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Research of the internal environment of the military camp buildings

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Original article

Abstract

One of the key tasks of this research work is to assess the carbon dioxide (CO_2) pollution in the resting areas of military camps under the current deployment conditions and to assess its impact on soldiers. In the process, the environmental impacts that affect the CO_2 concentration were researched in different rooms in different ways. In addition to the rest areas of a military camp, enumerating the major camp facilities that affect the "welfare" feeling of soldiers on foreign mission, we arrived at the kitchen complex and the work environment of the kitchen staff. One of the key parts of the camp kitchen complex is the food storage, where the raw materials needed for the supply are stored. Storage is very important in a crisis situation, when you have to be prepared to stay away from the homeland, to prevent any supply or procurement problems. A particularly important task in providing food raw materials is the so-called "Fresh" storage. The aim of the paper is to examine the changes in the CO_2 concentration of the camp storage room, which is of key importance in food supply, in the vegetable (fruit) storage places. By modeling at a measurement site set up in the laboratory of the host institution, we measure the CO_2 composition of the indoor air in the warehouse by placing various vegetables and fruits. The change of CO_2 concentration is examined separately for certain types of vegetables and fruits stored in closed storage rooms, taking into account the degree of effective storage capacity and determine the required fresh air value to ensure proper storage conditions. Finally, a mathematical model to simulate changes in storage conditions will be created, which offer help to plan of the military camp.

Keywords

- military camp
- inside air quality (IAQ)
- temporary facilities

Authors contributions

A – Conceptualization
B – Methodology
C – Validation
D – Data collection
E – Data analysis
F – Writing – original draft preperation
G – Writing, reviewing & editing
H – Project administration

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Conflict of interest

None declared.

Introduction

NATO members must play a greater role in peace operations, where troops are housed in temporary facilities – military camps. Based on the experience of NATO involvement over the past 20 years, the concept of military camps needs to be rethought.

IAQ (Indoor Air Quality) refers to any, not just thermal, properties of the air in a comfort space that affect a person's well-being. Pollutants that affect IAQ quality – according to Bánhidi and Kajtár [1] – include gases and vapors (CO, CO_2, SO_2, NO_x, O_3, Rn), odors (organic matter, human, animal and plant odors) and aerosols (dust, suspended solids, pollen, etc.).

Max von Pettenkofer studied the air in comfort rooms in the middle of the 19th century, based on which he classified the quality of indoor air based on its CO_2 content. He showed that the air quality of the interiors (flats, schools, lecture halls) differs from that of the outside air, according to which the concentration of carbon dioxide in the outside air is 0.03–0.04% v/v (300–400 ppm), while in the lecture halls it showed significantly higher values. Accordingly, it was found that a maximum of 0.1% by volume (1000 ppm) of CO_2 in the air was the "good air" criterion. This value has been called the Pettenkofer number by the profession [2].

A result of the laboratory study by Herceg [3] examined and quantified the effect of carbon dioxide concentration on human well-being. He found that after staying indoors above a carbon dioxide concentration of 3000 ppm for 2 x 70 minutes, the well-being of healthy young people deteriorates rapidly. Furthermore, it examined and quantified that objective physiological characteristics justify an unacceptable increase in human body load after an indoors of 2 x 70 minutes above 3000 ppm carbon dioxide concentration in healthy young people, where the condition used in the significance test is $p \leq 0.05$.

A thermal environment is a property of the internal environment that affects the heat exchange between the human body and the environment. General thermal comfort can be characterized by PMV-PPD values – according to standard of MSZ EN ISO 7730:2006, MSZ CR 1752: 2000, MSZ EN 15251:2008 [4, 5, 6]. Fanger developed his theory by collecting subjective heat sensory data from many individuals [7]. The so-called. Fanger diagrams are used to scale interiors, which can be used to ensure PMV = 0.

Materials and methods

The studies were conducted primarily in the resting areas of military camps, revealing changes in air quality under the load of the indoor environment.

Measurement in the real military camp

The comfort inspections are carried out in an operating, operated facility, with the internal air quality monitoring of the location areas of the Border Protection Bases (Figure 1) located at 4 locations on the southern border section of Hungary. The examined facility is a relocatable building complex that can accommodate a total of 150 people. The dimensions and advantages of the containers are in accordance with the ISO standard for 20 office containers. The construction is based on a stable frame structure and a removable panel system. The container transport system was designed and assembled based on the type design of Mobilbox Kft. [8]. As a base, the compacted crushed stone bed is leveled and supported using 3 concrete pavers at 6 points.

Figure 1. Military camp location building on the southern border of the country

The accommodation containers of the border protection camp are 30 cubic meters (2 m x 6 m x 2.5 m) each, which can provide for accommodate 4 people.

Measurement in the laboratory

Laboratory measurements were performed in the Hungarian University of Agriculture and Life Sciences, Building Engineering Laboratory area, modeling the military camp accommodation areas. The model set up by the laboratory is a container conforming to the ISO standard of the 10' containers, so its physical characteristics are exactly the same as those of military deployment containers in real locations.

Figure 2. Military camp model in the university laboratory

In the constructed model, the measurement of the indoor air condition and the parameters influencing it are performed. The change of CO_2 was measured in the indoor period in several periods, during the sleep period with 2 people and during the sitting work and at rest with 1, 2, and 3 people.

Instruments used for measurements

For the measurements, a Pyle PC02MT05 indoor air quality measuring device equipped with a digital carbon dioxide/air pollution sensor has been used. The device is a universal indoor air quality (IAQ) meter that records air carbon dioxide concentration, temperature, and humidity. Its gas measurement technology is performed with a non-dispersive infrared detector (NDIR), particle measurement is 2.5 μm particle size, CO_2 measurement range: 0 ~ 9999 ppm ±70 ppm. Temperature measuring range −10 ~ 70°C with an accuracy of ± 0.3°C. Humidity measurement range: 0 ~ 99.9% (relative humidity) with an accuracy of ± 3%. Device power supply: 110/220 V AC / DC 5 V USB wall adapter. To compare the recorded data, an ALMEMO 2590 type certified measuring instrument was used, which measures the internal temperature, air humidity, and CO_2 concentration, as well as the intensity of solar radiation.

To perform an authentic comparison of the parameters recorded by the instruments, a 24-hour calibration measurement was performed. When evaluating the results, it was shown that the recorded data run side by side. Applying the least squares principle, it can be shown that the PYLE instrument responds more slowly to dynamic change, its oscillations are damped, but when adjusting to the new values recorded as a result of the change, the differences fall below the 3% error limit in a short time (> 1 minute). By evaluating the calibration measurements, it can be determined that the data recorded by the PYLE measuring instrument is registered with a constant absolute error, so to eliminate this, by adding ΔYi = 200 ppm, we get the same result as the data recorded by the certified ALMEMO measuring instrument.

Results and discussion

To verify the expected value of CO_2 concentration by calculation - using the basics of the computer simulation program presented by Herczeg et al. To determine the amount of fresh air required [9] – we performed a mathematical model simulating the polluting sources of different measurement:
V_h – flow volume in the room,
k – concentration,
V_{sz} – ventilation air volume flow,

$$\dot{K} \cdot d\tau + \dot{V}_{sz} \cdot k_k \cdot d\tau - \dot{V}_{sz} \cdot k \cdot d\tau = V_h \cdot dk_b \quad (1)$$

1. part: amount from a pollutant source, 24 l/h for 2 persons, 36 l/h for 3 persons;
2. part: the amount of pollutants entering the room with the outside fresh air, calculated with a minimum (~ 1 m^3/h) filtration;
3. part: a the amount of pollutant leaving the room;
4. part: change in pollutants in indoor air.

$$k_b = k_k + \frac{\dot{K}}{V_{sz}} \cdot (1 - e^{-n\tau}) \quad (2)$$

if $\tau \rightarrow \infty$, then concentration in the interior:

$$k_b = k_k + \frac{\dot{K}}{V_{sz}} \quad (3)$$

The series of laboratory measurements show the results of static measurements of the carbon dioxide concentration in the loaded and unloaded container (Figure 3).

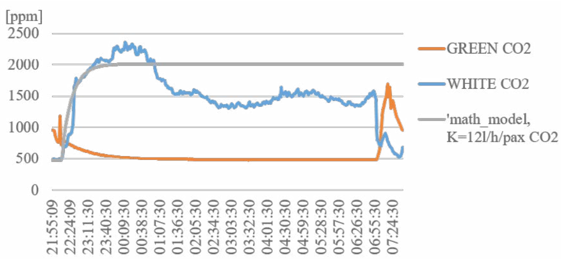

Figure 3. Container indoor air quality change in carbon dioxide concentration

From the static measurements it can be shown that if the internal point source used in the experiment is not located, the carbon dioxide concentration of the indoor air quality in the container assumes a value of around 490 ppm.

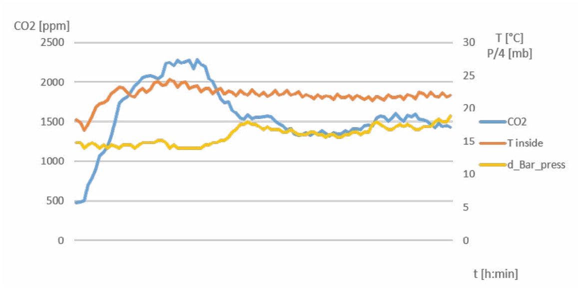

Figure 4. Changes in the internal air quality of a container loaded with two persons

In further studies, a change in the internal comfort space shall be observed under dynamic loading by placing an internal point source. To observe the expected result, we successfully performed a dynamic load test in the white container with 2 persons sleeping (Figure 4).

It is clear from the measured values that the carbon dioxide concentration initially rises rapidly to reach 2000 ppm and then slowly approaches 2500 ppm CO_2. The factor influencing the study was that a storm occurred at 1:00 in the morning, as a result of which the natural filtration increased due to the pressure of the stormy wind, therefore the concentration of CO_2 in the container decreased.

During the measurements at the military base (Figure 5), the training task divided the observation period into a short rest period.

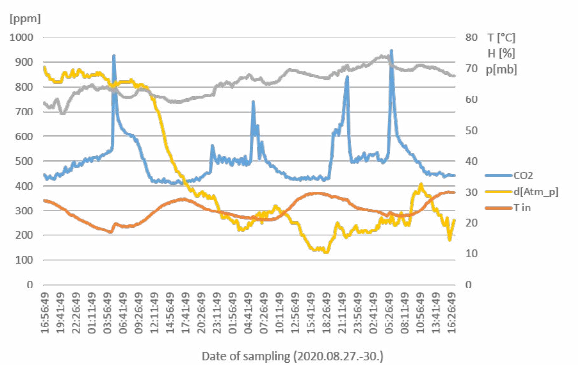

Figure 5. Carbon dioxide concentration change with load by 3 persons

The intensity of the change in indoor air quality temperature, humidity, and carbon dioxide concentration was observed with the measurements. The primary objective was to observe the change in CO_2, the change in which parameter is influenced by the supply of fresh air to the room in addition to the internal point source. To evaluate the intensity of the change, the changes in the temperature and humidity values of the indoor air quality and the intensity of the change are indicative data for the determination of the growth and decrease index of the room filtration.

The short rise time of the increase in the CO_2 content of the indoor air quality and with the external and internal parameters influencing the situation at rest were continued the observing (Figure 6).

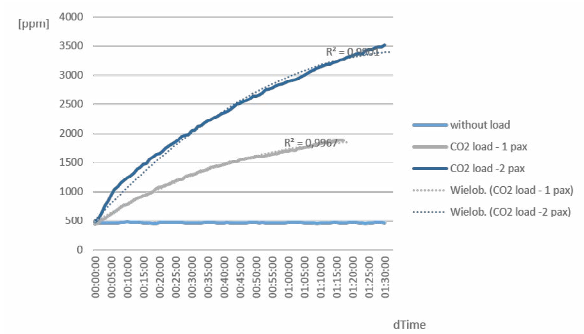

Figure 6. Increase in CO_2 concentration in the rest room

Our laboratory experiments have shown, respectively, that in a normal ISO 10' container, one and half an hour from the onset of load, one person develops a near 2000 ppm CO_2 concentration, two persons more than 3500 ppm.

Returning to our graph in Figure 3, we can see that the calculated value, similarly quickly reached the concentration of 2000 ppm at the measured value, the measured value also rose above this. However, around 1:00 a.m. the measured value dropped to almost half, so that there was really no change in the parameters that had an effect on the interior. The door and window were not opened and there was no change in the internal contaminant point source. It was presumed that the subsequent decrease in CO_2 concentration from 2500 ppm (> 2300 ppm) to 1500 ppm (~1300 pm) would not be negligible, especially in view of the fact that the external concentration (K_k) is close to 500 ppm, so the change in internal concentration is ~ ↑ + 1800 ppm, then ~ ↓ −1,000 ppm. An investigation was launched to find out the cause of this change.

By physically modeling the CO_2 emissions, setting a constant load, we performed several days of continuous measurements, where we can measure the values of temperature (inside and outside), humidity, wind and solar radiation together.

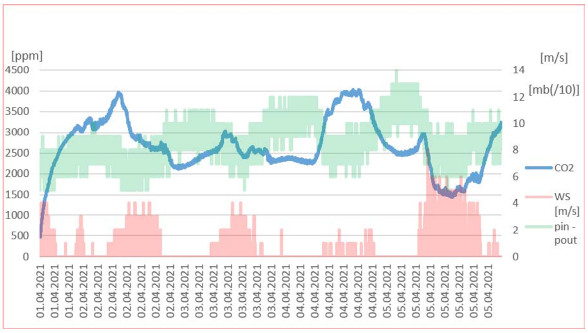

Figure 7. Change in the CO_2 content of the indoor air

In addition to the constant CO_2 point emission, the multi-day measurement series (Figure 7) shows even greater fluctuations, with values between 4000 and 1500 ppm. The value of the difference between the internal pressure and the external pressure [pin – pout] takes a minimum value, then the CO_2 concentration starts to decrease and when the value of the difference between the internal pressure and the external pressure [pin – pout] reaches a maximum value, CO_2 concentration increases (Figure 8a).

This change can also be illustrated by the value of the difference between the internal temperature and the outdoor temperature [Tin – Tout], and what we expected is plotted well on the graph: opposite values are formed by the values of the characteristics on the graph (Figure 8b).

However, the value of wind pressure cannot be neglected, which directly interferes with the change in our measurement data. If the observed wind pressure affects the filtration of the structure – which, according to our measurements, is already relevant above the wind speed of 2 m/s in the measured values – then, according to the experiments, the wind speed data must be taken into account when selecting sites (Figure 8c).

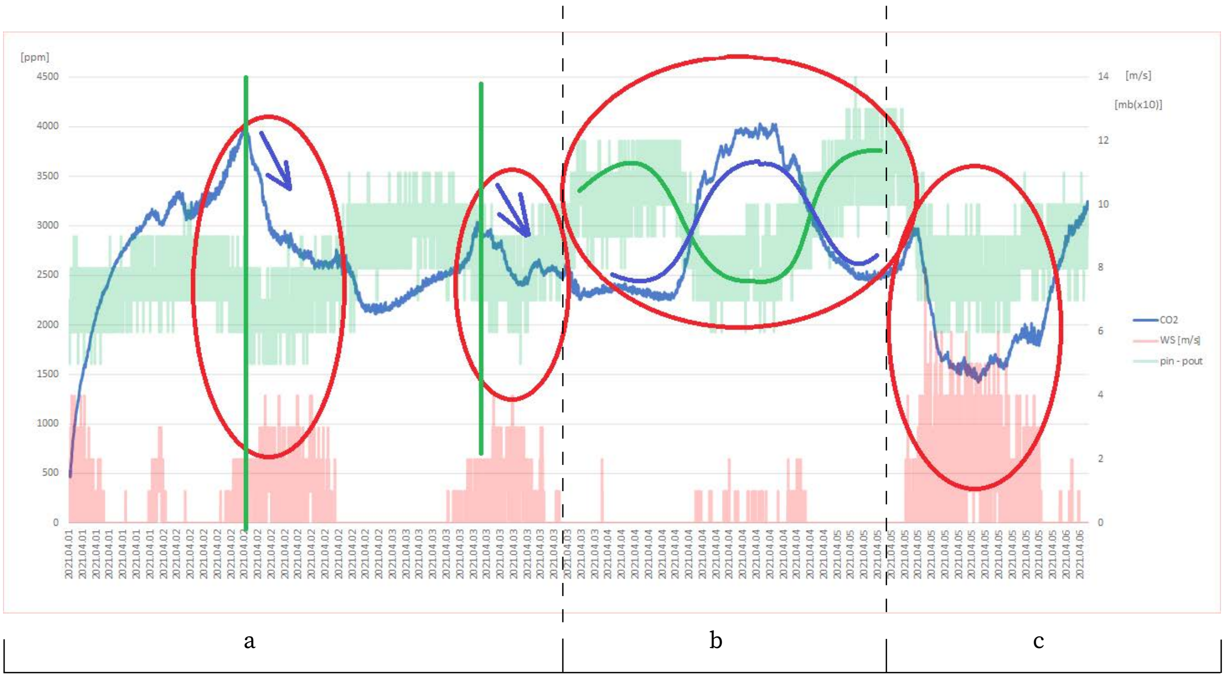

Figure 8. Remark/highlighting [a, b, c] of figure 7

Conclusions

1. It was observed by measurements that the 4-person resting areas of military container camps – where the internal air volume is 30 m^3 – relatively quickly reach the maximum value, which is allowed according to the standard described in the introduction, 5000 ppm CO_2 concentration.
2. Based on the above observation, a new calculation method needs to be defined to determine the indoor air quality pollution concentration, specifically for (military) standard container buildings, which should take into account the outdoor / indoor temperature difference and wind speed.

3. The measurements were performed with special attention to the planning of a camp construction required for a military operation, as well as to the pre-deportation military reconnaissance data – military geographic data, military meteorological data – based on the need for fresh air supply in the camp districts a factor reducing concentration – necessary for the planning and implementation of keeping it to a minimum level.
4. Extending the observations, with the support of the Hungarian Ministry of Innovation and Technology, this year we will start measuring the indoor air condition of the camp kitchen as written in the abstract of the article, specifically on the effects of fruit and vegetable storage. The mathematical model based on our observations can simulate the indoor air quality of a vegetable / fruit storage warehouse in a planned military camp, based on which the design requirements can be specified, taking into account compliance with occupational safety regulations and increasing the optimal storage time of raw materials.

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