and demographic load increase in the building. In addition to the factors mentioned above, the entry of equipment such as computers, photocopiers, laser printers, and many other equipment into office environments has led to the emergence of new pollutants inside the building, which worsened the situation. However, perhaps the rise in the price of energy carriers after the 2011 Targeted Subsidy Law and the pollution of the major cities has been one of the most important factors in increasing the prevalence of

the SBS in Iran.<sup>[1]</sup> The SBS is an uncertain condition with symptoms of headache, inflammation of the eyes, nose, throat, and skin, cough, dizziness, nausea, and fatigue. These symptoms quickly disappear after leaving the building.<sup>[2]</sup> Indoor air quality in the late 20<sup>th</sup> century has been considered as one of the most important factors in the development of the SBS. Many studies have also been conducted in this regard. Inappropriate ventilation, such as ventilation systems based on air recirculation, reducing the number of air changes per hour from 2 to 0.2 or 0.3 due to air pollution and the use of UPVC windows can be considered as effective

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factors in reducing the air quality of buildings.<sup>[1]</sup> One of the most important indicators that can be used to measure the parameters affecting indoor air quality is the measurement of carbon dioxide (CO<sub>2</sub>) concentration. Despite the fact that CO<sub>2</sub> is not a pollutant gas and does not have any effect on human health, it is always considered as an important factor in evaluating indoor air quality and as an indicator of how the ventilation system works. According to the report of American Occupational Safety and Health Administration, if the concentration of CO<sub>2</sub> in closed environments is higher than 800 ppm, it will cause a feeling of lack of fresh and still air. The usual range of CO<sub>2</sub> concentration in the closed environments is 450–675 ppm.<sup>[3]</sup> Bad air quality in rooms leads to fatigue, lack of concentration, and dissatisfaction of people, often due to improper ventilation of the building. This has a direct relation with CO<sub>2</sub> concentration; therefore, in some systems that use automatic ventilation, CO<sub>2</sub> concentration is used as a measure of the regulation of fresh air entering the system. Excessive CO<sub>2</sub> increase can cause becoming sick, headache, increased sweating, and difficulty in breathing.<sup>[4]</sup> Previous studies have shown that increasing the concentration of CO<sub>2</sub> in office environments increases the prevalence of the SBS symptoms such as headache, dizziness, eye symptoms, and respiratory symptoms.<sup>[5]</sup> Considering the fact that, in many studies, complaints of the SBS were more common in the office environment, the present study has been conducted aimed to investigate the relationship between the SBS and concentration of CO<sub>2</sub> in office environments.

## MATERIALS AND METHODS

This cross-sectional descriptive study was conducted in 2011 on workers of the two buildings of Petroleum Industry Health Organization located in Tehran. The study inclusion criteria included no illness such as cold or other illnesses with symptoms of the SBS, with a work experience of at least 1 year. Smoking and noncooperation until the end of the study were considered as the exclusion criteria of the study. The workers of the building No. 1 during the 8 h shift included 85 workers. The heating system of this building works through the fan coil. The ventilation system in the winter is only the natural ventilation. The building windows were not UPVC. The workers of the building No. 2 during the 8 h shift included 122 workers. The heating system works through the radiator. The ventilation and windows of this building are like the building No. 1. An integrated questionnaire used in the study of SKOV (1987), FANGER (2000), and HSE in England was used to study the symptoms of the SBS.<sup>[6]</sup> The questionnaire included personal, occupational, working conditions, and symptoms of the SBS such as mucus, skin, headache, and nausea. The questionnaire was prepared and reviewed by experts and after studying the validity and reliability was distributed among the workers and collected at the end of the day. The CO<sub>2</sub> concentration parameter was measured by the direct reading device of CO<sub>2</sub> METER-1370 (NDIR) model over a period of 2 weeks in January. The data were analyzed

by software SPSS version 16 (IBM, New York, United States) using Chi-square and independent *t*-test.

## RESULTS

### Individual characteristics

More than 94% of the total number of workers of the buildings No. 1 and 2 completed questionnaires. The average age of men and women in the building No. 1 was 40 ± 9 years and 33 ± 5.7 years, respectively, and the average work experience was 7 ± 2 years for men and 6 ± 3.7 years for women. In the building No. 2, the average age of men and women was 38 ± 9 and 32 ± 6.3 years, respectively, and the average work experience was 6 ± 3.7 and 6 ± 3.1, respectively.

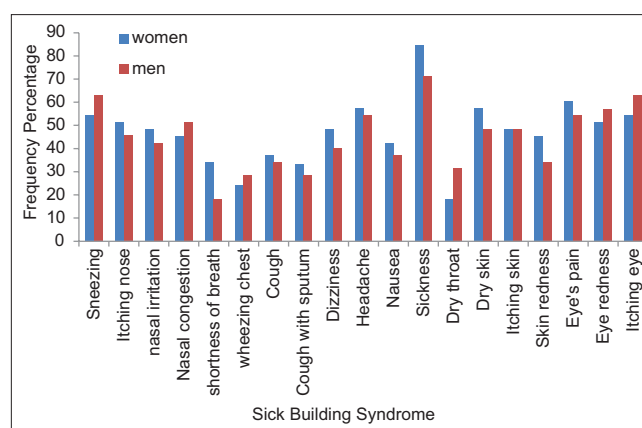
### Measurement results

The results of measurement of CO<sub>2</sub> concentration showed that the average concentration of this gas in the buildings No. 1 and 2 was 700 and 740 ppm, respectively. The allowed limits for CO<sub>2</sub> condensation in office buildings are 450–675 ppm. The gas concentration in both buildings is higher than the standard limit.

### The prevalence of symptoms of the sick building syndrome

The results of the study showed that the highest prevalence percentage of symptoms was in women and men population in the building No. 1 was related to the sickness (feeling bad) and for women (84%) and men (71%), respectively. The lowest percentage of symptoms in women and men population in this building was dry throat (18%) and asthma (18%), respectively. For the building No. 2, the highest prevalence of symptoms among women and men was related to headache (72%) and sickness (62%). The lowest prevalence of symptoms in this building for women was related to wheezing chest (15%) and cough with sputum (15%) and the lowest prevalence of symptoms for men was related to cough with sputum (15%). Most of the symptoms of the SBS were higher in female workers than male workers.

Figures 1 and 2, respectively, show the prevalence of the symptoms of the SBS among men and women working in the buildings No. 1 and 2.



**Figure 1:** Distribution of frequency percentage of symptoms of the sick building syndrome among women and men in the building No. 1

### The relationship between the symptoms and environmental parameters

The results of the evaluation of the relationship between the symptoms of the SBS and the concentration of CO<sub>2</sub> in each building showed that a significant relationship was found between increasing the CO<sub>2</sub> concentration and prevalence of symptoms such as nausea, headache, nasal irritation, shortness of breath, dizziness, sickness, and throat dryness ( $P < 0.05$ ).

Table 1 shows the prevalence of the symptoms of the SBS and its relationship with the CO<sub>2</sub> concentration for the workers in the buildings No. 1 and 2.

### DISCUSSION

This study has been conducted aimed to investigate the relationship between the SBS and CO<sub>2</sub> concentration inside

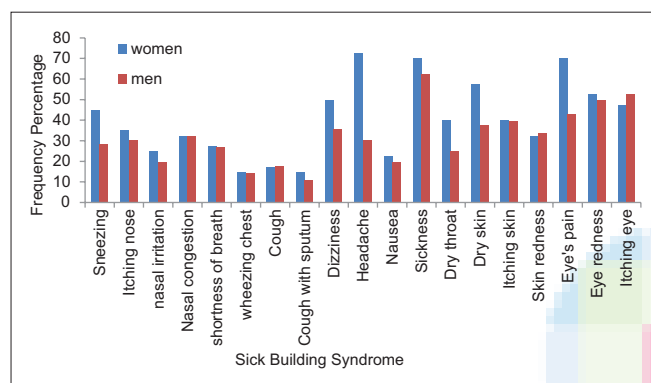


Figure 2: Distribution of frequency percentage of symptoms of the sick building syndrome among women and men in the building No. 2

two buildings of Petroleum Industry Health Organization. The results indicate that the highest percentage of symptoms in men and women in the buildings No. 1 and 2 is related to sickness (feeling bad) and headache, respectively. The lowest percentage of symptoms in these buildings is related to dry throat, shortness of breath, wheezing, and cough with sputum.

It was also found that most of the symptoms of the SBS in female workers are more than male workers. This finding is consistent with the results of Skov *et al.*<sup>[7]</sup> Furthermore, in the study of Kholasezadeh *et al.*, the frequency of symptoms of the SBS in the women population was more than that of men.<sup>[8]</sup> In a study by Brasche *et al.* conducted in one of the European countries, the prevalence of symptoms of the SBS in women was 1.5 times more than that of men.<sup>[9]</sup>

Furthermore, the results of measurement of CO<sub>2</sub> showed that the average concentration of this gas in the buildings No. 1 and 2 was 700 ppm and 740 ppm, respectively. Regarding the allowed limits for CO<sub>2</sub> in office buildings, the gas in both buildings of the ministry is higher than the standard limits. Various studies have shown that high concentration of CO<sub>2</sub> is not only related to air conditioning but also to population (the number of workers).<sup>[10]</sup> There are 122 workers in the building No. 2 and there are 85 workers in the building No. 1, as well as because of the closed space and a low number of windows in the building No. 2, and in contrast, high air flow rate in the building No. 1; in this regard, CO<sub>2</sub> concentration in the building No. 2 is greater than the building No. 1. This finding is consistent with the results of a study conducted by Burke (2004) in the United Kingdom and suggests that, in the buildings with mechanical ventilation, the prevalence of symptoms of the SBS

Table 1: The results of studying the relationship between carbon dioxide concentration and the prevalence of symptoms of the sick building syndrome in the buildings number 1 and 2

Symptoms	The building number 1				The building number 2			
	300-600	600-1000	>1000	P	300-600	600-1000	>1000	P
Sneezing	30.8	34.4	60	0.481	42.1	37.5	-	0.678
Itching nose	31.7	32.1	40	0.927	36.8	54.2	-	0.247
Nasal irritation	15.4	19.2	80	0.008	36.8	50	-	0.406
Nasal congestion	30.8	29.5	80	0.064	74.4	50	-	0.608
Shortness of breath	23.1	25.6	60	0.764	36.8	68.8	-	0.208
Wheezing chest	15.4	15.4		0.885	31.6	23.9	100	0.188
Cough	30.8	15.4	20	0.734	21.1	33.3		0.494
Cough with sputum	15.4	11.5	20	0.985	42.1	25.5	100	0.353
Dizziness	9.76	60	40	0.0312	52.6	29.6	100	0.392
Headache	32	23	80	0.0315	57.9	56.2		0.523
Nausea	46.2	14.7	20	0.049	44.4	44.7	50	0.965
Sickness	46	64.1	80	0.023	12.5	30.8	12.5	0.351
Dry throat	32.1	32.1	40	0.739	16.7	47.4		0.028
Dry skin	69.2	43.6	20	0.113	52.6	52.1	100	0.636
Itching skin	46.2	38.5	40	0.967	47.4	50	-	0.608
Skin redness	53.8	32.1	-	-	36.8	39.6	100	0.453
Eye's pain	61.5	52.6	60	0.805	52.6	56.2	-	0.382
Eye redness	61.5	48.7	60	0.637	52.6	60.4		0.421
Itching eye	61.5	38.5	20	0.184	42	25	100	0.351



is higher than that of the natural ventilation, which the main reason is the high concentration of CO<sub>2</sub>.<sup>[11]</sup> Furthermore, in a review of 22 studies on the relationship between the building ventilation and CO<sub>2</sub> concentration in a building with the health, comfort, and productivity conducted by Seppänen *et al.*, according to studies available on air-conditioned buildings, but not natural-conditioned buildings, a statistically significant positive relationship was found between SBS symptoms and CO<sub>2</sub> concentration (70%).<sup>[3]</sup> The results of this review are consistent with the results of the present study.

Furthermore, statistical analyses showed that a significant relationship was found between symptoms such as dizziness, headache, nausea, nasal irritation, shortness of breath, throat dryness, sickness, and CO<sub>2</sub> concentration. About half of the studies in the review by Seppänen *et al.* showed that a significant relationship was found between the level of CO<sub>2</sub> and SBS symptoms including headache, fatigue, eye symptoms, nose symptoms, and respiratory symptoms ( $P < 0.05$ ),<sup>[3]</sup> which is consistent with the results of this study. The study by Norbäck also produced similar results, with an average of 993 ppm CO<sub>2</sub> (674–1450 ppm) and symptoms such as significant eye, nose, and throat discomfort, shortness of breath, headache, and fatigue observed in higher CO<sub>2</sub> and temperature.<sup>[12]</sup> However, in Chung-Yen Lu study, complaints of eye and nonspecific symptoms were the most common symptoms of the SBS in women and men, and peripheral CO<sub>2</sub> levels in this study were not related to SBS.<sup>[13]</sup> Chung-Yen Lu study also showed that the symptoms of SBS increased among workers in high-rise buildings and had a stronger relationship with CO<sub>2</sub> concentration than the concentration of total volatile organic compounds in their office. The concentration of CO<sub>2</sub> in office units was measured from 467 to 2800 ppm on a scale. This study showed that the risk of dizziness and fatigue increased by 14% and 20%, respectively, which is related to CO<sub>2</sub> level. No relationship was found between CO<sub>2</sub> and respiratory, eye, and skin symptoms. Due to the increased CO<sub>2</sub> level of the environment, CO<sub>2</sub> level in the blood may increase, and the level of oxygenated hemoglobin reduces, which leads to a shortage of oxygen, which may explain the relationship between CO<sub>2</sub> and the complaint of fatigue and dizziness.<sup>[5]</sup> The relationship between CO<sub>2</sub> and SBS symptoms in Apte study on 41 US office buildings shows that, after adjusting the confounding variables, significant relationships were found between the symptoms of the lower respiratory tract and the increase in CO<sub>2</sub>; CO<sub>2</sub> increasing by 100 ppm increases the likelihood of symptoms of sore throat, nasal irritation, sinusitis, chest tightness, and wheezing by 1.1–1.5.<sup>[14]</sup> This chance (odds ratios) varies from 1.1 to 1.2 in Erdmann and Apte studies for symptoms of dry eye, sore throat, nasal irritation, sinusitis, sneezing, and wheezing with an increase of 100 ppm CO<sub>2</sub>.<sup>[15]</sup>

## CONCLUSION

The results of our study indicate that CO<sub>2</sub> concentration in both buildings is higher than the allowed limit. The results of the evaluation of the relationship between the symptoms of the SBS and CO<sub>2</sub> concentration in each building indicated

that a significant relationship is found between increasing CO<sub>2</sub> concentration and prevalence of symptoms such as nausea, headache, nasal irritation, shortness of breath, dizziness, boredom, and throat dryness. Given that the ventilation requirement is 10 per second per person, reducing the population in the building or increasing the natural ventilation can reduce the concentration of the gas and consequently reduce the symptoms of the SBS.

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## Conflicts of interest

There are no conflicts of interest.

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