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THE SPECIAL RELATIONSHIP BETWEEN ACOUSTIC, VIBRATION AND HUMAN RESPIRATION

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Abstract: *Wearing surgical face masks is among the measures taken to mitigate the transmission of the coronavirus disease (COVID-19) and reduce deaths. Respiratory aerosols are the main route of virus transmission and the widespread use of face masks decreases the ability to spread SARS-CoV-2 by minimizing the inhalation of respiratory droplets from asymptomatic infected individuals or from people who have not yet shown symptoms while preventing the elimination of respiratory particles by the contaminated persons. With help of the laser photoacoustic spectroscopy technique, in this preliminary research, the ethylene as a byproduct of oxidative stress from the human respiration were measured before and after wearing surgical face masks. Our study demonstrates a non-significant increase in the ethylene concentrations among volunteers while donning surgical mask for one hour.*

Keywords: *acoustic, vibration, sound, respiration, spectroscopy.*

INTRODUCTION

Are surgical masks free of possible harmful effects on the human body? Practically, wearing the mask several hours a day, in the long term, causes a pathological adaptation of the breathing physiology, expanding the dead respiratory space (nose, throat, trachea, bronchi), which, along with the retention of carbon dioxide, causes changes significant changes in blood

gases, leading to hypercapnia and hypoxia [1-3]. Thus, mask wearers are forced to re-inhale the carbon dioxide accumulated in the volume of the respiratory dead space, intensifying the respiratory activity, which results in a greater need for oxygen.
Guidelines for wearing masks have varied from country to country, and some health organizations, including the World Health Organization, have changed their advice over time [2,3].
A study by Otmar Geiss [4] in 2020 reported carbon dioxide concentrations ranging from 2150 to 2875 parts per million (ppm) and no differences were seen between the types of face masks tested. According to the specialized literature, these concentrations do not have a toxicological effect, but nevertheless, concentrations in the detected range can cause unwanted symptoms, such as fatigue, headaches and loss of concentration. Another study by Dattel et al., 2020 [5] explored the effects of face masks on carbon dioxide, heart rate, respiratory rate, and oxygen saturation for instructor pilots. The study presented results with relatively high concentrations of carbon dioxide (around 45,000 ppm) detected.
In all these studies found in the literature [1-5], ethylene from the human respiration of participants that wearing surgical face masks was not among the investigated parameters. The originality of this preliminary research is given by the assessment of ethylene from the healthy participant’s respiration after wearing a surgical mask using a modified version of the photoacoustic spectroscopy gas detection system.

1.TECHNICAL REQUIREMENTS

The preliminary research evaluates the ethylene gases founded in the human respiration before and after wearing surgical face mask using the CO_2 laser photoacoustic spectroscopy method with respect to the CO_2 laser frequencies [6-9].
We used a specially designed bags to collect a clean breath air sample with "alveolar" breath which comes from the lungs, where gaseous exchange between the blood and breath air takes place. For the identification of ethylene presence as a byproduct of oxidative stress, the volunteer’s respiration samples were collected in 0.75-L bags coated with aluminum and designed to accumulate and keep the human respiration [7-9]. In Figure 1, the volunteer positioned the piece in their mouth and naturally exhales through the mouth in the breathing sampling kit. When a proper respiration is collected, the participant stops the natural exhalation. The bag with the collected breath is delivered to the laboratory and transferred into the resonant measuring cell where we can detect the traces of gases by a gas flow controller.
The photoacoustic spectroscopy gas detection arrangement consists of a CO_2 laser, a lens, a chopper, a photoacoustic resonant cell, a powermeter, a lock-in amplifier, an acquisition panel, and a data-processing computer. The experimental detection system also includes a gas handling system with an essential role in the control of the studied gases, but it can also perform other actions described in detail in other articles [9-11]. Photoacoustic cell is an indispensable module in photoacoustic spectroscopy gas detection

technology, because the whole photoacoustic effect occurs in the photoacoustic cell.

Figure 1. The collection of a human respiration.

The photoacoustic spectroscopy gas detection used for the evaluation of the ethylene is summarized in Figure 2 and described in detailed in [6-12].

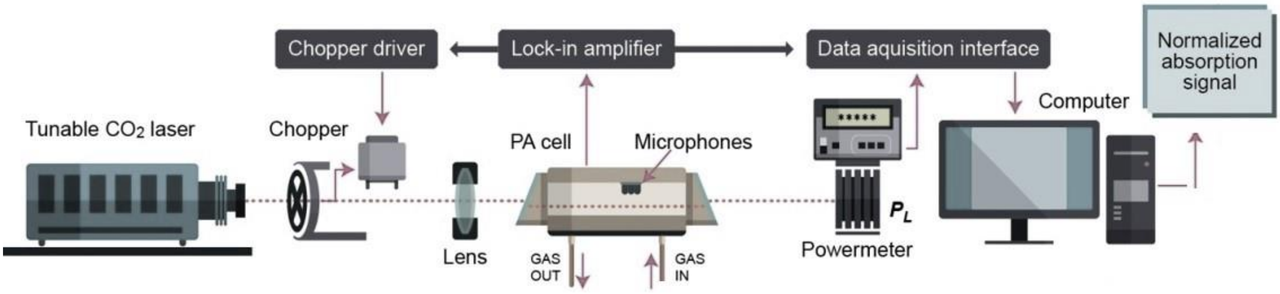


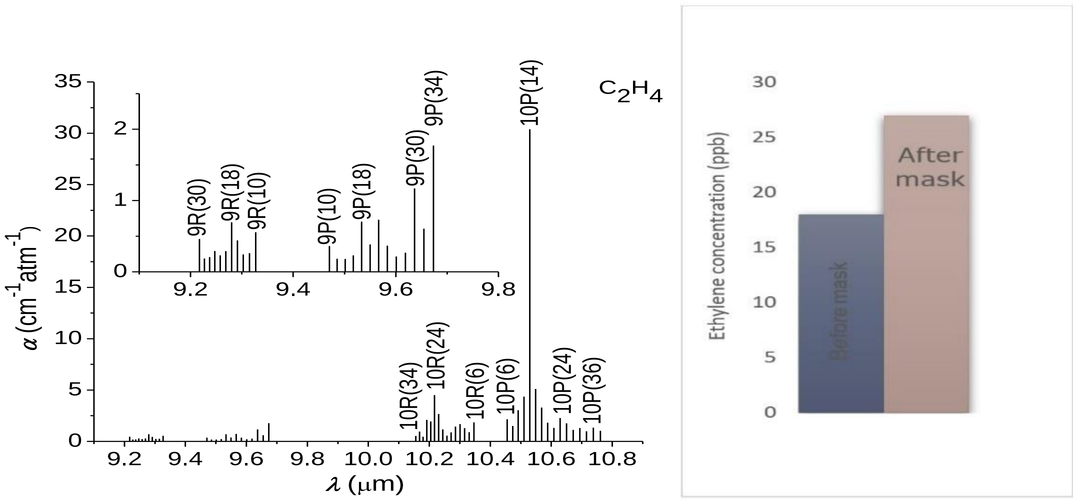
Figure 2. Spectroscopic set-up used for the evaluation of ethylene from the respiration of people wearing surgical mask.

In the experiments, the sample is enclosed in a resonant cell, where the acoustic waves are detected by four Knowles electret EK-3033 miniature microphones connected in series and mounted flush with the wall. Each microphone has a sensitivity of 20 mV/Pa and a total sensitivity of 80 mV/Pa. They are positioned at the loops of the standing wave pattern, at an angle of 90° to one another. The microphones are fixed to the resonator by holes with a 1 mm diameter, positioned on the central perimeter of the resonator. The battery-powered microphones are mounted in a Teflon ring pulled over the resonator tube. The signal is fed into a lock-in amplifier that provides the amplitude and phase of the photoacoustic signal. The value of the acoustic signal determined by microphones and normalized to the size of the CO_2 laser radiation power is comparable to the molecular absorption coefficient of the analyzed gas sample at a CO_2– used laser radiation wavelength. The microphones turn the acoustic signal into an electrical signal that is detected by a lock-in amplifier with a role in setting the chopper frequency and providing the photoacoustic signal. After passage through the stainless steel and Teflon cylindrical cell, the power of the laser beam is measured by a laser radiometer. Its digital output is introduced in the data acquisition interface module together with the output from the lock-in amplifier. The signals are gathers by an acquisition card and the data are recorded by a computer interface. The number of the absorbing molecules from the cylindrical cell is proportional with the amplitude of the photoacoustic signal. All experimental data are processed and stored by a computer. The frequency stabilized, line tunable CO_2 laser emits in the 9.2 –

10.8 µm range, where a large number of gas molecules possess a high absorption coefficient. Considering that the number of the absorbing molecules is proportional to the amplitude of the signal, ethylene emission was established in the case of healthy volunteers with age between 31-41 years.

A chemical compound that retains laser radiation is stimulated to a higher quantum condition causing a reduction in laser light intensity, which can be directly quantified via absorption spectroscopy [6-12]. The absorption characteristics distinctive to each chemical compound make it feasible to detect trace gases and establish their accumulations. To improve the quantification of ethylene absorption coefficients, an adjusted process was adopted: it is imperative to calibrate the resonant cell with a well-known gas compound and to establish the linearity of the detector with the concentration of the known gas over orders of magnitude. The linear responses of the cavity for low detection limit of ethylene in literature are reported [9-12]. For the ethylene absorption coefficients determination (see figure 3a) at laser lines, we used a commercially prepared, certified mixture containing 0.96 ppm ethylene in pure nitrogen certified and supplied by Linde Gas.

Figure 3b presents the concentration of ethylene from human respiration before and after one hour of wearing surgical face masks using photoacoustic spectroscopy gas detection technology.



a) **b)**

Figure 3 a) Absorption coefficients of ethylene at CO_2 laser wavelengths. **b)** ethylene from the respiration of people wearing surgical mask.

When analyzing figure 3b, the ethylene concentrations before the wearing of a surgical face mask presented a corresponding concentration of 18 ppb. In the case of ethylene from the human respiration after one hour wearing the surgical face mask, we registered an increase of the photoacoustic signal with an equivalent concentration of about 27 ppb.

2.CONCLUSIONS

The originality of our research is given by the assessment of ethylene from the volunteer's respiration after wearing a surgical mask using a modified photoacoustic gas detection system. Facemasks are essential components of personal protective equipment for health care workers in hospitals and public civilians alike. Notably, masks are helpful in preventing illness in healthy persons and preventing asymptomatic transmission, especially in a global pandemic. Although their use is now mandatory in many states because of the COVID-19, they were generally used in hospitals and operating rooms even before the current pandemic. Although the results show that gases concentrations from the participants respiration increases after wearing the surgical mask for an hour, they remains below short-term National Institute for Occupational Safety and Health limits.

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