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The Effect of Air Conditioner Maintenance Frequency on the Indoor Air Quality of DLSU Classrooms

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Abstract: With millions of deaths resulting from indoor air pollution each year, many look for methods to improve indoor air quality. A common solution is the use of air conditioners, which not only allow temperature control but also improve indoor air quality. Despite several studies proving that air conditioners improve indoor air quality, very little studies have been done on the importance of the maintenance of these appliances. This study aims to identify the effects of air conditioner maintenance on indoor air quality, the possible health effects that may arise from the operation of unmaintained air conditioners, and the ideal frequency of air conditioner maintenance is the purpose of this study. To achieve this, indoor air pollutant concentrations of DLSU classrooms were measured using an air quality monitor at different periods of time since the last maintenance schedule of their air conditioners. The study was able to align with previous related literature regarding the effect of air conditioners on indoor air quality, specifically $PM_{2.5}$ and PM_{10} concentrations. However, the trend between the indoor air quality and the time since the air conditioners were last maintained was inversely proportional, which is contrary to the expectation. There was a non-linear trend found between the indoor air quality and the time since the air conditioners were last maintained, showing that air conditioners should be maintained every 200-225 days

Keywords: air conditioner; air pollution; indoor air quality; air conditioner maintenance

1. INTRODUCTION

1.1. Background of the Study

With most people spending 90% of their lives indoors, it is no surprise that indoor air pollution causes millions of deaths per year (Tran et al., 2020). This is not an issue to be taken lightly as indoor air pollution could result from simple everyday activities such as cooking, smoking, consumer products, etc. According to Sun et al. (2019), polluted air is composed of formaldehyde, volatile organic compounds (VOCs), particulate matter, ozone, and biological contaminants. Exposure to these pollutants and poor air quality could negatively impact respiratory and cardiovascular health (Mulenga & Siziya, 2019). Ultimately, having poor indoor air quality in the places where most people spend their lives could degrade their quality of life.

It was mentioned by Wang and Zhang (2021) that the concentration of indoor air pollutants can reach up to 100 times that of outdoor pollutants. This signifies that it is necessary to further investigate the indoor air pollutants and how we can decrease their concentration. It is also mentioned by Wang and Zhang (2021) that the concentration coming from the indoor air pollutants contain different particles that have bacteria, fungi, acid oxides, organic pollution, and heavy metals which would harm the human body. This provides further importance on why indoor air quality should be assessed. Assuming that the indoor air quality is not maintained properly, several effects on the human body may happen; as according to Tham (2016), several effects of having poor indoor air quality towards humans may include:

Allergies, respiratory diseases, increased risk of lung cancer, cardiovascular diseases, and airway infections. These harmful effects on humans show why indoor air quality should be improved in all indoor areas. One method of reducing indoor air pollution is by turning on the air conditioner. Air conditioners are a common household appliance, mainly used for their ability to control indoor temperature. Aside from this, it is mentioned by Lin et al. (2013) mention that by turning on the air conditioner, an increase in cardiovascular health and indoor air quality can be achieved. This is because air conditioners contain filters that can remove particles from the indoor air (Aslam et al., 2020). Because of the benefits of using air conditioners, they are widely used in office and school settings to improve the overall indoor environment quality. However, a study by Payless Power (2021) said that only 42% of American Households have the air conditioners maintained. This raises the question of whether people know the importance of maintaining air conditioners.

Previous research papers have proven that air conditioner filters do improve indoor air quality. These studies monitored the indoor air quality of specific indoor spaces before and after air conditioner filters were used. According to Batterman et al. (2012), using an air conditioner filter in a child's bedroom reduced particulate matter (PM) levels by 50%. Another study by Zhu et al. (2021) found that air conditioner filters decreased PM levels by 11-82%. The variation in results was caused by different factors such as occupant behavior, geographical location, filtration technology employed, indoor environmental characteristics, and air pollution sources. Nonetheless, air conditioners have been proven to improve indoor air quality effectively. However, few studies have been done on the maintenance of these air conditioners. One study stated that air conditioner maintenance may extend the lifespan of air conditioners by 40% (Payless Power, 2021). Besides this, there seem to be few studies available on the effects of air conditioner maintenance. The purpose of this research is to identify the effects of air conditioner maintenance on the air quality of an indoor environment is the purpose of this research. Due to the lack of research on this topic, people are unaware of the possible effects of having an unmaintained air conditioner. The different effects, if there are any, of unmaintained air conditioners through a series of observations were investigated and identified in this study through a series of observations. Potential health consequences were also identified.

1.2. Research Objectives

The overall goal of this research is to assess the impacts of air conditioner maintenance frequency on the indoor air quality of a university classroom, as air conditioners may not successfully maintain acceptable indoor air quality if left unmaintained for an extended length of time. This study focuses on three main objectives. The first is to differentiate the impact of using an air conditioner on the interior air quality (in various aspects) of DLSU classrooms. Second, to determine any potential health issues that poorly maintained air conditioners could bring on. Lastly, it aims to identify the appropriate time interval for air conditioner maintenance in a DLSU classroom.

1.3. Scope and Limitations

De La Salle University - Taft is where 30 classrooms will be observed and monitored for this study. The total duration of the study would last for three months, wherein the air quality would be examined using an air quality monitor to gather data. Solely classrooms with non-centralized air conditioning will be observed. Furthermore, the brand and age of the air conditioners will also not be considered. The data collected would then include - the concentrations of $PM_{2.5}$, PM_{10}, and CO_2 (Carbon Dioxide). All this data will be gathered at specific times relative to the air conditioner maintenance schedules, exclusively the general cleaning by the university staff. Only the data mentioned above, and no other factors affecting indoor air quality, will be covered in this study, as only those are measured by the chosen air quality monitor.

1.4. Significance of the Study

For the students of DLSU-IS to gain critical knowledge about the classroom's air quality at DLSU. This information and previous studies and outcomes would help determine the necessary maintenance schedule for achieving ideal indoor air quality. HVAC Technicians would benefit from the relevant information obtained in this study, as it would aid in improving the creation of air conditioning systems and eliminating indoor pollutants that affect consumer health. The data gathered would assist the DENR in fulfilling its vision of a sustainable and clean environment,

supporting the Clean Air Act, and managing indoor appliances to reduce air pollution. For the DOH, the study's data would ensure that indoor air quality is safe for human use and help identify ways to enhance air quality when using air conditioners. Potential researchers would also benefit from the study as it provides references and essential data, guiding them to explore new perspectives and uncover unknown pollutants in unmaintained air conditioners. If the concentration levels of $PM_{2.5}$, PM_{10}, and CO_2 exceed the recommended amount for humans, it could cause several negative health impacts which include: Shortness of breath, coughing, sneezing, runny nose, eye, nose, throat, lung irritation, headaches, lightheadedness, dizziness, faster heartbeat, and high blood pressure. It can also aggravate respiratory and cardiac disorders like asthma and heart disease as well as increase the risk of heart attacks.

1.5. Review of Related Literature

$PM_{2.5}$ is the smaller and deadlier version of PM_{10} because since it is tinier, these particles could get into the lungs, or worse could get into the bloodstream of an individual. Such as the PM_{10}, the size of this particle is around 2.5 micrometers or less in diameter, hence it is labeled as PM.2.5. It is stated by the World Health Organization (2021) that the 24-hour average concentration exposure should not reach 15 µg/m3 for more than 3 - 4 days per year. Doing so would then harm the organs and could pose a big threat to one's life.

Carbon Dioxide, CO_2, is a gas without color that has a sour taste as well as a hint of sharp smell (WHO, 2009). It is also one of the gases associated with global warming because excessive amounts would warm up the planet, causing climate change.

Aside from the pollutants mentioned above, PM_{10} is an inhalable particle that is also one of the most common air pollutants. The size of this particle is around 10 micrometers or less in diameter, hence it is labeled as PM_{10}. According to Victoria (2020) this can be found both indoor and outdoor as it is not only found in dust and smoke but also in sea salt, exhaust fumes of cars and trucks, and also in industry. This shows that this type of particle could be commonly found in dusty and smoky areas which could be harmful for citizens.

Table 1
Guidelines for Indoor Exposure of Pollutants

Pollutant	Amount of Exposure
$PM_{2.5}$	5 µg/m^3 annual mean, 15 µg/m^3 24-hour mean
PM_{10}	15 µg/m^3 annual mean, 45 µg/m^3 24-hour mean
Carbon Dioxide	9000 mg/m^3

The guidelines for indoor exposure to pollutants is shown in Table 1.

2. METHODOLOGY

2.1. Research Design

A quantitative approach involving statistical data was used for this research. The method that was used in this study was an observational approach which entails watching objects and occurrences in their natural settings. Researchers utilized an observational strategy to acquire data without manipulating or controlling variables. In addition, descriptive statistics were used throughout the study to create summaries of a sample set of data.

2.2. Equipment Operation

Figure 1
Qingping Air Monitor Lite

Note. The Qingping Air Monitor Lite with firmware version

4.3.4 was used for the data collection of this study. The device is able to measure temperature, relative humidity, $PM_{2.5}$, PM_{10}, and CO_2 concentrations of the environment.

2.3. Sampling Procedure

The sampling procedure was performed in a total of 30 classrooms in DLSU Taft where their air quality was measured, specifically measuring their $PM_{2.5}$, PM_{10}, and CO_2 levels. The classrooms had decentralized air-conditioning, using either window-type or split-type air conditioners. To precisely measure the conditions during regular school days, the data collection was done from 10:00 AM to 2:00 PM. First, temperature stability was achieved in the room. This was assured by performing the sampling procedure when the air conditioners have been running for at least one (1) hour. Next, the baseline readings for each of the indoor air pollutants was determined. The corridor outside of the classroom served as the baseline environment for these measurements. The readings inside the classrooms were recorded once they had stabilized. For CO_2, this was once readings varied by 10 ppm or less. There was at least two (2) minutes of stabilization period per room for the air quality monitor. After obtaining the data, information about the last air conditioner maintenance of the examined rooms was requested from and provided by the Mechanical and Electrical Works Office of DLSU. All data was then recorded into tables on Microsoft Excel.

2.3. Data Analysis

The data were summarized using different descriptive measures such as: mean, standard deviation, standard deviations from the mean, and percent reduction. The data were also categorized by building, date, and type of air conditioner to look for possible trends and relationships. The data was also analyzed using a time course analysis, the variation of measurements over time is the main focus here. The mean concentrations of the indoor air pollutants were graphed against the time since the air conditioners were maintained. Trends and observations about the data were also identified. The effects of air conditioner maintenance on indoor air quality, whether the maintenance schedules of the university staff are appropriate, and the possible health effects on the people using the classrooms were identified. A sample comparison was performed using a t-test. A t-test is known for comparing the means of two different sets of data. Specifically, the t-test function in Microsoft Excel was used. In this study, this was used to compare the concentrations of pollutants gathered from different DLSU classrooms to the baseline readings. This portion was significant as it identified whether the indoor air quality in DLSU classrooms is affected by the use of air conditioners. Possible health effects from the interpretation of the data were also determined.

3. RESULTS AND DISCUSSION

Table 2
Percent Reduction of Indoor Air Pollutants

	$PM_{2.5}(ug/m^3)$	$PM_{10}(ug/m^3)$
	Baseline Readings	
Mean	24.2	28.3
SD	11	13.8
	Room Readings	
Mean	11.0	12.6
SD	8.0	9.0
Mean % Reduction	55%	56%
SD of % Reduction	33%	32%

Percentage reduction is used to measure the or decrease of a value compared to the original state. In table 2, the air quality in the rooms of the building and the baseline readings are being compared to identify if there is a difference of $PM_{2.5}$ and PM_{10} if an air conditioner is present. As shown in the data on table 2, the concentration of $PM_{2.5}$ was reduced by about 55% and PM_{10} was decreased by approximately 56% when an air conditioner is present. This supports the previously done literature that air conditioners improve air quality

Table 3
t-test: Baseline CO_2 vs Room CO_2

	Baseline CO_2	CO_2
Mean (ppm)	464.2	1528.00
Variance (ppm2)	7181.5	527088
SD (ppm)	84.7	726.0
SD from mean	12.6	1.5
t Stat	-7.96	
P(T<=) one-tail	3.47×10^{-9}	
t Critical one-tail	1.70	
P(T<=) two-tail	6.94×10^{-9}	
t Critical two-tail	2.04	

As shown in table 3, there is a significant increase in the CO_2 levels inside the rooms compared to the baseline readings. This is supported by the performed t-test, which has shown that the p-value for both the tailed and two-tailed tests is much less than the standard alpha value, which is 0.05. This result is possibly due to the students staying inside classrooms for a long period. Since we humans constantly exhale carbon dioxide, it will naturally accumulate in a closed room. Therefore, the CO_2 readings inside the classrooms are expected to be higher than in a more open area such as the corridors. From this, it could also be said that air conditioners do not improve the CO_2 levels inside a room.

Figure 2
$PM_{2.5}$ concentration vs. Time since last air conditioner maintenance

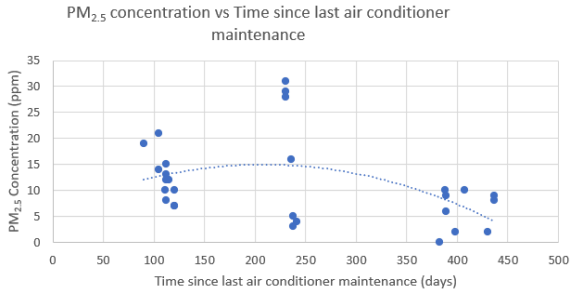
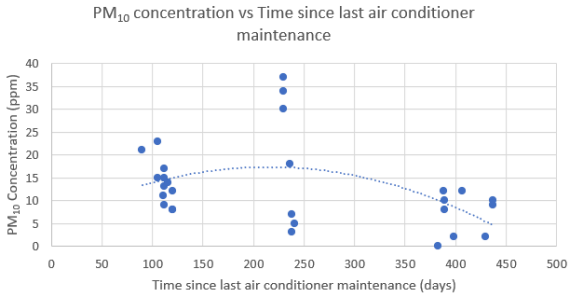


Figure 3
PM_{10} concentration vs. Time since last air conditioner maintenance



As shown in figures 2 and 3, there is a nonlinear relationship between the duration since the last maintenance of an air conditioner and the concentrations of $PM_{2.5}$ and PM_{10}. Initially, the trend is as expected that as time passes since air conditioners were last maintained, the concentrations of $PM_{2.5}$ and PM_{10} in the room will be higher since the air conditioner will be less efficient at filtration. However, this is only until the 200th to 225th day, as beyond that, the $PM_{2.5}$ and PM_{10} concentrations seem to start improving. According to Niu et al. (2020), dust accumulation in HEPA filters tends to improve their efficiency as the accumulated dust aids in capturing dust particles. However, this increase in filtering power would require the air conditioner to use more energy for the same output as the dust starts to clog the air filters (CCOHS, 2023). This explains the trend formed in the graph shown in Figures 2

and 3. The filtering power of the air conditioners slowly decreases as time passes, up until the 200-225 day mark, then starts to significantly increase from this point due to dust clogging the air filters. This means that after the 200-225 day mark, the air conditioner is already struggling to push air through the filter due to the clogging, which is evident from its high filtration power, causing the low levels of $PM_{2.5}$ and PM_{10}. The concentrations based on the trendline also still fall under the WHO guidelines on air quality. Thus, the air conditioner's energy efficiency is the major factor to consider for air conditioner maintenance would be the air conditioner's energy efficiency. Therefore, it would be ideal to maintain the air conditioners every 200-225 days to keep them efficient.

Table 4
t-test: Baseline CO_2 vs. Room CO_2

	$PM_{2.5}$		PM_{10}	
	Split-Type	Window-Type	Split-Type	Window-Type
Mean (ppm)	75.6%	42.7%	75.3%	44.2%
Variance (ppm2)	2.2%	12.0%	2.2%	11.4%
SD (ppm)	14.9%	34.6%	14.8%	33.7%
SD from mean	2.2	1.0	2.10	0.92
t Stat	3.61		3.47	
P(T<=) one-tail	6.14x10-4		8.75x10-4	
t Critical one-tail	1.70		1.70	
P(T<=) two-tail	1.23x10-3		1.75x10-3	
t Critical two-tail	2.05		2.05	

As shown in table 4, there is a significant difference in the $PM_{2.5}$ and PM_{10} concentration percent reduction of split type air conditioners as compared to window type air conditioners. This is also supported by the performed t-test, which shows that the p-value for both the tailed and two-tailed test is much less than the standard alpha value, which is 0.05. The means of both concentrations for both air conditioners types are equal to or greater than one standard deviation from each mean, stating that the difference is significant and not due to random error. This difference may be due to the difference in the air conditioners' engineering and type of filter. This result also suggests that it is significantly more efficient to use split type air conditioners rather than window-type air conditioners for improving the air quality inside a room.

4. CONCLUSIONS

The study aligned with previous related literature regarding the effect of air conditioners on indoor air quality, specifically $PM_{2.5}$ and PM_{10} concentrations. The results show that using air conditioners in a classroom reduces $PM_{2.5}$ concentrations by approximately 55% and PM_{10} concentrations by about 56%. This is relatively in the middle of the range concluded by Zhu et al., that PM levels in an air-conditioned room are reduced by 11-82%. This study also found that split type air conditioners reduce PM levels by plus 30% compared to window-type air conditioners. Additionally, CO concentrations seemed to have increased inside the classrooms compared to the baseline readings.

A non-linear trend was found between the indoor air quality and the time since the air conditioners were last maintained. The air conditioners' filtering power slowly decreased up until around 200-225 days after maintenance, when the accumulated dust clogged the filter, leading to an increase in filtering power as the accumulated dust helped catch particles in the air. However, this is suspected to lead to a decrease in the air conditioner's energy efficiency. Since the trend still falls under WHO guidelines for air quality, the prevalent factor to be monitored is the efficiency of the air conditioners. Therefore, air conditioners should be maintained every 200-225 days. $PM_{2.5}$ and PM_{10}

concentrations fall under the 24-hour WHO guidelines. Therefore, there should be no concern about health effects of this. On the other hand, the average CO_2 concentrations of 1528 ppm fall under the range of 1000-2000 ppm, which is where there are complaints of drowsiness and poor air. This may be the reason why students often fall asleep inside the classroom.

The researchers recommend that future researchers to explore this study with a larger sample size. For more accurate results, it is preferable to pursue this focusing on one type of room, as this paper examined classrooms together with laboratories, which could have varying exposure to indoor air pollutants. Furthermore, future researchers could also look into the energy consumption of the air conditioners and their relation to the time since they were last maintained. Lastly, for a deeper exploration of this field, the researcher also suggests considering the age of the air conditioners and their air filters.

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