Study of Air Quality in the Office Building

V V Agafonova

1NRU MGSU, Moscow State (National Research) University of Civil Engineering, 129337, Yaroslavskoye shosse, 26, Moscow, Russia

E-mail: agafonova-vv@yandex.ru

Abstract. This paper is devoted to assessment of air quality in an office space of a public building. Analysis of the results of researches made in this area by Russian and foreign authors showed that state of human health deteriorates at CO₂ concentration level of 600-800 ppm and more and this can lead to decrease in performance and increased fatigue of office workers. Long-term human exposure to carbon dioxide can lead to chronic diseases. Results of experimental study of changes in carbon dioxide concentration in 30 m² office space of a public building when 5 people are continually present in the office are given in this paper. CO₂ concentration measurement was carried out during 24 hour period using MT 8057 portable carbon dioxide detector. According to the measurements results, a graph of CO₂ concentration changes versus time was drawn. Conclusion that, in some periods of working day, air quality was unsatisfactory (from 10:40 to 13:30 and from 14:45 to 19:00: CO₂ concentration exceeded 1000 ppm) indicates insufficiency of existing ventilation system and excessive room sealing (due to application of plastic windows). There is a need in technical solutions to improve efficiency of supply and exhaust ventilation.

1. Introduction

In the last few decades, reduction of air quality in residential and office buildings has been a global problem. A course for this phenomenon is increase in room tightness due to widespread use of plastic windows (lack of natural ventilation), use of finishing materials and furniture made of toxic materials, as well as due to increased concentration of carbon dioxide in the room. Influence of the above factors on people health and performance was determined by foreign scientists as "sick building syndrome", a number of papers are devoted to this issue [1-6]. The main feature of this syndrome is decrease in attention concentration, increased fatigue, regular headaches, inflammation of mucous membranes, etc.

In European standards (EN 13779: 2005 Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems), CO₂ concentration is indoor air is used as a quality indicator. This is due to the fact that, under the same conditions, increase in carbon dioxide concentration is much more than increase in the concentration of hazardous impurities.

A number of articles [1-11] are devoted to study of air quality influence on health and performance. Authors of [7] calculated necessary volume of ventilation air based on given air quality (criterion - CO₂ concentration). It is concluded that, at air exchange rate of 30 m³/h which is declared in SP 60.13330.2012 "Heating, ventilation and air conditioning", carbon dioxide concentration will be about 0.1 % (1000 ppm [parts per million]). Developed method for assessment of comfort condition of a room is described in [8]. One of indicators estimated with use of this method is carbon dioxide level in...
the room. Paper [9] presents a review of foreign studies on impact of carbon dioxide concentration on health of office workers and schoolchildren. It is concluded that, even at CO$_2$ concentration of 600-800 ppm, office workers begin feeling that air quality is worsen (Table 1), and long-term effects of carbon dioxide on humans can lead to chronic diseases such as chronic fatigue syndrome, allergies, asthma, rhinitis, metabolic acidosis, etc.

Table 1. Effects of CO$_2$ concentration on human state of health.

| CO$_2$ concentration (ppm) | Effects on human state of health                      |
|---------------------------|-------------------------------------------------------|
| 350-400                   | Approximate CO$_2$ concentration in atmospheric air (depending on the area location) |
| 400-600                   | Normal air quality                                    |
| 600-1000                  | Noticeable worsening of air quality, reduced performance |
| 1000-2000                 | Discomfort, weakness, headache, decreased performance |

In accordance with the classification given in EN 13779: 2005, there are 4 classes of indoor air quality: IDA (indoor air). A level of comfortable carbon dioxide concentration is not more than 1000 ppm; if the concentration is above this value air quality is considered low, state of health and performance of most office workers in the room is sharply reduced (Figure 1).

![Figure 1. Classification of indoor air quality according to EN 13779: 2005.](image)

2. Materials and methods
Measurement of CO$_2$ concentration was carried out during 24 hours in a room of office building in the summer time. The room area was 30 m$^2$. There were 5 people in the room throughout the working day. At lunchtime and in the evening, the room was ventilated by opening windows.

Carbon dioxide concentration was measured using a portable carbon dioxide detector (MT 8057) (Figure 2). The results obtained are shown in Figure 3.
Figure 2. MT 8057 carbon dioxide detector.

Figure 3. Change in CO$_2$ concentration in the room of office building.

3. Discussion
At night, CO$_2$ concentration in the office building is 526 ppm (approximate CO$_2$ concentration in the air). Over time, this value gradually decreases (due to slightly open transom) and reaches minimum value for the period under consideration (at 7:10 am - 490 ppm). After this time, office workers begin to come to the office rooms and this causes increase in carbon dioxide concentration. Analysis of the results obtained in the course of the study showed that carbon dioxide concentration exceeds 1000 ppm after 10:30. At lunchtime (from 10:40 to 13:30), during ventilation, CO$_2$ concentration is reduced to acceptable value (not more than 800 ppm). Further, carbon dioxide concentration increases to 1343 ppm that indicates obvious insufficiency of ventilation. After repeated ventilation of the room (at 16:00), concentration is reduced to the value of 1179 ppm, then, again, there is increase in CO$_2$ concentration on the graph. Stable decrease occurs after the end of the working day (after 19:00).

The experimental studies allow concluding that increased concentration of carbon dioxide during the working day (from 10:40 to 13:30 and from 14:45 to 19:00) indicates obvious insufficiency of existing ventilation system and excessive sealing of the room (due to plastic windows). During normal working hours, air quality is unsatisfactory and corresponds to the lowest air quality class (IDA 4).

One of the solutions to this problem of air quality improvement is application of mechanical ventilation system with installation in the breathing areas of office workers of personalized air
distribution devices based on micro perforated textile terminals (Figure 4 - 6). The features of air distribution by means of textile diffusers with holes and micro-holes are described in [12-16]. The concept and principle of operation of the personalized device are given in [17]. A distinctive feature of this device is its ability to supply required volume of fresh air into the working area by means of micro jets, displacing harmful impurities from the human breathing zone. According to various studies, person thermal comfort varies widely [18-21]. For this reason, the device provides for the possibility of regulating the supply of fresh air depending on the individual needs of the office worker.

![Figure 4](image1.png)

**Figure 4.** Section of textile liner with micro-holes.

![Figure 5](image2.png)

**Figure 5.** Veiw of micro-hole.

![Figure 6](image3.png)

**Figure 6.** Schematic diagram for feeding supply air to the breathing area of a person.

1 - personalized air distribution device; 2 - air flow rate equal to normalized value per 1 person (micro jets)

4. Conclusion

It was concluded based on published research materials that, at CO₂ concentration of 600-800 ppm and more, human state of health deteriorates and this leads to decrease in performance and increased fatigue of office workers; long-term humans exposure to carbon dioxide leads to chronic diseases.

It was found that, during the working day, carbon dioxide concentration in the office room with area of 30 m² significantly exceeds comfortable for a person CO₂ concentration (at condition of regular ventilation). This indicates insufficiency of the existing ventilation system and excessive tightness of the room due to installation of plastic double-glazed windows.

A solution to the air quality improving problem is application of mechanical supply and exhaust ventilation with installation in the office building room, on desks of office workers, of personalized air distribution devices that effectively remove contaminated air by displacing hazardous impurities, including CO₂, thereby providing necessary microclimate indicators in the human breathing area.

References

[1] Wargocki P, Wyon D P and Fanger P O 2000 Productivity is affected by the air quality in offices *Proceedings of Healthy Buildings* 1 pp 635-640
[2] Wargocki P, Wyon D P, Baik Y K et al. 2000 Perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity in an office with two different pollution loads Indoor Air 9 (3) pp 165–179
[3] Lagercrantz L, Wistrand M, Willn U et al. 2000 Negative impact of air pollution on productivity: Previous Danish findings repeated in new Swedish test room Proceedings of Healthy Buildings 1 pp 653–658
[4] Fisk W J 2000 Health and productivity gains from better indoor environments and their implications for the U.S. Department of Energy Lawrence Berkeley National Laboratory 10–01 p 31
[5] Burge P S 2004 Sick building syndrome Occupational and Environmental Medicine 61(2) pp 185-190
[6] Zamani M E, Jalaludin J and Shaharon M N 2013 Indoor air quality and prevalence of sick building syndrome among office workers in two different office in Selangor American Journal of Applied Sciences 10(10) pp1140-47
[7] Mansurov R Sh, Gurin M A and Rubel E V 2015 Influence of carbon dioxide concentration on the human body Volga scientific journal 1 pp 60-64
[8] Bukhmirov V V and Prorokova M V 2015 Assessment of microclimate in the premises of residential, public and administrative buildings IGEU Bulletin 4 pp 1-6
[9] Gubernskiy Yu D and Shil’krot E O 2008 How much air does a person need for comfort? AVOK Journal 4 pp 4-12
[10] Suszanowicz D 2018 Optimization of ventilation system in the open office space MATEC Web of Conferences 174 pp 1-9
[11] Tsai D H, Lin J S and Chan C C 2012 Office workers’ sick building syndrome and indoor carbon dioxide concentrations Journal of Occupational and Environmental Hygiene 9(5) pp 345-351
[12] Rymarov A G and Agafonova V V 2015 Special considerations of air outflow by micro jets Privolzhsky Scientific Journal 1 pp 60-64
[13] Rymarov A G and Agafonova V V 2015 Research for potential application of textile air ducts in ventilation systems Natural and Technical Sciences 2 pp 141-143
[14] Nielsen P V, Topp C, Sonnichsen M et al. 2005 Air distribution in rooms generated by a textile terminal—comparison with mixing and displacement ventilation ASHRAE Transaction 8(1) pp 733–739
[15] Nielsen P V 2007 Personal exposure between people in a room ventilated by textile terminals: with and without personalized ventilation HVAC&R Research 13(4) pp 635–644
[16] Pinkalla C 2003 Fabric duct air dispersion for HVAC systems Construction Specifier 56(6) pp 57–64
[17] Rymarov A G and Agafonova V V 2018 Air supply device to the worker’s breathing zone Materials Science Forum 931 MSF pp 897-900
[18] Guenther J and Sawodny O 2019 Feature selection and Gaussian Process regression for personalized thermal comfort prediction Building and Environment 148 pp 448-458
[19] Ardakanian O, Bhattacharya A and Culler D 2018 Non-intrusive occupancy monitoring for energy conservation in commercial buildings Energy and Buildings 179 pp 311-323
[20] Kwon M, Remoy H, van den Dobbelsteen A and Knaack U 2019 Personal control and environmental user satisfaction in office buildings: Results of case studies in the Netherlands Building and Environment 149 pp 428-435
[21] Cosma A C and Simha R 2019 Machine learning method for real-time non-invasive prediction of individual thermal preference in transient conditions Building and Environment 148 pp 372-383