Investigation on the correlation between meteorological factors and particulate matter ($PM_{2.5}$) in Kaba-Aye Station, Yangon city, Myanmar

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Abstract- From April 2018 to December 2022, we collected the monthly meteorological parameters and hourly $PM_{2.5}$ μg/m^3 concentration monitoring data from Kaba-Aye station, Department of Meteorology and Hydrology (DMH), Yangon, Myanmar. Rainfall (RF) mm, wind speed (WS) mph^{-1}, temperature (Temp) ºC, and relative humidity (RH) % are the meteorological parameters. Our study investigated into the way variations in meteorological parameters affected the categories of the Air Quality Index (AQI) that include $PM_{2.5}$ measurements. The $PM_{2.5}$ concentration collected data are calculated AQI categories regarding $PM_{2.5}$ parameters using the Environmental Protection Agency (EPA) approach by equation. We discovered that there is a correlation between the seasonal impact of meteorological conditions and $PM_{2.5}$. The winter season had the highest concentration, while the monsoon season's wet season had the lowest. During the winter and rainy seasons, the highest and lowest yearly concentrations of $PM_{2.5}$ particles were found to be 68 μg/m^3 and 4 μg/m^3, respectively. Therefore, we found that the highest or unhealthiest categories appeared twice in 2021 (153 and 157) and the annual trend of $PM_{2.5}$ concentration significantly increased at the rate of 1.8 μg/m^3 per year due to year-to-year meteorological conditions always changing.

Index Terms- AQI, Air quality monitoring Kaba-Aye station, Meteorological parameters, $PM_{2.5}$ μg/m^3

I. Introduction

One of the world's biggest environmental issues now is air pollution [1]. The environment and public health are seriously threatened by ambient $PM_{2.5}$ μg/m^3 or fine particulate matter having a diameter of less than 2.5 [2]. According to the World Health Organization (WHO), about 3.7 million individuals died from outdoor urban and rural sources of air pollution in 2012[3]. The WHO established PMs as one of the most significant health risk factors [4]. Therefore, $PM_{2.5}$ monitoring stations have been established in a number of nations for epidemiological research, daily $PM_{2.5}$ measurements, and air quality management [5]. Our department of DMH, Myanmar has been monitoring the concentration of $PM_{2.5}$ in Kaba-Aye Station, Yangon by $PM_{2.5}$ automatic monitor (model FPM- 377C) started on 26 March 2018 donated by Acid Deposition Monitoring Network in East Asia (EANET), Japan. The PM index are helpful indicators of the city of Yangon's air pollution.

More than 7 million residents of Yangon, the largest city in Myanmar, must contend with both interior and outdoor air pollution [6]. According to previous studies conducted in Myanmar, the Yangon region is most susceptible to dust pollution [7]. In addition, long-term trend research shows that between 1999 and 2014, Myanmar's $PM_{2.5}$ concentrations significantly increased annually at a rate of 0.25 μg/m^3/year, exceeding the average yearly limit advised by the World Health Organization recommended level [8]. Moreover, the average annual $PM_{2.5}$ concentration in Yangon in 2016 was reported at 35 μg/m^3, above the WHO-recommended level, according to the WHO Myanmar newsletter-2019 [9].

In order to make the necessary changes in the management of air quality in our city and study on particle air pollution, which is acknowledged as a risk factor for public health, is necessary. The goal of our research is to find a correlation between seasonal effects of meteorological parameters and $PM_{2.5}$ AQI category parameters. An indicator of the quality of the air you are breathing is the AQI score. In simpler terms, the AQI is a measure of how 'clean' the air you are breathing [10]. It uses color-coded categories and provides statements for each category that tell us about air quality in our area, which groups of people may be affected, and steps we can take to reduce our exposure to air pollution [11]. In order to determine at a glance whether air pollutants are approaching detrimental levels in the area, the AQI is divided into six categories with a distinct color assigned to each category Table 1 [12]. According to the EPA, data has shown links between ambient airborne particles and a number of serious health issues, such as worsened asthma, chronic bronchitis, nonfatal heart attacks, and early mortality, since 2006 [13].

Therefore, this study's research will contribute to filling up the knowledge gaps about how Yangon, Myanmar's growing industrialization, urbanization, modernization, and automobile proliferation have affected the ambient air quality. It will also highlight the influence of informal RF, RH, WS, and Temp on the AQI and individual parameters of $PM_{2.5}$.

Table 1: Information and categories related to the Air Quality Index (AQI)

Air Quality Index	Air Quality	Color code	Health Advisory
0 to 50	Good	Green	Good air quality, there are no health risks.
51 to 100	Moderate	Yellow	People who are unusually sensitive may think about reducing extended or strenuous activity.
101 to 150	Unhealthy for sensitive groups	Orange	Children, elderly adults, and those with heart or lung illness should limit prolonged or strenuous activity.
151 to 200	Unhealthy	Red	Children, elderly adults, and those with heart or lung illness should abstain from strenuous activity for lengthy periods of time. Everyone else should lessen sustained or intense exertion.
201 to 300	Very Unhealthy	Purple	All outdoor physical exercise should be avoided by people with heart or lung illness, elderly people, and kids. Everyone else should abstain from strenuous or extended activity.
>300	Hazardous	Maroon	Healthy persons experience a decline in exercise tolerance, overt symptoms, and the early onset of various diseases.

II. Material and Data Process

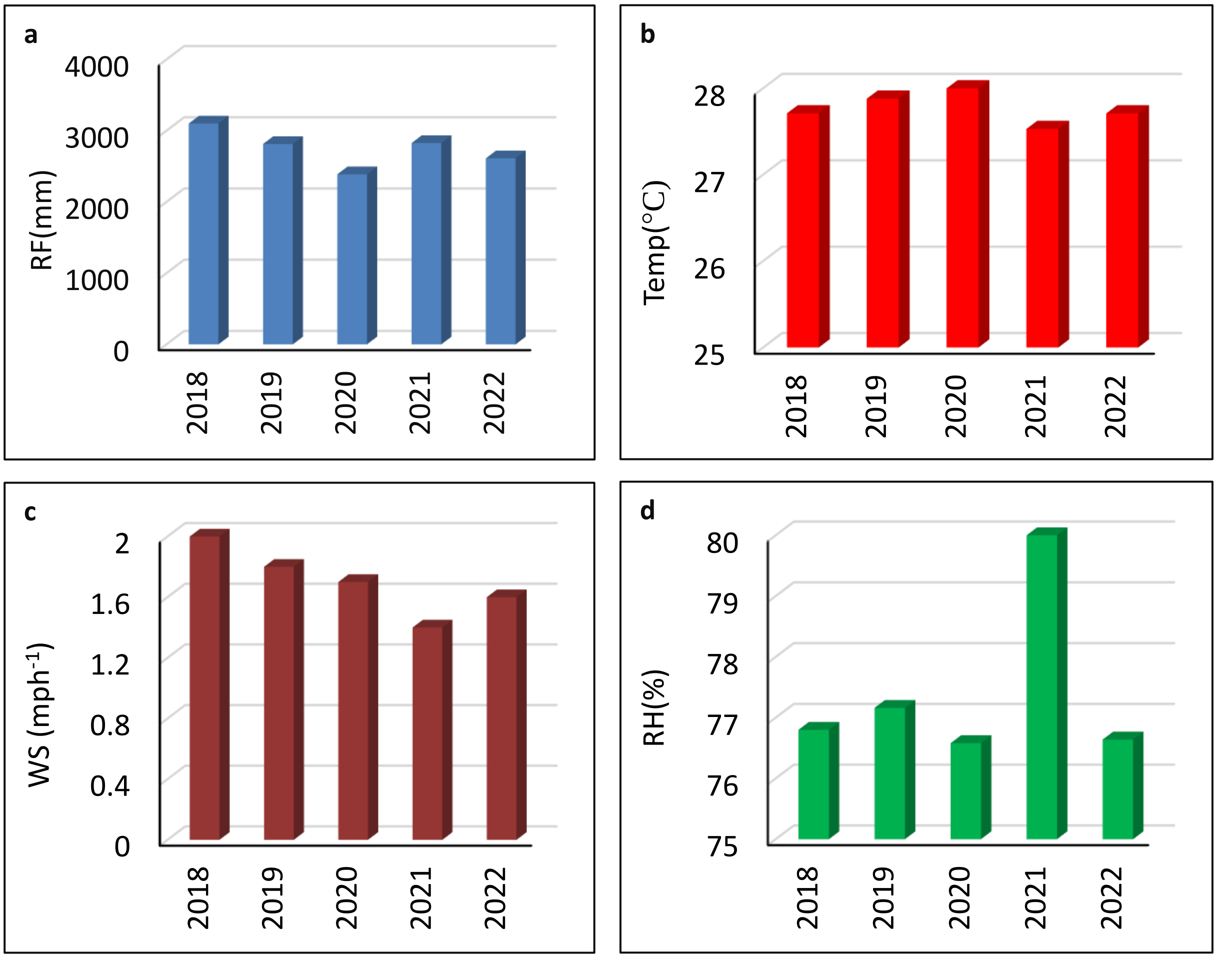
Study Area

More over five million people live in Yangon, the second capital of Myanmar, which is situated in the South Asian nation of Myanmar [14]. It is now time to research the air quality in Yangon due to the city's recent rapid economic development, rise in motorized traffic, expansion of industries, and urbanization. The aim of this study was to evaluate the $PM_{2.5}$ AQI distribution in Yangon's Kaba-aye station. The study site is located at latitude 16°30' N and longitude 96°07' E, and 22 meters above MSL, Kaba-Aye station, Yangon city, Myanmar shown in Figure-1.

Figure 1: Location of study site at Kaba-aye, Yangon, Myanmar

Meteorological Conditions

Myanmar is located in an area with a tropical monsoon climate. The seasons of the climate are divided into (1) the summer season (March to Mid-May), (2) the rainy season (Mid May to October), and (3) the winter season (November to February) [15]. The Köppen system of climate classification classifies Yangon as having a tropical monsoon climate (Am). The precipitation is clearly seasonal, with summer getting the least amount of precipitation and rainy season getting the greatest amount. The region's heavy rainfall throughout the rainy season is the main factor in its classification as a tropical monsoon climatic region. Due to the southwest monsoon winds, the direction of the wind is typically southwest during the rainy season and northeast during the winter [16]. The yearly average temperature is 26.8 °C, with a 6.0 °C variation in the average temperature during the year. August has the city's highest average relative humidity, and it stays warm all year round, with oppressive wet and humid conditions in the dry and muggy and partly cloudy conditions in the dry season [17]. Figures 2 shown the profile of yearly average total rainfall, yearly average temperature, yearly average relative humidity, and yearly average wind speeds from January 2018 to December 2021, respectively in Kaba-Aye station of Yangon.



Figures 2: (a)Yearly total average rainfall, (b) yearly average temperature, (c) yearly average wind speed and (d) yearly average relative humidity from 2018 to 2022

Data Collection

Data of $PM_{2.5}$ Concertation and meteorological parameters (RF, Temp, WS and RH) of Kaba-aye station, Yangon were collected from the Department of Meteorology and Hydrology (DMH), Myanmar for the period of April 2018 to December 2021.

Data Processing

For measuring particulate matter (PM) mass concentrations, we used $PM_{2.5}$ monitor (model FPM-377C) and the following Table 2 expresses and shows the validity or specification, by the 'ß' ray absorption technique. The measurement method is the beta (hereafter called 'ß') ray absorption method. With the ß- ray absorption method, $PM_{2.5}$ in the air is collected by a fitter and the 'ß' ray is irradiated and the transmitted beam intensity is measured to obtain the mass concentration of fine particulate matter. The measured data and various I/O signals can be connected to a central monitoring center via a telemeter. The $PM_{2.5}$ monitor is measuring $PM_{2.5}$ of air quality hourly. Firstly, the $PM_{2.5}$ data are collected from the $PM_{2.5}$ monitor by CF memory card. Secondly, CF memory card is connected with a computer to transfer $PM_{2.5}$ data from the CF card to a computer. And then the $PM_{2.5}$ data are calculated by excels for comparison with Air Quality Index (AQI). Therefore, the $PM_{2.5}$ concentration data calculated AQI values using the EPA approach by excel software [18].

Equation 1 represents the linear interpolation-based model for a single pollutant. The AQI is computed using Eq. 1 and the EPA breakpoint values and pollutant concentration data. Two primary steps are involved in the formulation and AQI: Individual Air Quality Index (IAQI) is calculated for each pollutant ($PM_{2.5}$, PM_{10}, CO, NOx, SO_2, and O_3). In our study, we focus on $PM_{2.5}$ pollutants only and Table 3 displays the pollutant-specific sub-indices for guidance on the AQI utilized for this study [19].

$$AQI = \frac{(AQI_{Hi}) - (AQI_{Lo})}{(Conc_{Hi}) - (Conc_{Lo})} \times \left((\mathbf{Conc_i}) - (Conc_{Lo})\right) + (AQI_{Lo}) \qquad \textit{Equation 1}$$

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Where;
$Conc_i$: Input concentration for a given pollutant
$Conc_{Lo}$: The concentration breakpoint that is less than or equal to $Conc_i$
$Conc_{Hi}$: The concentration breakpoint that is greater than or equal to $Conc_i$
AQI_{Lo} : The AQI value/breakpoint corresponding to $Conc_{Lo}$
AQI_{Hi} : The AQI value/breakpoint corresponding to $Conc_{Hi}$

Table 2: Specification of $PM_{2.5}$ Automatic Monitor

No	Item	Parameter
1	Collection method	The filtration method
2	Sizing method	Cyclone method (VSC cyclone)
3	Suction flow rate	16.7L/min (actual flow rate)
4	Collection Time	59 minutes
5	Minimum display value	0.01 µg/m3
6	Power supply	220VAC, 50/60Hz
7	Allowable ambient temperature and humidity	0 to 40 C 85%RH or less
8	Mass	PM_{10} inlet + $PM_{2.5}$ sizer…3.2kg (excluding downtube)

Table 3: AQI and Concentration Breakpoints by Pollutant

$PM_{2.5}$	Con_{Lo}(µg/m^3)	Con_{Hi}(µg/m^3)	AQI_{LO}	AQI_{Hi}
Good	0.0	12.0	0	50
Moderate	12.1	35.4	51	100
Unhealthy for Sensitive Group	35.5	55.4	101	150
Unhealthy	55.5	150.4	151	200
Very Unhealthy	150.5	250.4	201	300
Hazardous	250.5	500.4	301	500

III. Results and Discussion

After calculation using the EPA approach by Excel software, the average monthly AQI categories regarding $PM_{2.5}$ concentrations are listed in Table 4 along with the results. Generally, the maximum AQI is mostly observed in the months of March and February and the minimum AQI in rainy is reached at the same time each year in October. Although, the meteorological effect in the year 2020 appears more complex than those observed. Because that year's observations of maximum AQI in April and in December previous deviated from the general trend. In 2020, we found that the total rainfall is less than in other years as shown in Figure 2a, and the temperatures as Figure 2b, have been higher than in the other years. However, it was observed that the relative humidity was the lowest that year compared to other years shown Figure 2d. Therefore, we observed that the variability of meteorological conditions from year to year significantly influenced AQI categories.

Table 4: Monthly AQI categories regarding $PM_{2.5}$ parameters

Time Period	AQI											
	Summer			Rainy					Winter			
	M	A	M	J	J	A	S	O	N	D	J	F
2018	*	93	57	**50**	42	52	50	70	105	110	*	*
2019	**112**	102	74	**42**	42	42	50	59	60	68	117	**132**
2020	**76**	**107**	**55**	**17**	**17**	**33**	**50**	**50**	**107**	**134**	**74**	**80**
2021	**147**	87	53	**35**	29	29	42	53	89	127	153	**157**
2022	**112**	87	61	**50**	29	29	33	59	89	93	134	**144**

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Yearly critical air quality index

Figure 3 shows the AQI category frequencies with respect to $PM_{2.5}$ from 2018 to 2022. We observed four different AQI categories regarding the $PM_{2.5}$ parameters (good, moderate, unhealthy for sensitive groups, and unhealthy) and the highest or unhealthy group of AQI categories occurred in the winter season of 2021. Especially, we found that the amount of rain that occurred on average in the winter season of that year was 50 mm, about three and four times less than what occurred in the winter of 2018 (222mm) and 2022 (275mm) respectively shown in Figure 4. As rainfall and AQI are significantly inversely correlated, the low precipitation levels accelerated the accumulation of pollutants in the atmosphere and raised AQI. Therefore, this result is consistent with the study report [20] that the seasonal fluctuation of $PM_{2.5}$ concentration in urban areas is significantly influenced by variations in rainfall from year to year. As shown in Figure 2c and d, WS had lower than in other years and the RH had higher than in other years. Therefore, the high RH during the winter season increase particle production by condensation, and there became higher $PM_{2.5}$ concentrations.

Due to the abovementioned factors, moderate and unhealthy AQI categories for $PM_{2.5}$ characteristics for sensitive groups of people have been quantitatively increasing each year, as shown in Figure 5. Moreover, we observed that the annual trend of $PM_{2.5}$ concentration significantly increased at the rate of 1.8 $\mu g/m^3$ per year shown in Figure 6. Therefore, during the study years, there was a larger potential health risk associated with AQI for those categories, as shown in Table 1 people who are extremely sensitive may think about cutting back on extended or strenuous activity and people who children, elderly adults, and those with lung or heart illness should limit strenuous activity for lengthy periods of time.

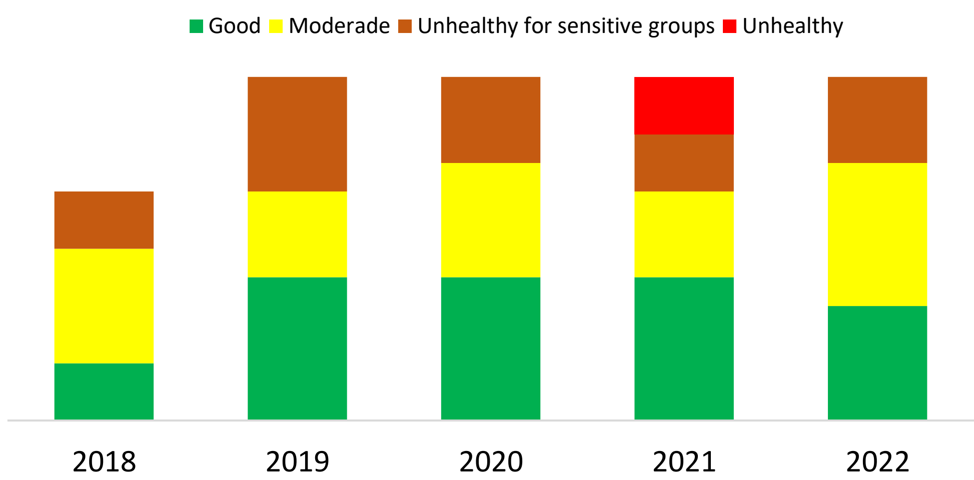

Figure 3: Yearly frequencies of each AQI categories

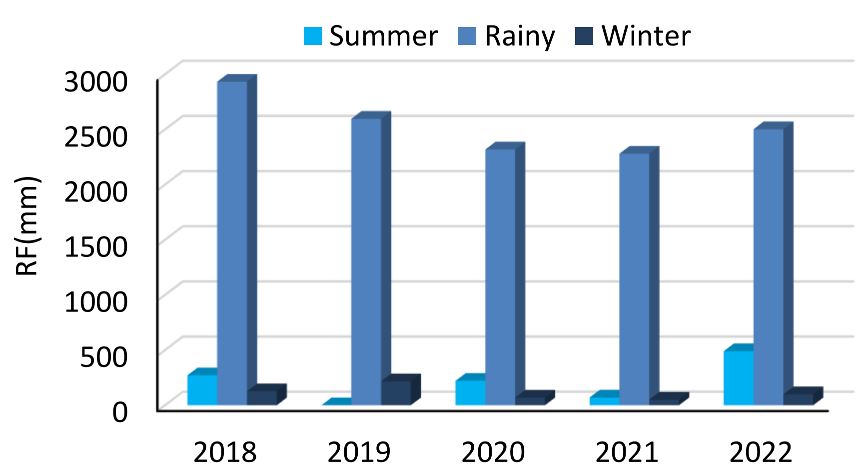

Figure 4: Seasonal frequencies of total average rainfall from 2018 to 2022

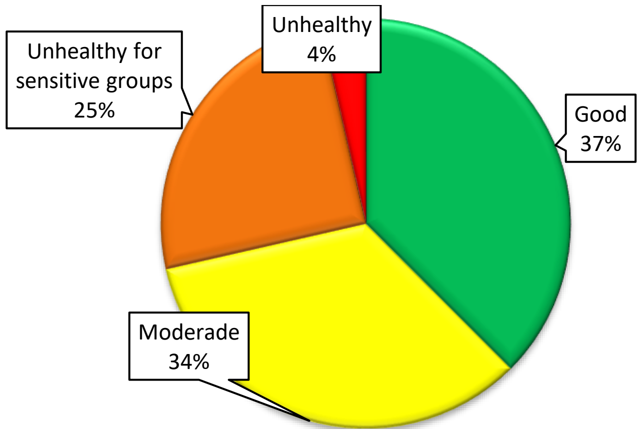

Figure 5: The quantitative of AQI frequency for each year

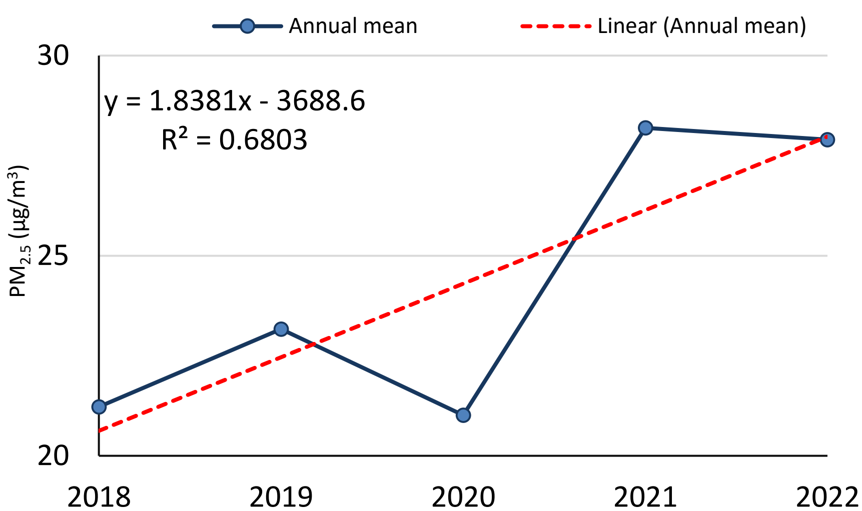

Figure 6: Annual mean $PM_{2.5}$ concentration

Seasonal variation on AQI

According to these [21] and [22] research, high $PM_{2.5}$ concentrations in the winter are caused on by a combination of elevated emissions from heating sources and a low boundary layer height. In our research, as the result of Figure 7, the highest AQI was in the winter season and the lowest was in the monsoon period of the rainy season. The results indicated that the possible health concerns associated with AQI were high in the winter. Therefore, mostly is good and moderate in the rainy season and moderate and unhealthy for sensitive groups of persons in the summer and winter seasons. Also, we noted that meteorological parameters including RF, WE, Temp, and RF are believed to influence the motion and dispersion of air pollutants in the atmosphere. Because in our study area, we found that AQI level in the summer-to-rainy transition period of May to June has a significant drop and in the transition periods of October to November in the rainy season to winter seasons, have a significant rise shown in Figure 8.

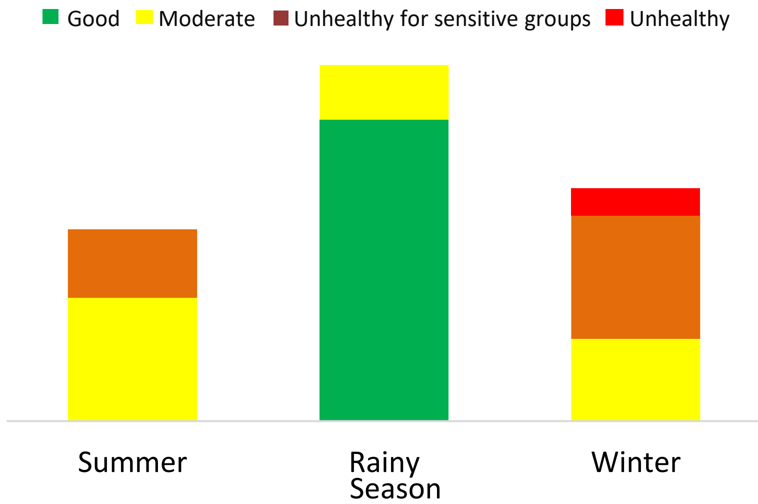

Figure 7: Seasonal frequencies of each AQI categories

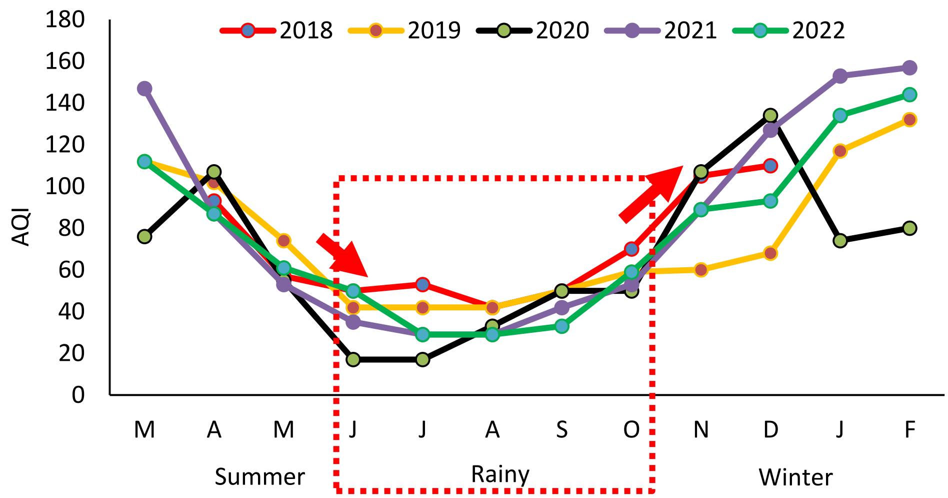

Figure 8: Seasonal variation trend of AQI

IV. Conclusion

We investigated for Kaba-Aye station of Yangon the preliminary analysis of $PM_{2.5}$ concentration and AQI and its relation to the meteorological parameters. We observed four different AQI categories regarding the $PM_{2.5}$ parameters (good, moderate, unhealthy for sensitive groups, and unhealthy) and the highest or unhealthy group of AQI categories occurred in the winter season of 2021. Then moderate and unhealthy for sensitive groups of people in the AQI categories regarding $PM_{2.5}$ parameters had been happening more quantitatively occurring each year. The meteorological parameters and yearly variations of their relationships with $PM_{2.5}$ exist in the years of April 2018 to December 2022 of study. The annual trend of $PM_{2.5}$ concentration significantly increased at the rate of 1.8 μg/m^3 per year. The maximum and minimum yearly concentrations of $PM_{2.5}$ particles were found to be 68 and 4 μg/m^3 during the winter and wet seasons, respectively. Additionally, we discovered an effective correlation between $PM_{2.5}$ particle concentration, air quality index (AQI), and rainfall, temperature, and relative humidity.

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