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# Determination of Indoor Air Quality in University Student Canteens

Gülgün DEDE[1], Cemile DEDE*[2]

Abstract

The negative effects of indoor air quality cause a decrease in the working efficiency of people, and health problems. For this reason, monitoring the indoor air quality of the places where students spend time such as canteen, cafeteria and library is important in terms of quality of life. Particulate matter is the leading source of pollutants affecting indoor air quality. For this purpose, the indoor air quality of student canteens in a public university located in Marmara Region, Turkey was examined in terms of temperature, relative humidity, person density, area, particulate matter ($PM_{2.5}$ and $PM_{10}$) parameters. The relative humidity in canteens was found to be within normal range in terms of comfort conditions, and the temperature was slightly higher depending on seasonal conditions and canteen conditions. According to the results of Spearman's correlation analysis applied, a statistically significant negative correlation between temperature and $PM_{2.5}$ (r=-0.449) and $PM_{10}$ ( r=-0.339) measurements, a positive correlation between humidity and $PM_{2.5}$ (r=0.974) and $PM_{10}$ (r=0.440) measurements, and a positive correlation between the number of people and $PM_{2.5}$ (r=0.320) measurements ($p<0.05$), a positive correlation between $PM_{2.5}$ (r=0.454) and $PM_{10}$ were detected ($p<0.01$). It was determined that World Health Organization (WHO) limit values and air pollution regulation limit values were exceeded in canteens except E3 and A1 canteens. Due to the insufficient ventilation of the canteens, it was determined that particulate matter may pose a risk to the students and the employees of the canteen, and recommendations were made to improve the indoor air quality.

**Keywords:** Indoor air quality, $PM_{2.5}$, $PM_{10}$, temperature, relative humidity, canteen

## 1. INTRODUCTION

The air quality within and around buildings and structures, particularly relating the building occupants' health and comfort, is considered as Indoor Air Quality (IAQ) [1]. It has been stated that low IAQ may cause building-related diseases and adversely affect human health. Nowadays, people spend most of their time in indoor environments where there are crowded communities such as houses, workplaces, schools, indoor shopping centers and canteens [2]. However, according to the U.S. Environmental Protection Agency (EPA) pollutants levels in indoor air may be two to five times and sometimes even more than 100 times

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higher than outdoor air levels [3]. Therefore, IAQ has a significant impact on health. The adverse health effects of indoor air pollutants may be occur immediately after exposure or may show up years later [1]. Both short-term and long-term exposure to IAP can cause a wide variety of diseases. Short-term effects include eye, nose and throat irritation, headache, dizziness and fatigue. Other health effects may occur years after exposure has occurred or only after prolonged or repeated exposure periods. These effects, which include some respiratory diseases, heart disease and cancer, can be fatal [4].

IAQ can be affected by many sources of pollution such as outdoor air, building materials, furniture materials, fuels used in activities such as heating, lighting or cooking, pollutants arising from user activities like cleaning, smoking [5-8]. Some of the indoor air pollutants which are known their hazardousness to health are benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, polycyclic aromatic hydrocarbons, radon, trichloroethylene and tetrachloroethylene [9]. In terms of health, one of the most important pollutants in indoor air is particulate matter (PM). The particulate matter, also known as PM or particle pollution, is a complex mixture of airborne solid and / or liquid particles. These particles may exist in different sizes, shapes and compositions [4,10]. $PM_{10}$ refers to particles less than or equal to 10 μm in diameter and $PM_{2.5}$ refers to fine inhalable particles with diameters that are generally 2.5 micrometers and smaller. Particles that are 10 micrometers in diameter or smaller are especially concern because they are inhalable. They can penetrate the upper regions of the body's respiratory defense mechanisms [11, 12]. In a study, it was predicted that the number of deaths attributable to $PM_{2.5}$ is 4.2 million between 1990 and 2015 and 20% increased for the same period [13]. According to World Health Organization (WHO), air quality limit values are 10 $\mu g/m^3$ (annual mean) and 25 $\mu g/m^3$ (24-hour mean) for $PM_{2.5}$. For $PM_{10}$, the specified limit values are 20 $\mu g/m^3$ (annual mean) and 50 $\mu g/m^3$ (24-hour mean) (Table 1) [14]. The limit values stated in the Air Quality Assessment and Management Regulation (2008) in our country is 50 $\mu g/m^3$ (24-hour mean) for $PM_{10}$ (Table 1) [15].

Limit values recommended in national and international standards on indoor air quality are shown in Table 1 [4, 9, 11, 15, 16, 17].

Table 1. Limit values recommended in national and international standards on indoor air quality

| | |
|---|---|
| Turkey | $PM_{10}$ <40 $\mu g/m^3$ (annual mean)<br>$PM_{10}$ <50 $\mu g/m^3$ (24-hour mean) |
| Canada | $PM_{2.5}$<40 $\mu g/m^3$ (8-hour mean)<br>$PM_{2.5}$<100 $\mu g/m^3$ (1-hour mean) |
| China | $PM_{10}$<150 $\mu g/m^3$ (24-hour mean) |
| WHO (World Health Organization) | $PM_{10}$<20 $\mu g/m^3$ (annual mean)<br>$PM_{10}$<50 $\mu g/m^3$ (24-hour mean)<br>$PM_{2.5}$<10 $\mu g/m^3$ (annual mean)<br>$PM_{2.5}$<25 $\mu g/m^3$ (24-hour mean) |
| EPA (Environmental Protection Agency) | $PM_{10}$<150 $\mu g/m^3$ (24-hour mean)<br>$PM_{2.5}$<12 $\mu g/m^3$ (annual mean)<br>$PM_{2.5}$<35 $\mu g/m^3$ (24-hour mean) |
| England | $PM_{10}$<50 $\mu g/m^3$ |
| Norway | $PM_{2.5}$<20 $\mu g/m^3$ |
| EU (European Union) | $PM_{10}$<40 $\mu g/m^3$ (annual mean)<br>$PM_{10}$<50 $\mu g/m^3$ (24-hour mean)<br>$PM_{2.5}$<25 $\mu g/m^3$ (annual mean) |
| Hong-Kong | $PM_{10}$<20 $\mu g/m^3$ (Level 1)<br>$PM_{10}$<180 $\mu g/m^3$ (Level 2)<br>(8-hour mean) |
| Belgium | $PM_{2.5}$<15 $\mu g/m^3$ (24-hour mean)<br>$PM_{10}$<40 $\mu g/m^3$ (annual mean) |
| Korea | $PM_{10}$<100 $\mu g/m^3$ (24-hour mean)<br>$PM_{10}$<100 $\mu g/m^3$ (8-hour mean) |
| Portugal | $PM_{2.5}$<25 $\mu g/m^3$ (24-hour mean)<br>$PM_{10}$<50 $\mu g/m^3$ (annual mean) |

Among the indoor environments canteens are especially important places for students because they may spend long times and be influenced from IAQ inside them. Investigating the inhalable particle concentrations inside them is great significance for human health [18]. The importance of this has been emphasized in many studies in the literature. Slezakova et al. (2019), assessed UFP levels in different indoor school microenvironments including classrooms, canteens, gyms, libraries. They conducted real-time Ultra Fine Particles (UFP) measurements in 20 public primary schools located in Oporto city which is the 2nd largest city in Portugal. Their results showed that canteens were the microenvironment with the highest UFP levels among the investigated indoor school microenvironments [19]. Zhang et al. (2017), measured cooking particle concentrations at university canteens having enclosed and open style cooking units. Their results revealed the cooking style at canteens have significant role in the particle concentrations. They determined that $PM_{10}$ mass concentration in the open-style cafeteria can reach to 450 μg/m$^3$ and exceeds maximum allowable concentrations. The researchers recommended the improving ventilation in canteens with open-style dining hall to reduce the detrimental effects of particulate matter on human health [18].

The aim of this study is to determine the indoor air quality in student canteens, especially in terms of particulate matter. Another purpose of this study is to help raise public awareness of the need to provide a better IAQ in student's canteens.

## 2. MATERIALS AND METHODS

The study was carried out in a total of 9 student canteen in a public university located in Marmara Region, Turkey. The locations and the areas of the canteens were shown in Table 2. The ventilation of the canteens is provided by mechanical ventilation system and the heating and cooling systems are similar. The hardware features of the canteens are as follows; double-glazed windows, floor tiles, interior doors, tables and chairs are standard, walls are standard plastic paint. In addition, the materials of the canteens are standard (oven, rotary cooking stove, tea stove, etc.). The buildings are outside the city and the traffic density is negligible. The measurements were made in spring semester in April, 2019. In each of the selected canteens, measurements were made in the time interval of 10:00 AM and 19:00 PM for one day. Measurements were carried out regularly for nine consecutive days.

As the IAQ parameters, temperature, relative humidity, $PM_{10}$ and $PM_{2.5}$ values were measured simultaneously and meanwhile, the areas of the examined canteens, and the people densities during the measurements were determined. The Particle Measuring Device PCE-MPC 10 was used to determine particulate matter ($PM_{10}$ and $PM_{2.5}$) level, temperature and relative humidity. Temperature and relative humidity were measured at the time of the sampling and the number of people in the cafeteria during the air sampling was counted. The study was carried out by measuring the average 10 hours of $PM_{2.5}$ and $PM_{10}$. Measurements were carried out at each hour during the day between 10:00 AM-19:00 PM and 1.5 meters above the ground (the height at which the air is inhaled).

Table 2. Locations and the areas of the canteens

| Location | | Area (m$^2$) |
|---|---|---|
| Faculty of Engineering | E1 | 75 |
| | E2 | 30 |
| | E3 | 30 |
| Faculty of Arts and Sciences | A1 | 70 |
| | A2 | 180 |
| Faculty of Theology | T1 | 200 |
| Faculty of Health Sciences | H1 | 90 |
| Business School | B1 | 110 |
| Central cafeteria | C1 | 5075 |

The results were statistically analyzed by spearman correlation analysis (Table 3).

## 3. RESULTS AND DISCUSSION

**Temperature** It is reported that the ideal temperature for indoors can vary between 15-26 ºC. Although the indoor air temperature is chosen according to the outdoor temperature in summer conditions, the indoor temperature in winter is determined according to the purpose and type of use of the environment. Indoor temperature affects air movement/velocity and clothing selection. It is also a factor that affects distraction and work efficiency. Temperature and humidity form an inseparable relationship. In general, more moisture is retained in the air at lower temperatures and constant barometric pressure. Below these "dew point" temperatures, water can condense on cold surfaces inside a room or building. This can contribute to the collection and accumulation of airborne dust and debris containing fungal spores on wet surfaces, followed by mold growth [16, 20, 21].

Measurements regarding indoor air quality were taken during working hours on certain days in April. Temperature (°C) distribution in canteens were shown in Figure 1. According to the obtained values, it was observed that the indoor temperature ranged between 19.3 °C and 34.2 °C (Fig. 1). In the morning (10:00-11:00), the temperature values determined between 19.3 °C - 25 °C (Fig. 1). The detected values are low and this can be attributed to the coolness of the morning weather and the lack of indoor people due to the class hours. At noon (12:00-14:00) there was a significant rise in temperatures thanks to warming of the air and sunlight. In addition, the frequent use of open style cooking units for crowded and food orders created by the students on lunch breaks in canteens is the main reason for this temperature increase. The highest values were determined during this time period (20.2 °C-34.2 °C) (Fig. 1).

In the afternoon (15:00-19:00) the loss of the sun caused significant reductions in outdoor temperature, and in addition, the density of people in the canteens was reduced due to the fact that the formal education students had finished their classes and left the campus area. In the afternoon (15:00-19:00), the indoor temperatures in the canteens were determined between 20.3 °C and 30.9 °C (Fig. 1). This decrease in temperature can be attributed to the fact that the students of night education are very few and they do not prefer canteens to spend time.

According to the results of the Spearman's correlation analysis applied, a statistically significant negative correlation was found between temperature and $PM_{2.5}$($r=-0.449$) and $PM_{10}$ ( $r=-0.339$) ($p<0,05$) (Table 3).

Tablo 3. Results of Spearman's correlation analysis

| | | $PM_{2.5}$ | $PM_{10}$ |
|---|---|---|---|
| Temperature | r | -0,449 | -0,339 |
| | p | 0,000* | 0,001* |
| Humidity | r | 0,974 | 0,440 |
| | p | 0,000* | 0,000* |
| Number of people | r | 0,320 | 0,036 |
| | p | 0,002* | 0,736 |
| $PM_{2.5}$ | r | | 0,454** |
| | p | | 0,000 |

*:p<0,05, **: p<0,01

**Humidity** Relative humidity levels can affect the release rate of many indoor pollutants, their concentration in the air, and the growth of microbial organisms. Relative Humidity also has an impact on human comfort. Areas with 30-70% relative humidity are suitable for human comfort, productivity and health. In general, relative humidity levels below 30% cause drying of the skin, eyes and mucous membranes, while levels above 70% can contribute to mold growth and the growth of pathogenic and allergic organisms [16, 21].

When we examined the relative humidity content, it was observed that it generally varied between 34.8-61.5% (Fig. 2). In the morning (10:00-11:00), the humidity levels determined ranged from 38.1% to 61.5% (Fig. 2). At noon (12:00-14:00) it was found that the amount of moisture decreased and changed in the range of 34.8-53.2% (Fig. 2). In the afternoon (15:00-19:00), an increase in the amount of moisture was observed and it was found to vary between 35.9-55.1% (Fig. 2). According to the results of Spearman's correlation analysis, a statistically significant positive correlation was found between moisture and $PM_{2.5}$ ($r=0.974$) and $PM_{10}$ ($r=0.440$) ($p<0,05$) measurements (Table 3).

Similar to our study, Işık and Çibuk (2015), carried out measurements of parameters related to indoor air quality in a university canteen and cafeteria. As a result of the measurements made in the cafeteria and canteen, which are heated by the central heating system in the winter period, they have determined that the indoor temperature and relative humidity do not pose a significant problem since they are within the desired range in terms of comfort [16].Bulut (2011), investigated indoor air quality in public living spaces in his study. According to the results obtained, the relative humidity remained at low values in terms of comfort (average 36.2%, minimum 14.2%, maximum 68.6%). The low relative humidity is due to the fact that the region is a dry region and the humidification process is not performed in the ambient air conditioning. There is a statistically significant relationship between the number of people and $PM_1$, temperature, CO, $CO_2$ and relative humidity. In addition, a significant correlation was found between the relative humidity in the indoor environment and PM values [22].

Menteşe et al. (2018) investigated the potential to improve IAQ of a rotor turbine ventilator (RTV) installed outside the kitchen chimney of a cafeteria. After RTV setup, total TB (Number of airborne bacteria), PM, TVOC (Total volatile organic compounds) and $CO_2$ were clearly reduced, while ozone and CO levels did not change significantly during the study. In addition to examining the effectiveness of RTV, they found cross-correlations between air pollutants, temperature-relative humidity, and occupancy regardless of RTV setup. In addition, statistically significant correlations ($p<0.05$) were found for the number of people in the cafeteria and both $CO_2$ and TB levels throughout the study [23].

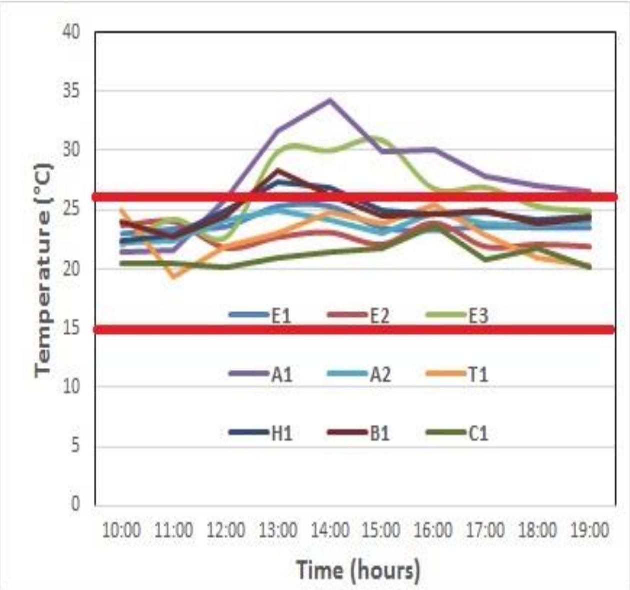


Figure 1. Temperature (°C) distribution in canteens

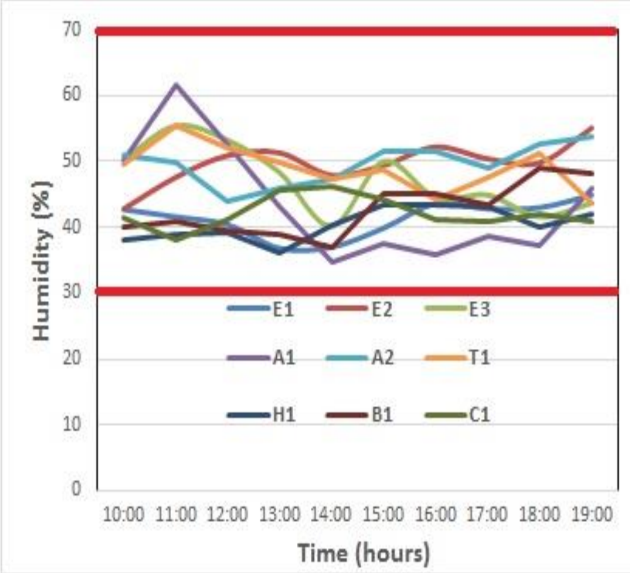


Figure 2. Humidity (%) distribution in canteens

**People density** When we look at the number of people in the canteens, there is generally a decrease in the morning hours (10:00-11:00) (5-50 people) (Fig. 3). This can be attributed to morning classes. However, with the arrival of the lunch hours (12:00-14:00), the number of people identified in the canteens increased (10-160 people) (Fig. 3). This is of course due to the fact that students eat lunch at the canteens. However, in the case of canteens E1, E3 and A1, this is exactly the opposite. The reason for this is the location of buildings with canteens. The fact that these buildings are close to the student refectory causes the students to eat their meals in the refectory. In the afternoon (15:00-19:00), it is seen that the number of students in the canteens has decreased (3-107 people) (Fig. 3). A positive correlation between the number of people and $PM_{2.5}$ ($r=0.320$) measurements was detected ($p<0.05$) (Table 3).

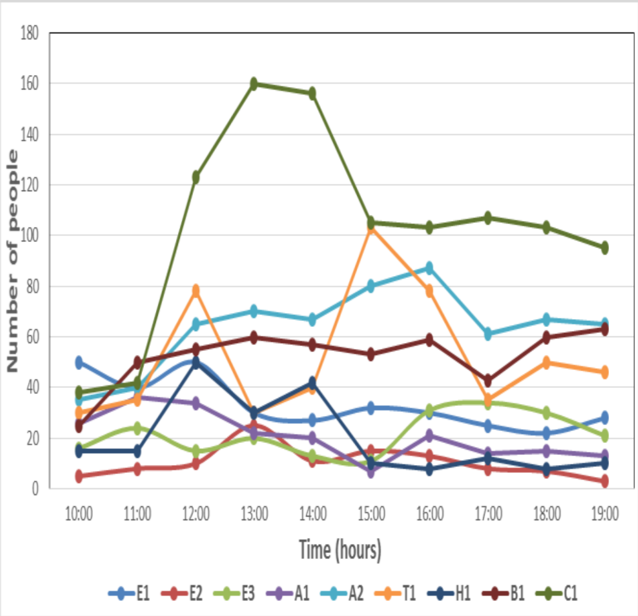


Figure 3. Hourly people density in canteens

**PM2.5** When the $PM_{2.5}$ measurement results were examined, it was found to be directly proportional to the number of people in the canteens. According to the results of Spearman correlation analysis, a statistically significant positive correlation was found between the number of people and the measurement of $PM_{2.5}$ ($r=0.320$) ($p<0.05$) (Table 3). $PM_{2.5}$ values generally varied between 3-130 μg/m$^3$ (Fig. 4). $PM_{2.5}$ values measured in the morning hours (10:00-11:00) were between 3-126 μg/m$^3$ (Fig. 4). This was especially the case during the morning when students bought toast and tea from the canteens. However, it should be noted that the concentrations of $PM_{2.5}$ detected in canteens are as effective as 1 hour after the concentration of the individual.

At noon (12:00-14:00), $PM_{2.5}$ level increased with the increase in the number of people (3-130 μg/m$^3$) (Fig. 4). This is an expected rise. However, in the afternoon (15:00-19:00), $PM_{2.5}$ values were also decreased due to the decrease in students, and they were measured in the range of 3-99 μg/m$^3$ (Fig. 4). When we examine Figure 4, hourly changes of $PM_{2.5}$ levels are similar for all canteens.

During the morning hours (10:00-11:00) $PM_{2.5}$ is at low levels. However, after 11:00, the students had to leave the classes and enter the lunch break and there were intensities in the canteens and therefore the $PM_{2.5}$ values increased. As of 14:00, a decrease was seen again, but this did not last longer at 15:00 with the arrival of night education students increased $PM_{2.5}$ values (Fig. 4). When the $PM_{2.5}$ values in all canteens were examined, it was found that the limit values (<25 μg / m$^3$) specified in the WHO regulation were exceeded except for the E3 and A1 canteens [14]. The 50 percentage of number of samples is higher than the standard of $PM_{2.5}$ in WHO regulation (<25 μg / m$^3$).

Zhu (2015) examined the relationship between indoor and outdoor particulate matter concentrations and suggested better measures to improve indoor air quality. Zhu determined that the concentration of particulate matter in campus underground spaces and canteens is quite high. Zhu even determined that the concentration of particulate matter in the external environment can reach two to three times. Therefore, researcher concluded that uncirculated air sometimes increases $PM_{2.5}$ concentration and cooking can be a new source of pollution to some extent [24].

Kumar and Jain measured PM in the student occupants area in India. Among the investigated areas canteen had the highest PM level. In their study, the average $PM_{2.5}$ concentration in canteen was 87 ± 26.45 μg/m$^3$ [25].

In our study a positive correlation between $PM_{2.5}$ ($r=0.454$) and $PM_{10}$ was detected ($p<0.01$). In a recent study carried by Liang et al., indoor air chemical contaminants including PM2,5 and PM10 were measured in public buildings in China. Liang et al., also determined a positive correlation between $PM_{2.5}$ and $PM_{10}$ in the canteen that investigated and Pearson correlation coefficient was 0.3. They detected that the $PM_{2.5}$ concentration in the canteen during the cooking periods before breakfast, lunch and dinner, reached extreme values with concentrations of 32.5 μg/m3,, 30.6 μg/m3, and 30.3 μg/m3, respectively [26].

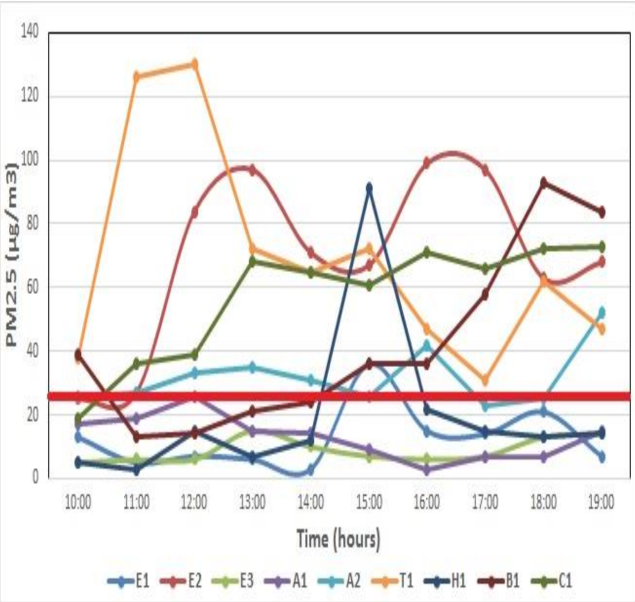


Figure 4. Hourly $PM_{2.5}$ ($\mu g/m^3$) concentrations in canteens

**$PM_{10}$** The result show that the average $PM_{10}$ concentrations of 10 hour are in the range of 8-253 $\mu g/m^3$ (Fig. 5). In the morning hours (10:00-11:00), $PM_{10}$ values were between 8-235 $\mu g/m^3$ range (Fig. 5). At noon (12:00-14:00), $PM_{10}$ values were determined in the range of 10-253 $\mu g/m^3$ (Fig. 5). In the afternoon (15:00-19:00), $PM_{10}$ levels in canteens decreased (11-177 $\mu g/m^3$) (Fig. 5). When the canteens where the measurements were made were examined, the highest (253 $\mu g/m^3$) $PM_{10}$ value was determined in the canteen of the faculty of theology at 12:00. When the $PM_{10}$ values in all canteens were examined, it was found that the limit values (<50 $\mu g$ / $m^3$) specified in the WHO and Air Quality Assessment and Management Regulation (2008) were exceeded except for the E3 and A1 canteens [14, 15]. The 42 percentage of number of samples is higher than the standard of $PM_{10}$ in WHO regulation (<50 $\mu g$ / $m^3$).

According to the results of Spearman's correlation analysis applied, a statistically significant negative correlation between temperature and $PM_{10}$ ( r=-0.339) measurements and a positive correlation between humidity and $PM_{10}$ (r=0.440) ($p<0.05$) measurements, and a positive correlation between $PM_{2.5}$ (r=0.454) and $PM_{10}$ was detected ($p<0.01$). The correlation between number of people and $PM_{10}$ was not statistically significant (Table 3).

Thongsanit et al. (2017), aimed to investigate the particle size of particles smaller than 10 microns ($PM_{10}$) in the canteens of a university and determined the 8-hour average $PM_{10}$ concentrations in the range of 49.0 to 294.1 $\mu g/m^3$. The results they obtained supported the results we found, and they stated that there may be many factors affecting the amount of $PM_{10}$ in canteens, including the number of people and their activities, and the cooking process is effective [27].

In the study performed by Liang et al. (2021) the $PM_{10}$ concentration in the canteen peaked to 59 $\mu g/m^3$ [26]. The average PM $_{2.5}$ concentration in canteen was 138 ± 34.19 $\mu g/m^3$ in the study caried by Kumar and Jain. [25].

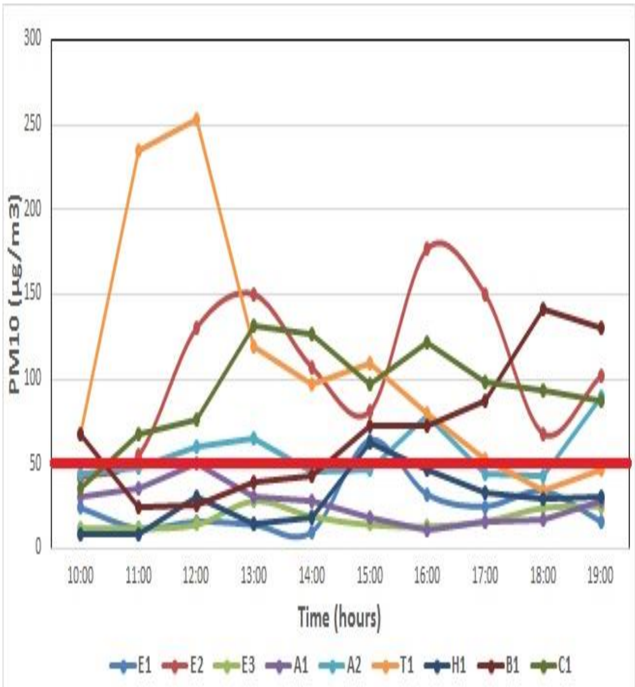


Figure 5. Hourly $PM_{10}$ ($\mu g/m^3$) concentrations in canteens

In our study, it is observed that particulate matter ($PM_{10}$ and $PM_{2.5}$) levels reach its highest value at 15:00 in canteens E1 and H1 (E1; $PM_{10}$: 64 $\mu g/m^3$; $PM_{2.5}$:36 $\mu g/m^3$) (H1; $PM_{10}$: 63 $\mu g/m^3$; $PM_{2.5}$:91 $\mu g/m^3$). However, when we look at the densities of people in both canteens, we see the highest student crowd at 12:00 noon. It should be noted that particulate matter concentrations detected in canteens in the literature are effective up to 1 hour after the highest concentration of people. Considering this situation, it is seen that the 1-hour period increases even more (2-3 hours) depending on the high level of activity of the person. Similarly, in the canteen E2, the highest student density was observed at 13:00, while the highest particulate matter levels were detected at 16:00 (approximately 2-3 hours later) following this hour ($PM_{10}$: 177 μg/m$^3$; $PM_{2.5}$:99 μg/m$^3$). In the canteen no. A1, the highest particulate matter levels were measured 1 hour after 11:00, when the person density was highest, in line with the literature data ($PM_{10}$: 50 μg/m$^3$; $PM_{2.5}$:26 μg/m$^3$). When we look at the canteen numbered A2, similar to the canteens E1, E2 and H1, the highest particulate matter levels were observed 2-3 hours after 16:00 when the density of people was highest ($PM_{10}$: 90 μg/m$^3$; $PM_{2.5}$:52 μg/m$^3$). When we examined the values we obtained, we found the highest student density in the central cafeteria no. C1 (160 people). It is expected that the central cafeteria, which is frequented by the students of all faculties, has the highest crowd. However, the highest particulate matter levels were detected in the canteen T1 ($PM_{10}$: 253 μg/m3; $PM_{2.5}$: 130 μg/m$^3$). The highest levels were measured at 12:00. This may be due to the fact that the T1 canteen is far from the cafeteria and the central cafeteria. However, while the highest student density in the T1 canteen was expected at 12:00, the most crowded hour was determined at 15:00 (103 people). When we look at 12:00, we see a relatively crowded canteen with a density of 78 people. This crowd, seen at 12:00, was determined as the second highest level of rudeness in the given time period.

## 4. CONCLUSIONS

Indoor temperature and humidity are the most important parameters of indoor air quality and human comfort. Especially these two parameters are known to affect air quality and influence the growth and sporulation of the present fungi. The indoor temperature is 15-26 ℃ and the relative humidity is recommended between 30% and 70% for different environments [21]. In the canteens where the measurements were made, the temperatures determined were slightly higher (19.3-34.2 ℃) (Fig. 1). However, this situation can be attributed to the increase in outdoor temperature in season, the crowd experienced at certain hours and the increase of indoor air temperature of canteens serving with open style cooking system. The relative humidity levels were consistent with the literature (34.8-61.5%) (Fig. 2). The canteens measured according to the relative humidity values obtained can be considered as the environment with suitable humidity area. Canteens usually have central air conditioning systems, heating and cooling is provided in this way. However, such systems are used for air heating and cooling and use indoor air when performing this operation. Therefore, it is advisable to use heating and cooling systems against high temperatures depending on the weather conditions.

When we look at the $PM_{2.5}$ and $PM_{10}$ concentrations, it was found that both parameters exceed the regulations limit values at certain hours in all canteens except E3 and A1 (Fig 4., Fig. 5). This situation has negative effects on human health and may cause some acute and chronic diseases. In such places, ventilation should be done regularly, cleaning should be repeated frequently, air conditioning systems should be reviewed and their filters should be cleaned and maintained. Performing these routines regularly is essential for a healthy and productive life.

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***The Declaration of Conflict of Interest/ Common Interest***

No conflict of interest or common interest has been declared by the authors.

***Authors' Contribution***

The authors contributed equally to the study.

***The Declaration of Ethics Committee Approval***

This study does not require ethics committee permission or any special permission.

***The Declaration of Research and Publication Ethics***

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

## REFERENCES

[1] https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality (Access Date: 02.01.2020).

[2] C.J. Matz, D.M. Stieb, K. Davis, M. Egyed, A. Rose, B. Chou, O. Brion, "Effects of age, season, gender and urban rural status on time-activity: canadian human activity pattern survey2 (chap2)." Int. J. Environ. Res. Public Health, 11, pp. 2108–2124, 2014.

[3] https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools (Access Date: 02.01.2020).

[4] https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality (Access Date: 02.01.2020).

[5] E. Hollbacher, T. Thomas, R.G., Cornelia, E. Srebotnik, "Emissions of indoor air pollutants from six user scenarios in a model Room", Atmospheric Environment,150, pp. 389-394, 2017.

[6] T. Salthammer, M. Bahadir, "Occurrence, dynamics and reactions of organic pollutants in the indoor environment", Clean-Soil, Air, Water 37, pp. 417-435, 2009.

[7] P. Wolkoff, G.D. Nielsen, "Organic compounds in indoor air - their relevance for perceived indoor air quality?" Atmos. Environ. 35, 4407-4417, 2001.

[8] C. Dede, N. Çınar, "Indoor (Household) Air Pollution and Children Health", Research on Science and Art in 21st Century Turkey, Chapter 68, Editors: Arapgillioğlu H., Atik A., Elliot RL., Turgeon, E., Gece Publishing, Ankara, Turkey, Volume:1, pp:612-620, 2017, ISBN: 978-605-180-771-3.

[9] World Health Organization, "WHO guidelines for indoor air quality. Selected pollutants". WHO Regional Office for Europe, Copenhagen, 2010.

[10] World Health Organization, "Health effects of particulate matter. Policy implications for countries in eastern Europe, Caucasus and central Asia (2013)", WHO Regional Office for Europe, Copenhagen, 2013.

[11] https://www.epa.gov/pmpollution/particulate-matter-pm-basics#PM (Access Date: 02.01.2020).

[12] EPA, "The Particle Pollution Report, Current Understanding of Air Quality and Emissions through 2003", U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, North Carolina, EPA 454-R-04-002 December 2004.

[13] P.J. Landrigan, R. Fuller, N.J.R. Acosta, et al. "The lancet commission on pollution and health", Lancet. 391:462–512, 2018.

[14] World Health Organization, "Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005, Summary of risk

assessment", WHO/SDE/PHE/OEH/06.02, 2006.

[15] T.R. Air Quality Assessment and Management Regulation, 2008.

[16] E. Işık and S. Çibuk, "Yemekhaneler ve kantinlerde iç hava kalitesi ile ilgili ölçüm sonuçları ve analizi -Tunceli Üniversitesi örneği", Dicle Üniversitesi Mühendislik Fakültesi, Mühendislik Dergisi, Cilt:6, sayı:1, pp. 39-50 , 2015.

[17] ASHRAE, "Standard 62.1-2019. "Ventilation for Acceptable Indoor Air Quality", American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 2019.

[18] D. Zhang, X. Jin, L. Yang, X. Du, Y. Yang, "Experimental study of inhalable particle concentration distribution in typical university canteens", Journal of Building Engineering, 14, pp. 81–88, 2017.

[19] K. Slezakova, E.O. Fernandes, M.C. Pereira, "Assessment of ultrafine particles in primary schools: Emphasis on different indoor microenvironments",Environmental Pollution, 246, pp. 885-895, 2019.

[20] OSHA Policy on Indoor Air Quality: Office Temperature/Humidity and Environmental Tobacco Smoke. USDOL/OSHA, Washington DC. 2003

[21] Pennstate, Environmental Health and Safety. EHS Indoor Air Quality Standard Procedures Guide. 2014.

[22] H. Bulut, "İnsan Yoğunluklu Toplu Yaşam Ortamlarında İç Hava Kalitesinin Analizi", Ulusal İklimlendirme Kongresi-İKLİM 2011 Bildiriler Kitabı, 377-386, Antalya, 2011

[23] S. Mentese, O. Çotuker, B. Selçuk, "Indoor air quality of a cafeteria with a rotor turbine ventilator (RTV) and cross-correlations between indoor air pollutants, occupancy rate and meteorological parameters", Environmental Engineering and Management Journal, Vol.17, No. 9, 2051-2059, 2018.

[24] Y. Zhu, "A study on the correlation of the indoor and outdoor particulate pollution levels in the university premises", International Conference on Economics, Social Science, Arts, Education and Management Engineering (ESSAEME 2015).

[25] S. Kumar, M. K. Jain, "Exposure to Particulate Matter and CO2 in indoor conditions at IIT(ISM) Dhanbad", Article in Press.

[26] X. Liang, Z. Li, H. Zhang, X. Hong, "Study of the characteristics and comprehensive fuzzy assessment of indoor air chemical contamination in public buildings", Frontiers in Public Health, 9, pp.1-17, 2021, doi: 10.3389/fpubh.2021.579299

[27] P. Thongsanit, N. Kaewvisate, C. Tajumpa, "Particulate Matter in the Cafeterias in Naresuan University, Phitsanulok Province, Lower Northern Part of Thailand", Advanced Science Letters, 23(5), pp. 3960-3962, 2017.