Usage of "Heat Transfer" and "Mass Loss" within Mask Quality Control Tests

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The COVID-19 pandemic caused by the SARS-CoV-2 virus has caused the death of approximately 2.5 million people, and the number of cases continues to increase day by day at the global level. As it is known, the spread of the virus can be prevented by the protection of social distance, with hand hygiene and with the use of masks. Some masks are sold in the marketplace without undergoing certain tests. In this research, it is aimed not to use products that are not suitable for breathing and other than their intended usage. Based on the literature review, no study was found examining heat transfer and mass loss parameters, and therefore, in this study, alternative tests that require less money and time were presented in addition to the existing mask efficiency tests. As a result of the experiments, consistent results were obtained and it has been seen that professional and medical masks are the least suitable type for breathing. For this reason, the importance of heat transfer and mass loss parameters that we tested has been proven.

Introduction

It has been observed in the reviewed literature that the methods used in standardized breathability tests require advanced technology and therefore a serious budget (approximately 70,000 ₺). During the time we wear the mask; the temperature of the environment between the mask and the mouth different than the outside environment, depending on our body temperature, our breathing, and the increase in carbon monoxide in the environment. For this reason, the amount and speed of heat transfer should be examined as the cause of difficulty in breathing through masks. In addition, while exhaling, some gas particles will pass from inside the mask to the outside. Accordingly, mass transfer should be observed. It has been hypothesized that the rate of heat transfer and mass loss is directly proportional to the breathing provided by the mask.

Project Goal

It is aimed to examine the permeability and thus the breathability of the masks used in the COVID-19 process, depending on heat transfer and mass loss that have not yet been standardized.

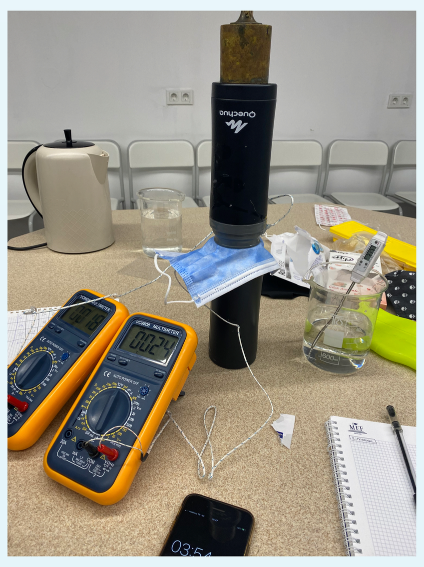
Methodology

In our project, Ohm's Law is modeled with Fourier's Law. In Ohm's Law, current (I) represents heat transfer, while potential difference (V) represents temperature difference. The resistance (R) in Ohm's Law models the resistance that the mask exerts on gas particles.

$$q = -kA\frac{dT}{dx} \qquad R = \frac{V}{I}$$

Experiment 1 (Heat Transfer Experiment)

Since there will be heat exchange between the experimental system and the environment, two identical insulator flasks were used as the system. In order to measure the temperature of both flasks, microholes were drilled with a column drill and thermocouples were passed through these holes. After the water at 35°C was placed in the lower (partially hot) flask and covered with a mask, the temperatures of both the upper and lower flasks were measured over time. The assumption is that the more permeable the mask, the faster the flask temperatures will change.



Experiment 2 (Blown Heat Transfer Experiment)

The bottom of one of the flask was drilled with a column drill. Since two identical conductive (aluminum) flasks were used in the experiment, the flasks were surrounded with bubble nylon, an insulating material, in order to minimize heat exchange with the air. The system was heated with a hair dryer. The assumption is that the greater the temperature difference between the two flasks after 6 minutes, the less suitable the mask for breathing.

Experiment 3 (Mass Loss Experiment)

The experiment was carried out at the Istanbul Technical University Physics Laboratory at a room temperature of 21°C. First, the water in the beaker was brought to 21°C. A hole exactly the size of the thermometer tip was drilled through the mask and the temperature was measured at the beginning of every minute through this hole. The mass of water was then measured per minute for each mask until the 6th minute. Thus, at the end of each minute, the mask that loses the most mass will be the most permeable.

Results

mask	representation
surgical mask 1	A
surgical mask 2	B
surgical mask 3	C
respiratory mask	D
fabric mask 1	E
fabric mask 2	F

Experiment 1 (Heat Transfer Experiment)

The mask that provides the slowest achievement of the predetermined temperature difference (T=4) is the mask that resists the substance the most and therefore the least breathable when put on. Based on this hypothesis, the resistance (Ω) comparison of the masks is as follows:

$$\Omega_D > \Omega_A > \Omega_C > \Omega_B > \Omega_E > \Omega_F$$

Experiment 2 (Blown Heat Transfer Experiment)

The mask where the temperature difference is high is the mask that applies the most resistance and is the least permeable. Based on this hypothesis, the resistance (Ω) comparison of the masks is as follows:

$$\Omega_D > \Omega_C > \Omega_A > \Omega_B > \Omega_E > \Omega_F$$

Experiment 3 (Mass Loss Experiment)

The mask with the lowest temperature difference is the mask that has the most resistance and is the least breathable when worn. Based on this hypothesis, the resistance (Ω) comparison of the masks is as follows:

$$\Omega_D > \Omega_A > \Omega_C > \Omega_B > \Omega_E$$

Conclusion

- As seen in the values obtained, the breathability of the mask is not only dependent on the passage of certain gases, but also directly proportional to the heat transfer and mass loss.
- As a result of the three experiments, it was seen that mask D was the least permeable and least suitable for breathing, while masks E and F were proven to be the most permeable and the most easily breathable.
- Despite existing methods, heat transfer and mass loss tests have proven to be useful methods with minimal budget and time.
- The international quality standard results (FFP, CE, TS-EN) of the marks used as exemples in our experiments and our findings show parallelism.

Suggestions

- Heat transfer and mass loss tests, which are practical compared to standard mask control tests, can be added to the existing breathability tests in order to reduce cost and time loss.
- In the following steps of research, the experimental setup can be compacted using more advanced methods.
- The permeability of masks can also be tester microbiologically.
- In the blown heat transfer experiment, our experiment can be strengthened by measuring the velocity differences of the gases in the two environments.
- By developing the project, it can be researched which mask is more efficient for people with asthma and similar diseases.

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