Qualitative Assessment of Bioaerosol and Improvement of Indoor Air Quality of Grocery Store in Tuguegarao City

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Abstract

Grocery stores are primary establishments where people purchase food, supplies, and household items. Most stores are open daily, and some even for 24 hours. Customers enter Rodamel Grocery Store in Tuguegarao City, Cagayan, during the operating hours to buy goods. To ensure public health safety, there is a need to measure/analyze the IAQ of the Rodamel Grocery Store and compare the gathered data to existing IAQ standards. For three consecutive days, air quality monitoring devices were used to measure the ventilation, temperature, humidity, also the concentrations of CO2, formaldehyde, and particulate matter such as PM2.5 and PM10. Bioaerosol samples were also collected and grown using a process called Growth Culture Analysis to qualitatively identify how much is inhaled depending on the grocery shopper's exposure time. Based on the results, only the temperature and the humidity did not meet the acceptable ranges from the standards, exceeding the maximum of 27˚C and 60 respectively. For the bioaerosol sampling, all the 18 samples show a relationship that the longer the shopper stays inside the grocery store, the more bioaerosol exposure is experienced. Further recommendations are also given to the Rodamel Grocery Store to address their indoor air issues.

Keywords
Indoor air quality, bioaerosol, particulate matter, formaldehyde

1. Introduction

Groceries and supermarkets are usually populated places since goods and commodities were commonly purchased in this kind of place. These were the heart of shopping centers in Italy since other activities such as cooking and food preparation are being carried out within the establishment (Santana et al., 2018). The said phenomena are pretty evident here in the Philippines nowadays, which causes people to stay longer and increasing the establishment's population.

Since these types of establishments are enclosed spaces, excellent and adequate ventilation is a must for the health and safety of the occupants within these establishments. Inadequate ventilation could cause Sick Building Syndrome (SBS), Building-Related Syndrome (BRI), and Multiple Chemical Sensitivity (MCS) due to the concentration of pollutants within (TSI, 2003). Moreover, occupants within the establishment may be at risk of having Infectious Diseases, Respiratory Illnesses, and even Cancer due to the bioaerosol particles suspended in air (Douwes et al., 2003), especially during this time of pandemic caused by COVID-19. This recently discovered airborne virus can be present in the air for 3 hours (van Doremalen et al., 2020).

This study was conducted in a grocery named Rodamel Grocery Store, which is situated in Cagayan, Philippines, and the general objective of the researchers is to assess the Indoor Air Quality (IAQ) of the grocery with the use of the air quality monitors and the bioaerosol within via settle plate method. Currently, the said establishment has no IAQ solutions installed, such as dehumidifiers, filters, etc. The parameters that were assessed to achieve such objective were the determination of the pollutant concentration within the establishment, specifically Carbon Dioxide (CO_2), Particulate Matter (PM_{10} & $PM_{2.5}$), and formaldehyde, the assessment of temperature, humidity, and ventilation within the establishment and compared the said parameters to the international and local testing standards such as American Society of Heating, Ventilation, and Air-Conditioning Engineers (ASHRAE), United States Environmental Protection Agency (USEPA), and Department of Energy (DOE) the Philippines. The IAQ of the establishment was also assessed using Time Weighted Average (TWA) paired with the ASHRAE62.1, as well as Air Quality Index (AQI) as a basis. As for the bioaerosol assessment, the researchers only correlated bioaerosol accumulation to the shopping time and were presented via photographs. The relationship between temperature, humidity, carbon dioxide, PM10, PM2.5 to the number of occupants will be determined as well; on the other hand, formaldehyde will be correlated to the number of parked vehicles outside Rodamel Grocery Store to check if there is any significant relationship between them as well.

1.1 Objectives

This study is conducted to properly assess the air quality of the Rodamel Grocery Store to determine whether it is safe for occupancy in terms of the concentration of the pollutants present inside the establishment. Additionally, it will contribute to the set of available data regarding the IAQ of a grocery store. The implemented procedures, calculations, and formulated conclusions will help future researchers conduct further indoor air quality studies. Finally, this study has cited a set of engineering solutions that will significantly improve the IAQ of a grocery store based on the researchers' findings.

The study is focused on measuring the concentration of the following pollutants: PM2.5, PM10, Formaldehyde, and CO2, for these pollutants, specific data collecting time frames would be implemented, derived from the averaging time presented on standards such as those in ASHRAE Standard 62.1 and USEPA. Furthermore, another means will be provided to evaluate the concentration, which is the AQI. The researchers would not identify the virus/bacteria/fungi that have grown as this is a new field of study altogether; instead, the researchers are only concerned with the amount of bioaerosol inhaled within a specific exposure time.

The other parameters that may affect the IAQ of the grocery/supermarket, such as lighting, ambiance, and odor, will not be measure as it will be too intrusive on the part of the management of the grocery/supermarket that would interfere with their regular operation. Therefore the researchers have decided not to measure it quantitatively.

2. Literature Review

2.1. Indoor Air Quality Assessment

According to TSI Inc. (2003), people spend a significant amount of time indoors compared to being outdoors. Due to this, the quality of air is a massive concern as contaminated air pose several health problems; some of these problems are (1) Sick Building Syndrome (SBS) – Discomfort felt by the occupants within a building (i.e., headache, eye/nose/throat irritation, itchy skin, and dizziness/nausea); (2) Building Related Illness (BRI) – An actual diagnosable illness by medical standards that is related to being confined to a building; and (3) Multiple Chemical Sensitivity (MCS) – A condition in which the occupants experience sensitivity to even a low concentration of chemicals caused by their extended exposure to it.

To ensure the health and welfare of the occupants within the establishments, IAQ standards were established as the the baseline of parameters that were measured within the establishments. Some of these standards were imposed by organizations such as USEPA and ASHRAE. Numerous parameters were considered when conducting an IAQ assessment. Some of these are temperature and humidity, pollutant concentration, and ventilation. First is the temperature and humidity; they are fundamental parameters examined in an assessment as both are directly linked to comfort according to ASHRAE Standard 55 (TSI, 2003). In layman's terms, temperature refers to the degree of "hotness" or "coldness" of the surroundings, while humidity is the "wetness" of the surrounding air. If both were compromised, it might cause discomfort to the occupants of an establishment, affecting their concentration and productivity. The international standards for the mentioned parameters may not be applicable for some countries like the Philippines due to its climate. Therefore, it is more advisable to use local standards. In the Philippine setting, the

standard imposed by the Department of Energy (DOE) of the Philippines is the more applicable baseline of comparison for temperature and humidity, as shown in Table 1.

Table 1. Temperature and Relative Humidity Values set by DOE

Parameter	Value
Maximum dry bulb temperature	27˚c
Minimum dry bulb temperature	23˚c
Maximum relative humidity	60%
Minimum relative humidity	50%

Next is pollutant concentration. Numerous pollutants were considered when conducting an IAQ assessment. For the sake of simplicity, the discussion would only be limited to CO2, Particulate matter, and formaldehyde. CO2 is a compound that an individual usually exhales, and CO2 levels are also being examined to determine the quality of the ventilation inside an enclosed space (TSI, 2003). Particulate Matter or Airborne Particles refers to those inhalable particles that have an aerodynamic diameter of 10 micrometers (PM10) or smaller; as these particles enter our respiratory system, the body's defense mechanism gets strained as they repeatedly enter the body, which may cause adverse health reactions. Airborne Particles are typically produced through dust and cigarette/tobacco smoke (TSI, 2003). Formaldehyde is a widely used chemical and is commonly present outdoor and indoor. It has numerous sources and some of which are forest fires, burning fuels, and smoking tobacco. Being exposed to formaldehyde has various short-term and long-term effects such as irritation and sore in the airways, eyes, chest, and abdominals (Kim, Jahan, Lee, 2011).

Another one is ventilation. Ventilation refers to the amount of air that is circulating within an enclosed space. It is a direct measurement of fresh air that the occupants should inhale. Furthermore, ventilation also helps in diluting existing pollutants within a confined space (TSI, 2003). Improper ventilation allows air to be stagnant inside an enclosed establishment, thus, slowly accumulating concentrations of harmful pollutants and even bacteria, viruses, and fungi inside the establishment could cause respiratory illnesses to prevail amongst the individuals that are staying inside the establishment or even frequent visitors (ASHRAE, 2003).

2.2. Bioaerosols Assessment

Bioaerosols are defined as airborne particles that contain biological matter. In other words, they are released from a living organism; the size of a Bioaerosol ranges from less than 0.1 micrometers up to 100 micrometers in diameter; in simple terms, bioaerosol refers to the following: fungi, yeasts, molds, pollen, bacteria, endotoxins, and viruses. It is a known fact that all of these have hazardous health effects that may lead to death. These effects are Infectious diseases, respiratory illnesses, and cancer (Douwes et al., 2003).

There are two methods of collecting bioaerosol samples. The first one was the active sampling method, wherein bioaerosol samples are collected using button samplers, impingers, etc. The other was passive sampling, wherein either settled dust from the surfaces is collected as samples (Hoisington, 2013) or via the settle plate method (Napoli, Marcotrigiano, Montagna, 2012). The agar plates were exposed to the surroundings to collect bioaerosol samples. Techniques such as Growth Culture Analysis were employed to determine and analyze bioaerosol samples (TSI, 2003).

3. Methods

Due to the pandemic occurring in the country, the chances of finding a grocery that would allow this kind of study in the National Capital Region (NCR) are slim. Therefore, the researchers surveyed a grocery in a rural area. The chosen grocery was Rodamel Grocery Store, which is situated at Brgy. Craig Sur, Tuguegarao City, Cagayan, and has a floor area of 208m2. It was divided into four zones, as shown in Figure 1.

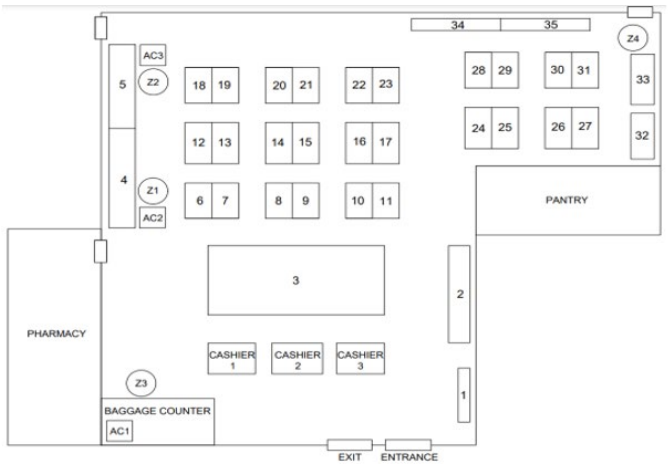

Figure 1. Floor Plan of Rodamel Grocery Store

To measure the parameters needed for the assessment, the researchers utilized the equipment manufactured by Benetech since these were affordable and had certifications and proofs that the equipment were calibrated. So, the equipment used were Benetech GM1360A Temperature Meter for measuring the temperature and relative humidity, Benetech GM8802 Carbon Dioxide Meter for measuring the CO2, Benetech GM8803 Air Quality Detector for measuring PM10 and PM2.5, Benetech GM8801 Formaldehyde Meter for measuring formaldehyde, and Benetech GM816 Digital Anemometer for measuring the air velocity of the Air-Conditioning Units.

To properly correlate the standards set by governmental and environmental agencies, the researchers have decided to conduct a survey that will prompt the shoppers to identify how long it takes them to shop at the supermarket a
nd the time when they frequent shop the most. This will give the researchers the proper grasp on how long the testing of each pollutant under concern. Furthermore, this will also be the basis on how long we would run the bioaerosol collector to qualitatively show the nature of bacteria growth as exposure time increases.

For the testing proper, the pollutants considered are PM2.5, PM10, Formaldehyde, and CO2. The data points were gathered for a total of 4 hours based on the averaging hours required for the TVOC taken from the ASHRAE standards. The said testing time was divided into 2 (Morning and Evening). The pollutants are to be measured at the height of 1.45m with the study of Almutairi et al. (2019) as its basis. The Air Quality Index of the mentioned pollutants was also determined to assess the risk of the measured concentration to human health. Similarly, the pollutants' correlation to the occupants was determined to see if the former were influenced by the latter (except for formaldehyde since it was correlated with the parked vehicles outside instead of occupants). In assessing the temperature and humidity, the researchers utilized the standards imposed by DOE as shown in Table 1 since the standards set by ASHRAE for these parameters are barely applicable in the Philippine setting.

The bioaerosol sampling was done based on the shoppers' average shopping time, which directly relates to their exposure to the bioaerosol. Following this, the researchers applied the procedure called Air Sampling by Settle/Sedimentation Plate Method. This is a method in which the agar plates were uncapped and allowed to be in contact with the surrounding air in which each agar plate were exposed to the air depending on the increment of the exposure time that is given through the survey of shoppers (e.g. 30 mins, 1 hr., or 2 hrs.). After the exposure time had lapsed, the agar plate was again sealed and labeled with the location/zone in which it was taken from and the corresponding time frame it was collected. Once the bioaerosol samples have been collected for the designated periods, they will be immediately subjected to a growth culture wherein the bacteria/fungi/virus present in the agar plate would be cultured for visualization. It was incubated for two weeks (Lindsley et al., 2017) at room temperature of 25˚C (Ahern, 2018). Once two weeks had passed, the researchers took photographs of the fully grown samples and tabulated them according to their period, which is equivalent to the time exposure of the shoppers.

Based on ASHRAE 62.1, a ventilation requirement must be satisfied to determine if an establishment has good IAQ. Thus, the researchers have decided to include it as an additional parameter other than the pollutant concentration and bioaerosol sampling. This will give the researchers additional evidence to the amount of pollutant concentration and bioaerosol in the air. Inadequate ventilation results in stagnant or unused air in the vicinity, therefore, putting the

occupants at risk the longer they are exposed to the air inside the establishment in the subject. Before the measurement of ventilation, the researchers would have to measure the dimensions of the duct; the size to be taken depends on the geometry of the diffusers that are installed in the establishment; for a rectangular duct its length and width would be measure through the use of a steel tape, on the other hand, the diameter would be measured for a circular duct, as per AS AE 41.2 (2018) a rectangular duct's equivalent circular diameter must be calculated to use it in the identification of air volume flow rate as the anemometer only measures airspeed and not air volume flow rate. The air velocity was measured at the diffuser of the working air conditioning units for ten (10) trials at each diffuser. All the mentioned procedure was done in three consecutive days, during December 2020, at four hours a day as per USEPA standards.

4. Results and Discussion

For the ventilation, all the measured average air flowrate values as shown in Table 2 and 3 for the three-day sampling period exceeded the minimum zone outdoor airflow required, a baseline value that must be computed following ASHRAE 62.1. Even though they were all the same brand and model, the three Air-Conditioning (AC) units differ in flow rate due to their positioning in the grocery, as shown in Figure 1. The air flow rate average value of Diffuser 2 was that it was not in use on some days (1st day for the case of the researchers) for the management to save electricity.

Table 2. Comparison of Average Air Flowrate Values to the Minimum Zone Outdoor Airflow Required (Morning)

Diffusers	Flowrate values (cfm)
Diffuser 1	1193.182
Diffuser 2	625.693
Diffuser 3	580.221
Minimum zone outdoor airflow required	268.66

Table 3. Comparison of Average Air Flowrate Values to the Minimum Zone Outdoor Airflow Required (Afternoon)

Diffusers	Flowrate values (cfm)
Diffuser 1	1222.284
Diffuser 2	569.308
Diffuser 3	641.154
Minimum zone outdoor airflow required	268.66

For the temperature (see Figures 2 and 3), even though the morning data are within the DOE standards, the afternoon data are at the maximum value required by the standards, which is 27˚C. Considering that these data were gathered in December, it will go higher during the summer season, surpassing the maximum level imposed by the standard. The time-weighted average for days 1, 2, and 3 are 26.46 ˚C, 26.3 ˚C, and 27.01 ˚C, respectively.

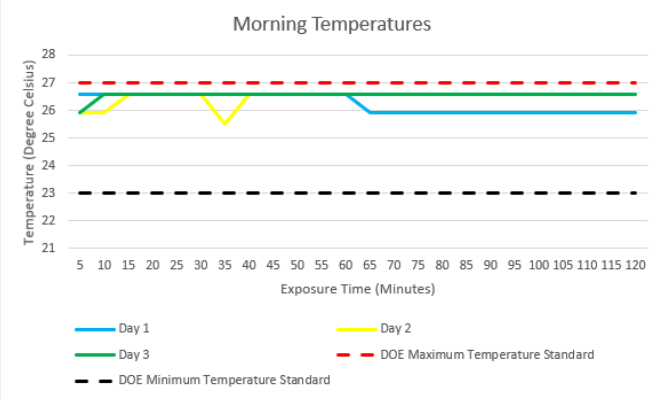

Figure 2. Comparison of Morning Temperatures to DOE Standard

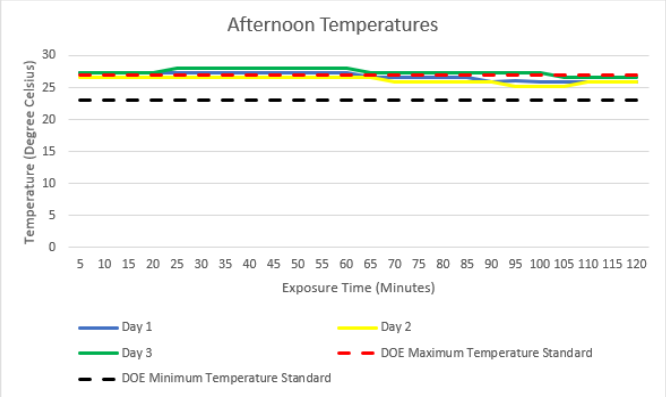

Figure 3. Comparison of Afternoon Temperatures to DOE Standard

All data exceeded the maximum value imposed by DOE for the humidity, 60%, as shown in Figures 4 and 5. The time-weighted average for humidity from days 1 to 3 is 71.8%, 75.06%, and 72.56%, respectively.

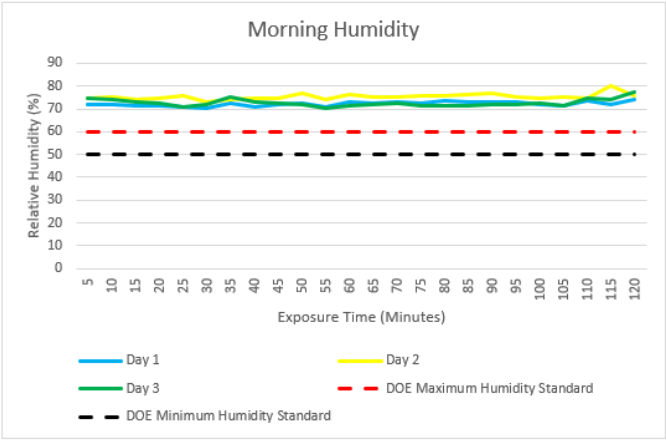

Figure 4. Comparison of Morning Humidity to DOE Standard.

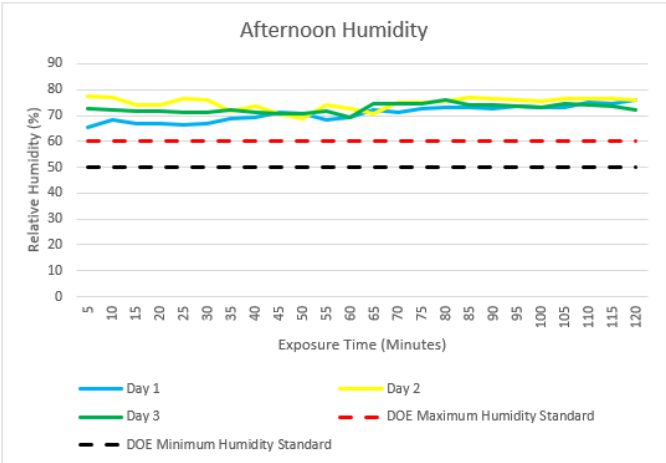

Figure 5. Comparison of Afternoon Humidity to DOE Standard.

For the CO2 Concentration, as shown in Figures 6 and 7, all the gathered data were below the ASHRAE standard value of 5000 ppm. The time-weighted average for CO2 concentration from day 1 to 3 is 777.20 ppm, 654.03 ppm, and 697.94 ppm, respectively.

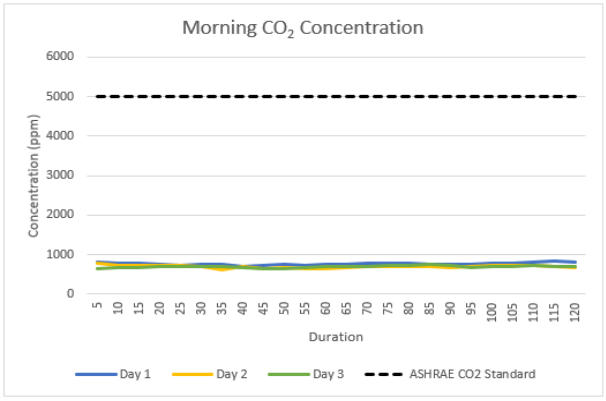

Figure 6. Comparison of Morning CO2 Concentration to ASHRAE Standard

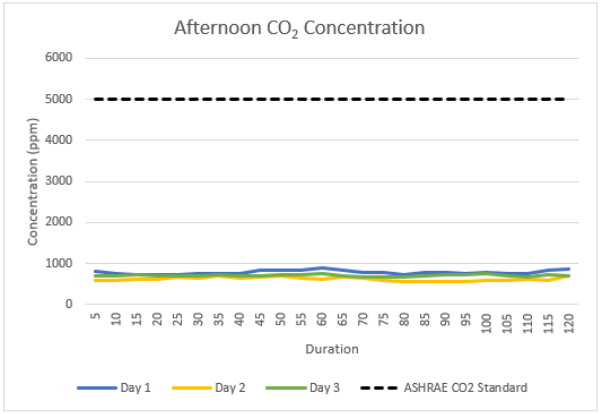

Figure 7. Comparison of Afternoon CO2 Concentration to ASHRAE Standard

For the formaldehyde, as shown in Figures 8 and 9, all the gathered data were also below the imposed standard value by ASHRAE, which is two ppm. The high variation of its concentration within the establishment is because the doors of the establishment were open most of the time, allowing the infiltrations of outside pollutants. The time-weighted average for Formaldehyde concentration from day 1 to 3 is 1.688 ppm, 1.329 ppm, and 1.844 ppm, respectively.

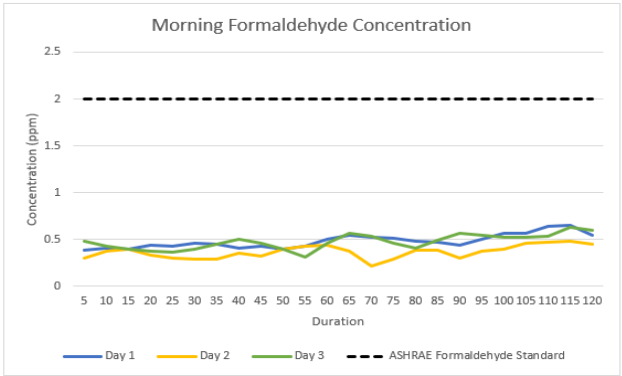

Figure 8. Comparison of Morning Formaldehyde Concentration to ASHRAE Standard.

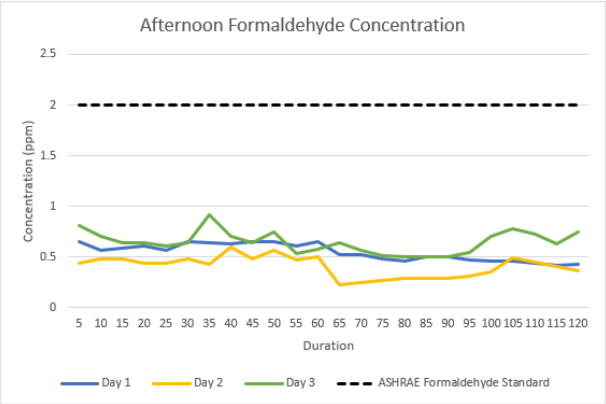

Figure 9. Comparison of Afternoon Formaldehyde Concentration to ASHRAE Standard.

As for the results of AQI, Formaldehyde and PM10 fall into the "Good Air Quality Index" since their average AQI for the three-day testing falls within the range of 0-50 (20.35, 34.2, and 21.13 for Formaldehyde and 16.47, 13.35, and 18.11 for PM10). This means that these pollutants pose little to no threat to the occupants. CO2 and PM2.5 fall on the “Moderate Air Quality Index” since their three-day AQI average falls within the 51-100 range (61.32, 60.82, and 56.7 for CO2 and 53.15, 42.24, and 53.69 for PM2.5).

For the correlation of parameters, most of the results were expected except for CO2, PM10, and PM2.5. This was for the case of CO2; the ventilation within the establishment influences the CO2 concentration, other than the occupants, considering that the doors in the establishment are open most of the time. For the case of the two particulate matters, the occupants' clothing may contribute to its concentration levels as well as the biological agents that the occupants expel via itching, etc.

For the Bioaerosol Qualitative analysis, it can be seen that the bioaerosol accumulation increases as the time of exposure increases as shown in Figure 10 -15. The researchers could only present the results in photographs since it was stated in the earlier paragraphs. Still, it is also because the microbial communities in these types of places are diverse. Their variability is high as it is mainly influenced by the occupants and the surrounding environment of the building. Therefore, the microbial species commonly residing in the building cannot easily be classified in one sampling session (Hoisington, 2013). The results are presented in the succeeding Figures 10-15.

Figure 10. Bioaerosol Samples in Zone 1 on December 8, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

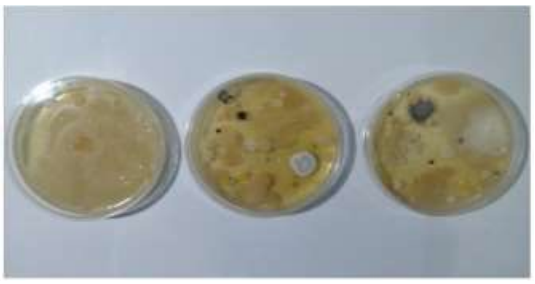

Figure 11. Bioaerosol Samples in Zone 2 on December 8, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

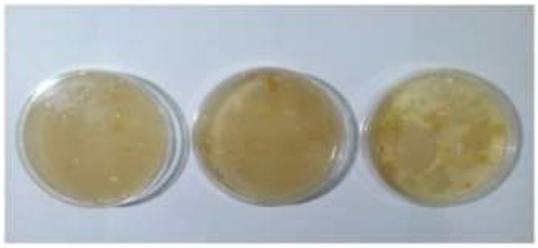

Figure 12. Bioaerosol Samples in Zone 3 on December 8, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

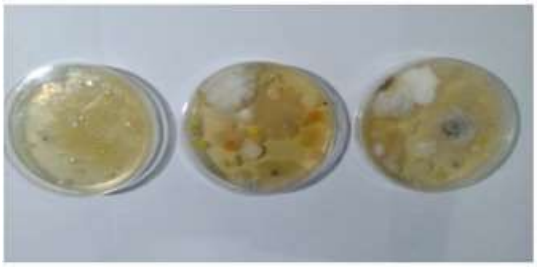

Figure 13. Bioaerosol Samples in Zone 4 on December 8, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

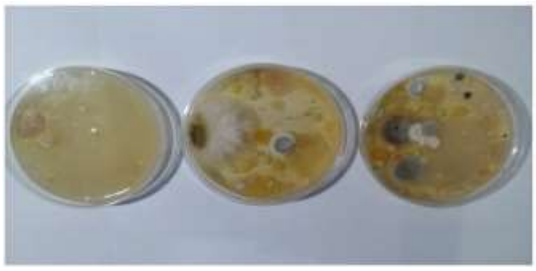

Figure 14. Bioaerosol Samples in Zone 2 on December 9, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

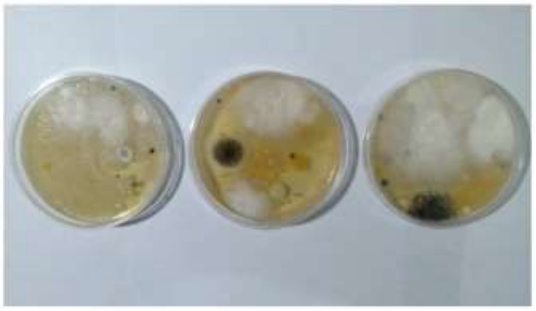

Figure 15. Bioaerosol Samples in Zone 4 on December 9, 2020 (left to right: 30 minutes, 45 minutes, and 1 hour).

5. Conclusion

Based on the findings and analysis of the researchers, most of the parameters passed the standards except for the temperature and the humidity within the establishment. The moisture in the grocery dramatically exceeds the maximum humidity level imposed by DOE, which is 60%. At the same time, even though the evening data shows that it is mainly on the top level of 27˚C, this study was conducted during colder months of the year. Therefore it would be expected that the temperature in the establishment would be higher during the summer seasons.

As for the pollutants, all of them are within standard limits imposed by ASHRAE, and most of them are in the "Good. The Air Quality Index" of the AQI, except for CO2, falls into the "Moderate Air Quality Index." Most of the statistical parameter correlations conducted were expected except for the case of the CO2 since it was affected by the frequently opened doors of the establishment, and for the possibility of PM10 and PM2.5 because of the clothing of the occupants and the biological agents, they expel via desquamation or scratching of the skin.

For the Bioaerosol qualitative analysis, it was concluded that the microbial accumulation increases over time, mainly due to the accumulated microbiota from the occupants and the surrounding environment of the establishment.

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