Meteorology / Climate Report
For
MM Port FZE Project ESIA

Executive summary

Overview: Measurement of micro-meteorological parameters within the proposed project area forms an essential part of the baseline meteorological and climatic assessment of the area. Both measured primary data recorded at the proposed project site and collected historical secondary meteorological data were used to provide an understanding of the short-term and long-term meteorological scenario and weather conditions of the proposed project area.

Methodology: Field monitoring of diurnal meteorological parameters at the proposed project site was carried out from the 3rd of July to 20th of July 2023. The methodology adopted and employed for meteorological assessment and monitoring was in compliance with standard norms laid down by the Nigerian Meteorological Agency (NiMet). Hourly meteorological data were collected at the proposed project site using a Davis Vantage Pro2™ Plus Automated Weather Station (AWS) mounted in an open space at the proposed project site. In addition, a five year (January 2018 to Dec 2022) historical meteorological data were obtained from National Aeronautics and Space Administration (NASA) and the 30years average data from NiMet, Port Harcourt Station.

Results and discussion: The environmental baseline describing the pre-construction meteorology of the proposed project area has been conducted through intensive measurements and analysis of field data (primary data) and historical meteorological parameters (secondary data) of the area. The micro-meteorological parameters assessed in the study were wind speed, wind direction, ambient temperature, relative humidity, barometric air pressure, rainfall, and cloud cover.

Wind speed and direction: The mean wind speed measured at the proposed project area was 1.84±0.4m/s; while the mean value of the historical data was 1.81±0.25m/s. Both the field data and the historical data indicated no period of calmness in the proposed project environment. The absence of calm conditions indicates the dominance of unstable atmosphere, which will favour the dispersion

of air pollutants during the construction and operation of the proposed project. The study reveals the prevalence northeast (NE) wind in the dry season months (January, February, March and December), and southwest (SW) wind in the rainy season months. The dominance of South-Westerly (SW) wind in the area was due to the long period of rainy season that characterized the area. This suggests that air pollutants would be dispersed towards the northern direction in the rainy season and towards the southern direction in the dry season.

Temperature: The mean temperature measured at the proposed project area was 25.81 ± 1.22^{0}C; while the mean value of the secondary data was 28.76 ± 0.96^{0}C. The project area exhibits the characteristics of an unstable atmospheric condition, which prevents temperature inversion and favours air pollutants dispersion. The moderate levels of temperature observed in the area may result in the formation of photochemical oxidants such as ground-level ozone. The project area exhibits the characteristics of an unstable atmospheric condition, which prevents temperature inversion and favours air pollutants dispersion.

Relative humidity: The mean relative humidity measured at the proposed project area was 92.69±6.17; while the mean value of the historical data was 88.92±4.98%. Relative humidity was high in the rainy season months and low in the dry season months. Relative humidity was observed to be high when there was overcast cloud and low when it was sunny during field monitoring. High relative humidity will tend to wash dissolved air pollutants (SO_2 and NO_2 and suspended particles) out of the atmosphere.

Barometric air pressure: The mean wind speed measured at the proposed project area was 101.21±0.14kPa; while the mean value of the five-year secondary data was 101.02±0.16kPa. Both the measured field data and the secondary data indicated the barometric air pressure in the project area was relatively constant. The project area frequently experiences low pressure in the rainy season, which is associated with clouds, high winds, warm air, precipitation, and tropical storms. The area also experiences high pressure in the dry season, which is associated with clear sky and high long wave solar radiation or insolation.

Cloud covers: A cloudy weather condition was observed in the proposed project area during the period of field monitoring during day hours. Cloud covers ranging between 5 and 8 Oktas, with average values between 6 and 7.5Oktas were observed in the project area. A lofty cloudy weather of this nature is a common characteristic of the proposed project area during the months of rainy season. Sunny days are observed during dry season and hence minimal cloud cover, this may tend to encourage unstable atmospheric conditions that promotes atmospheric emission dispersions.

Rainfall: The daily rainfall values measured at the proposed project area ranged from 8.2mm to 68.4mm; while the monthly mean values of the secondary data ranged from 21.44mm to 431.34mm. The secondary data indicated that monthly maximum amount of average rainfall occurs in the months of June, July, August, and September indicating the periods of peak rainfall in the Onne, Eleme area, while monthly minimum average rainfall occurs in the months of December (mean = 21.44mm), followed by January (mean = 23.57mm). The 30 years (1990-2020) secondary data of the proposed project area shows that monthly rainfall between May and October averages over 300 mm, while the monthly averages for the months of dry season are below 40 mm. Rainfall in the project area begins in late March and ends in early-December due to closeness of the area to tropical wet maritime air mass of the Atlantic Ocean. Rainfall in the area is expected to play a significant role in atmospheric wash-out of dissolved air pollutants.

1. Introduction

1.1 Meteorology and Climatic Conditions of the project area

The Niger Delta region, where the proposed project is to be sited is a tropical, warm, and humid/wet region. The area experiences a tropical climate that consists of lengthy wet/rainy season (mid-March to November) and short dry season (December to March). The climate of Onne, Eleme in the Niger Delta region can be classified into two seasons. The rainy season starts in late March and can continue through November. During this period mean temperatures range from a minimum of 21.8°C to a maximum of 32.0°C. Nights are much cooler, and the average humidity is around 80.0%. July and September experience increased rainfall from the Southwest monsoon. During this time, daytime temperatures average around 28.7°C. The dry season starts in December and lasts through March. During this time, temperatures range from a minimum of 20.5°C to a maximum of 36.0°C. Moderate temperatures, wind speed and high relative humidity are common characteristics of the proposed project area (Adejuwon, 2012; Igweze et al., 2014; Yorkor et al., 2017).

The rainy season is characterized by cloudy skies and heavy precipitation/rainfall of about 230 days, with a temporary cessation of rain (a period of short sunshine usually in the month of August) within the raining season commonly referred to as *'August break'* (Ofomata 1975). The August break may last for a period of two weeks. The heaviest precipitation is usually observed in the months of July and September every year (double Maxima) with an average of 367 mm of rainfall. During the rainy season period, winds are mainly southerly, the sea breeze blows steadily, and sea and river levels usually rise above normal. The complex coastline and low-lying flat topology of the area results in composite surface wind speed patterns, especially during low wind activity when land and sea breezes dominate the surface wind of the area (Yorkor et al., 2017).

December and January are the driest months of the proposed project area (Ofomata, 1975). The dry season harmattan, which climatically influences many regions in West Africa, is also pronounced in the proposed project area. December on average is the driest month of the year, with an average rainfall of 20 mm. Temperatures throughout the year in the area are relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 23°C and 32°C in the area. The relative humidity in the area is often high (80 – 90%) during the raining season and reduced to about 50 – 60% during the dry season because of the drier tropical continental air mass referred to as *harmattan* (Wali, 2017).

2. Methodology

Measured meteorological variables during the field monitoring period provided a useful information for interpretation of the baseline condition of the proposed project area. Measurement of micro-meteorological parameters within the proposed project area during the air quality monitoring exercise forms an essential part of the baseline air quality assessment of the area. Both measured primary data recorded at the proposed project site and collected historical secondary meteorological data were used to provide an understanding of the short-term and long-term meteorological scenario and weather conditions of the proposed project area. These data were also used in the explanation of the variations of meteorological vectors including wind variation scenarios that influence the air quality of the area.

2.1 Primary Data

Field monitoring of diurnal meteorological parameters at the proposed project site was carried out from the 3rd of July to 20th of July 2023. The methodology adopted and employed for meteorological assessment and monitoring was in compliance with standard norms laid down by the Nigerian Meteorological Agency (NiMet). On-site monitoring was conducted for various meteorological variables in order to obtain site specific data. Hourly meteorological data were collected at the proposed project site using a Davis Vantage Pro2™ Plus Automated Weather Station (AWS). Meteorological parameters recorded were wind speed, wind direction, temperature, humidity and rainfall and cloud cover.

The Automated Weather Station (AWS) was set up at N4^{0}40'02.71" and E7^{0}08'44.65" coordinates in an open space at the proposed project site (see Figure 1). The AWS has an Integrated Sensor Suite (ISS), connected with console through WeatherLink software. The weather station is equipped with a solid-state magnetic sensor for wind speed, Wind vane, potentiometer for wind direction, PN Junction Silicon Diode for temperature, Film capacitor element for relative humidity, barometric pressure sensors and Tipping bucket type rain collector. The Davis weather station complies with World Meteorological Organization (WMO) specifications as shown in Table 1. Cloud cover was measured through visibility in Oktas.

Table 1: Weather Station Specifications

Variables	Unit	Range	Accuracy	Resolution	Averaging time
Air temperature	^{o}C	-40 to 60	±0.1^{o}C	0.1^{o}C	1 minute
Relative humidity	%	0 to 100	±5%	1%	
Wind speed	m/s	0 to 67.0	±0.5m/s for ≤5m/s 10% for ≥5m/s	0.5	2 minutes
Wind direction	^{0}	0 to 360	±5%	10^o	2 minutes
Rainfall	mm	0 to 999	3%	0.25mm	
Atmospheric pressure	mbar	610 to 1134	±0.1mbar	0.1mbar	1 minute

Figure 1: Weather station mounted at Project Site

2.2 Secondary Data

Historical data on meteorology also play an important role in identifying the general meteorological status of the proposed project area. Site specific data were compared with historical data in order to identify changes which may have taken place due to the various developments in the area. A five year (January 2018 to December 2022) historical data was obtained from National Aeronautics and Space Administration (NASA). Also, a 30-year meteorological data was obtained from the Nigerian Meteorological Agency (NiMet). The collected historical data include temperature, humidity, rainfall, wind speed, and wind direction recorded on daily basis.

3. Results and discussion

3.1 Field Result

The statistical summary result of the daily (24 hours) averages of meteorological variables obtained in the proposed project site is shown in Table 2. The plots of the trends in daily average diurnal of the meteorological parameters measured at the project site are presented in Figures 2 to 5.

Table 2: Statistical summary meteorological variables measured at proposed project Site.

Date		Wind Speed (M/s)	Temp. (0C)	Rel. hum. (%)	Air Pressure (kPa)	Rainfall (mm)	Cloud cover (Oktas)
03-Jul	Min.	1.49	24.55	75.56	101.15	0.0	5
	Max.	2.40	29.17	97.31	101.44	5.0	8
	Mean	1.91	26.18	90.74	101.28	1.5	
	Stdev.	0.25	1.6	7.88	0.09	1.8	
04-Jul	Min.	1.41	24.65	86.38	101.19	0.0	7
	Max.	2.58	26.98	97.75	101.44	5.9	8
	Mean	1.84	25.55	94.52	101.32	1.4	
	Stdev.	0.31	0.86	4.04	0.08	1.6	
05-Jul	Min.	0.75	24.30	77.62	101.19	0.0	6
	Max.	1.83	27.62	97.88	101.50	15.8	8
	Mean	1.28	25.76	90.73	101.32	2.1	
	Stdev.	0.32	1.14	7.17	0.1	3.4	
06-Jul	Min.	1.40	24.10	72.81	100.89	0.0	6
	Max.	2.53	29.32	97.19	101.20	5.8	8
	Mean	1.88	26.18	88.65	101.07	1.1	
	Stdev.	0.4	1.83	8.9	0.1	1.3	
07-Jul	Min.	1.51	24.36	85.00	101.02	0.0	5
	Max.	2.34	27.11	97.88	101.34	7.9	7
	Mean	1.92	25.46	94.38	101.17	1.2	
	Stdev.	0.22	0.9	4.33	0.09	2.0	
08-Jul	Min.	1.12	24.19	86.75	101.11	0.0	7
	Max.	2.68	26.65	97.12	101.48	3.4	8
	Mean	1.99	25.23	94.15	101.3	0.9	
	Stdev.	0.5	0.84	3.39	0.13	1.1	
09-Jul	Min.	1.20	23.89	77.19	101.20	0.0	7
	Max.	2.07	28.03	97.50	101.56	3.8	7
	Mean	1.62	25.56	91.02	101.37	1.0	
	Stdev.	0.28	1.4	7	0.1	1.1	
10-Jul	Min.	1.10	23.60	70.00	101.07	0.0	6
	Max.	2.09	29.06	97.88	101.46	1.8	7
	Mean	1.65	25.79	89.33	101.24	0.5	
	Stdev.	0.31	1.8	10.16	0.1	0.6	
11-Jul	Min.	1.50	24.16	76.00	100.91	0.0	6
	Max.	2.71	28.69	97.81	101.25	3.7	7
	Mean	2.12	25.96	90.69	101.09	0.7	
	Stdev.	0.43	1.54	7.95	0.1	1.0	
12-Jul	Min.	1.67	24.65	88.00	100.93	0.0	6
	Max.	2.76	26.50	97.25	101.25	5.7	8
	Mean	2.24	25.34	94.61	101.06	1.1	

Date		Wind Speed (M/s)	Temp. (0C)	Rel. hum. (%)	Air Pressure (kPa)	Rainfall (mm)	Cloud cover (Oktas)
	Stdev.	0.34	0.66	3.08	0.1	1.4	
13-Jul	Min.	1.38	24.57	80.94	100.90	0.0	6
	Max.	1.90	27.69	97.19	101.27	3.1	8
	Mean	1.58	25.82	92.16	101.1	0.9	
	Stdev.	0.15	1.13	5.62	0.11	1.0	
14-Jul	Min.	1.42	24.74	81.81	100.95	0.0	6
	Max.	1.91	28.15	97.19	101.31	6.4	7
	Mean	1.67	26.05	92.65	101.11	0.5	
	Stdev.	0.14	1.2	5.52	0.1	1.3	
15-Jul	Min.	1.41	24.80	84.62	100.98	0.0	6
	Max.	1.81	28.02	97.69	101.27	3.6	8
	Mean	1.62	26.11	93.48	101.14	0.7	
	Stdev.	0.11	1.2	4.97	0.09	1.0	
	Min.	1.49	24.53	86.62	100.96	0.0	5
	Max.	2.17	27.19	97.75	101.28	3.1	8
16-Jul	Mean	1.84	25.73	93.86	101.1	0.7	
	Stdev.	0.17	0.94	4.34	0.09	1.0	
17-Jul	Min.	0.98	24.90	83.94	101.04	0.0	5
	Max.	2.68	28.17	97.81	101.37	1.8	7
	Mean	1.88	26.11	94	101.2	0.3	
	Stdev.	0.49	1.13	4.87	0.11	0.6	
18-Jul	Min.	1.19	24.92	90.00	101.14	0.0	5
	Max.	2.98	26.70	97.81	101.44	2.1	6
	Mean	1.99	25.69	95.31	101.3	0.4	
	Stdev.	0.42	0.65	2.89	0.09	0.6	
19-Jul	Min.	1.44	24.75	85.19	101.14	0.0	5
	Max.	2.55	27.97	98.12	101.39	3.1	7
	Mean	1.94	26.1	94.53	101.28	0.8	
	Stdev.	0.32	1.08	4.48	0.07	0.8	
20-Jul	Min.	1.61	24.85	86.19	101.09	0.0	5
	Max.	2.89	27.44	97.81	101.41	13.4	6
	Mean	2.2	25.93	93.59	101.26	3.2	
	Stdev.	0.41	0.95	4.38	0.09	3.4	

3.2 Secondary Result

Statistical summaries of monthly and yearly meteorological variables of the five years data (2018 to 2022) around the project area obtained from National Aeronautics and Space Administration (NASA) are presented in Tables 3 and 4 respectively. The 30 year monthly average meteorological data obtained from NiMet is shown in Table 5.

Table 3: Statistical summary of monthly meteorological variables around the project area (2018-2022)

Parameter	Month/ Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp (0C)	Min.	26.97	26.56	26.26	26.73	26.69	25.85	25.73	24.40	25.50	26.22	26.09	26.32
	Max.	32.45	33.54	32.62	31.65	31.14	31.12	28.05	29.96	30.40	31.24	31.55	31.56
	Mean	29.82	30.42	29.56	29.30	28.75	27.93	27.68	27.71	27.68	28.10	28.78	29.51
	Stdev.	1.12	1.31	1.07	1.02	0.89	1.06	0.92	0.97	0.90	1.11	1.22	1.20
Rel.hum. (%)	Min.	63.56	60.12	62.69	66.19	66.50	69.12	70.12	71.75	73.56	72.31	67.44	66.50
	Max.	63.50	91.56	94.06	94.75	95.62	96.12	97.12	95.19	95.44	95.56	96.06	94.12
	Mean	82.97	83.98	88.92	89.34	90.93	91.53	91.34	90.36	91.58	91.04	90.20	84.70
	Stdev.	6.84	6.31	3.01	3.24	2.83	3.00	2.84	2.75	2.36	2.19	3.34	6.51
wind speed (m/s)	Min.	0.05	0.01	0.04	0.20	0.03	0.80	0.74	0.97	0.24	0.12	0.08	0.09
	Max.	4.17	3.00	3.23	3.15	3.28	3.41	3.81	4.46	4.12	2.95	3.56	2.80
	Mean	1.64	1.74	1.79	1.69	1.61	1.76	2.12	2.46	1.91	1.66	1.70	1.63
	Stdev.	0.78	0.70	0.59	0.58	0.52	0.47	0.65	0.74	0.70	0.45	0.56	0.61
Air pres (kPa)	Min.	100.70	100.67	100.58	100.62	100.79	100.80	100.97	100.87	100.89	100.80	100.66	100.68
	Max.	101.18	101.18	101.16	101.18	101.38	101.43	101.47	101.48	101.38	101.30	101.23	101.22
	Mean	100.96	100.88	100.88	100.89	101.03	101.16	101.22	101.22	101.13	101.04	100.94	100.95
	Stdev.	0.10	0.11	0.11	0.12	0.11	0.11	0.10	0.14	0.10	0.09	0.10	0.11
Rainfall (mm)	Min.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Max.	52.48	64.43	173.51	317.93	363.18	419.74	506.23	486.42	521.69	402.58	154.44	33.29
	Mean	23.57	58.53	141.82	206.7	239.84	337.69	428.73	407.5	431.34	281.37	98.62	21.44
	Stdev.	12.64	29.28	47.69	52.15	78.21	103.47	98.64	69.43	110.41	83.46	97.82	27.39
Prominent wind dir.		NE	NE	SE	SW	SW	SW	SW	SW	SW	SW	SW	NE

Source: NASA

Table 4: Statistical summary of yearly meteorological variables around the project area (2018-2022)

Parameter	**Year/ Statistics**	**2018**	**2019**	**2020**	**2021**	**2022**
Temp (0C)	Min.	24.40	25.25	25.49	26.23	25.45
	Max.	33.54	31.81	33.38	32.39	31.93
	Mean	28.70	28.80	28.90	28.68	28.70
	Stdev.	1.49	1.40	1.59	1.28	1.32
Rel.hum. (%)	Min.	63.56	68.06	60.12	62.69	66.50
	Max.	95.49	95.62	96.06	95.75	95.38
	Mean	89.10	88.90	88.50	89.60	88.72
	Stdev.	5.09	5.03	5.52	4.05	4.66

Parameter	Year/ Statistics	2018	2019	2020	2021	2022
wind speed (m/s)	Min.	0.01	0.04	0.05	0.02	0.03
	Max.	4.06	3.86	4.39	3.81	4.46
	Mean	1.10	1.15	1.20	1.08	1.10
	Stdev.	0.48	0.45	0.44	0.46	0.50
Air pres (kPa)	Min.	100.64	100.68	100.69	100.66	100.58
	Max.	101.43	101.40	101.48	101.47	101.38
	Mean	101.00	101.05	101.10	101.01	101.00
	Stdev.	0.17	0.16	0.14	0.17	0.17
Rainfall (mm)	Min.	0.01	0.01	0.01	0.01	0.01
	Max.	371.35	549.17	418.26	420.15	341.63
	Total	3501.68	3706.17	4053.66	4005.21	2723.46
	Mean	286.71	293.58	278.38	282.57	225.51

Table 5: Average Weather Trend for Port Harcourt (1990-2020)

S/No	Month	Average Temp (^{0}C)	Rainfall (mm)	Cloud Cover (oktas)	Pressure (mbar)	R/H (%)	Wind Speed (m/s)	Prominent Wind Dir.
1	January	33.5	17.2	6.5	1007	74	2.9	NE
2	February	34.2	76.5	6.6	1007	79	2.8	SW
3	March	33.8	95.2	6.8	1006	83	3.6	SW
4	April	31.7	144.1	6.8	1007	83	3.7	SW
5	May	31.9	248.4	7	1007	87	3.8	SW
6	June	30.3	312.2	7	1009	91	3.9	SW
7	July	28.1	368.0	7	1010	92	4.3	SW
8	August	28.6	325.2	7	1010	92	4.3	SW
9	September	28.3	374.5	7	1009	92	4.4	SW
10	October	30.8	241.9	7	1009	89	3.8	SW
11	November	32.4	74.0	6.6	1007	84	2.9	SW
12	December	33.4	20.4	6.5	1007	73	2.6	NE

Source: NIMET, Port Harcourt

4. Discussion

4.1 Wind speed and Wind direction

The result obtained during field monitoring (Table 2) indicated temperate wind speeds around the proposed project area ranging from 0.75m/s to 2.98m/s with a mean deviation of 1.84±0.4m/s. Similarly, analysis of the five years secondary data (Table 3) also indicated temperate wind speeds ranging from 0.01m/s to 4.46m/s with a mean deviation of 1.81±0.25m/s. Monthly analysis of historical data (Table 3) indicates that mean wind speed was minimum (1.61m/s) in May and maximum (2.46m/s) in August. Similarly, Yearly analysis of secondary data (Table 4) indicates that mean wind speed was minimum (1.08m/s) in 2021 and maximum (1.2m/s) in 2020s. Diurnal trend in field data (Figure 2) indicates steady increase in mean wind speed at the proposed project site.

The field data wind speed frequency distribution (Figure 3) indicates three main prevailing wind class of the project area in the range of 0.5 - 2.0m/s, 2.0 – 2.5 and 2.5 - 3.5 m/s, constituting about 37.5%, 25.0% and 33.3% frequencies of occurrences respectively for the wet season. Similarly, analysis of the secondary data (Figure 4) indicated three prevailing wind classes in the range of 0.5 - 2.0m/s, 2.0 - 2.5m/s and 2.5 - 3.5m/s, constituting about 50%, 41.7% and 4.2% frequencies of occurrences respectively for both the wet and dry seasons. Both the field data and the secondary data indicated no period of calmness in the proposed project environment. The absence of calm situation around the project site can be attributed to the sea breeze blows steadily across the area.

A calm weather occurs in a stable atmosphere and is very important to air pollution studies because it is often associated with *temperature inversion*. Inversion refers to a very *stable atmosphere* with vertical temperature increasing with height. This vertical temperature gradient traps pollutant emissions at ground level leading to a condition known as *fumigation*. The absence of calm conditions indicates the dominance of unstable atmosphere, which will favour the dispersion of air pollutants during the construction and operation of the proposed project.

The wind rose plots for the field data and the secondary data are shown in Figures 5 and 6 respectively. The wind roses show the general wind direction and wind speed for each sampling period. It is evident from Figures 5 and 6 that both the field data and secondary data show similar wind rose pattern. The field data wind rose (Figure 5) shows that during this particular sampling period the wind blew from the southwest 29.7% of the time, while the secondary data wind rose (Figure 6) shows that the wind blew from southwest 21.3%, from the south 8.5% and the northeast 4.25% of the time. The statistical analysis of the secondary data (Table 3) indicates the prevalence northeast (NE) wind in the dry season months (January, February, and December); while southwest (SW) wind prevails in the rainy season months. The analysis of both the field and the secondary data shows the dominance of south-westerly (SW) wind in the area, which can be attributed to the long period of rainy season that characterized the area.

Study has shown that wind speed and direction are the parameters that mostly influence pollutants concentrations in the ambient air of the proposed project area and determined the transport and dispersion of air pollutants along prevailing wind of direction Yorkor et al. (2017). It is clear from the wind roses (Figures 5 and 6) that air pollutants would be dispersed towards the northern direction in the rainy season and towards the southern direction in the dry season. These factors will influence pollutant dispersion in the project area during construction and operation of the proposed project. The coastal area where this study was carried out is dominated by the tropical maritime (mT) air-mass from the Atlantic Ocean most time of the year. The influence of this moisture laden wind depends on the position of the counter tropical continental air mass, separated by the inter-tropical discontinuity (ITD) (Adejuwon, 2012).

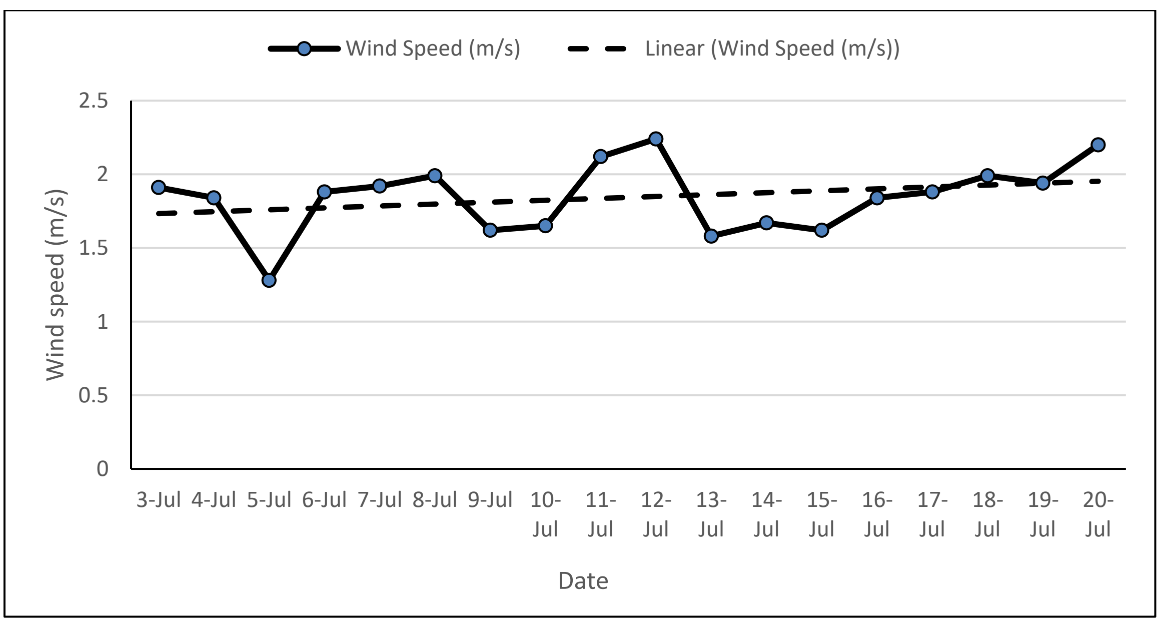

Figure 2**:** Trend in daily average diurnal wind speed (July 3 – July 20, 2023)

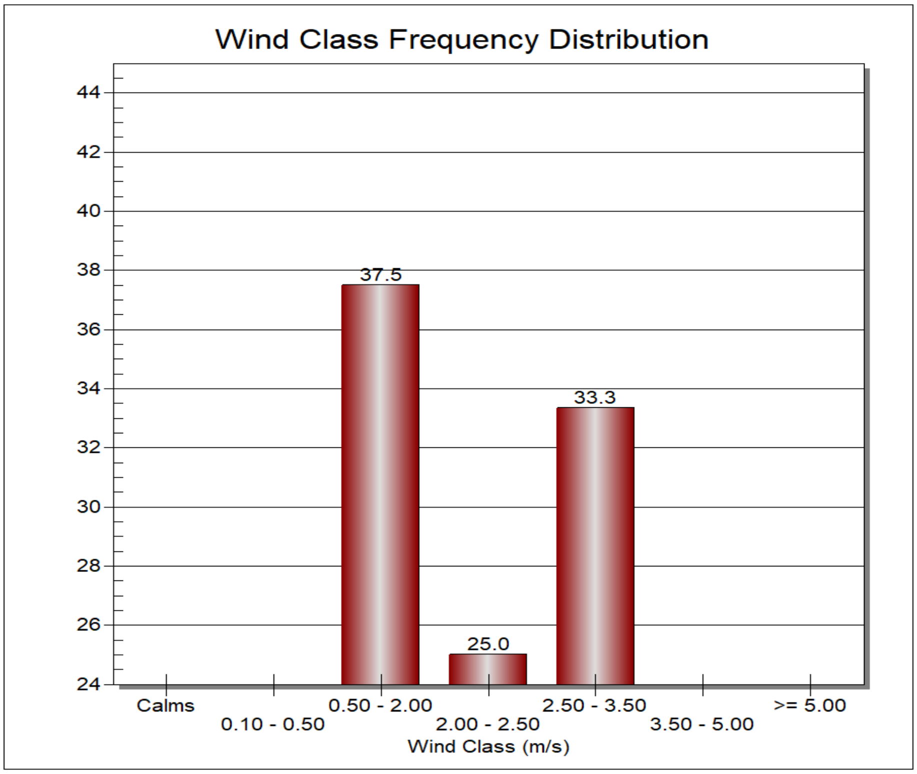

Figure 3: Wind class of field meteorological data (July 3 – July 20, 2023)

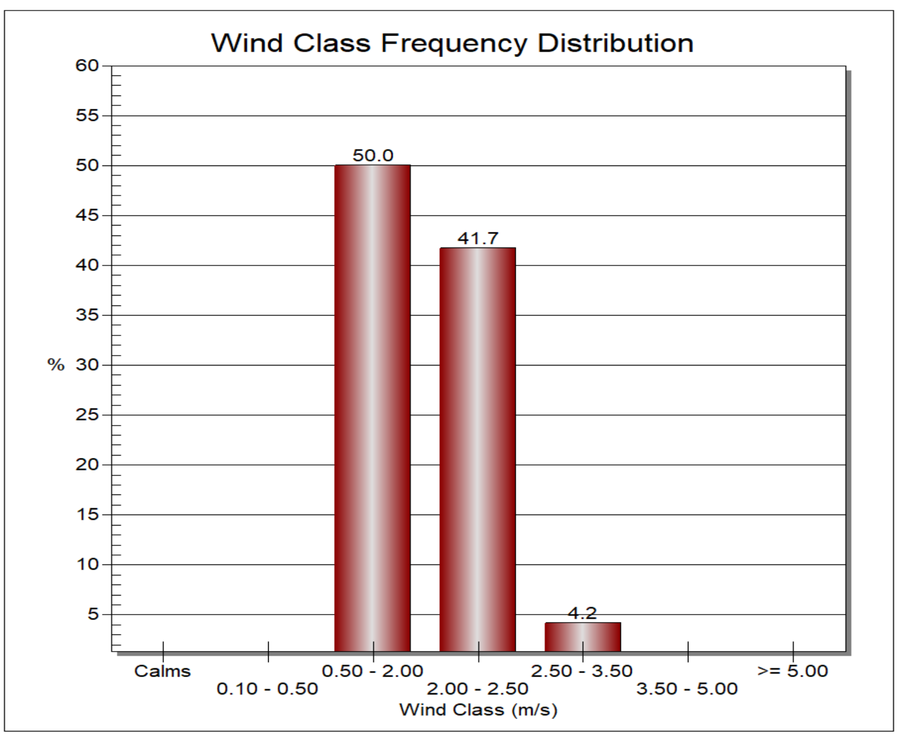

Figure 4: Wind class of secondary meteorological data (2018 – 2022)

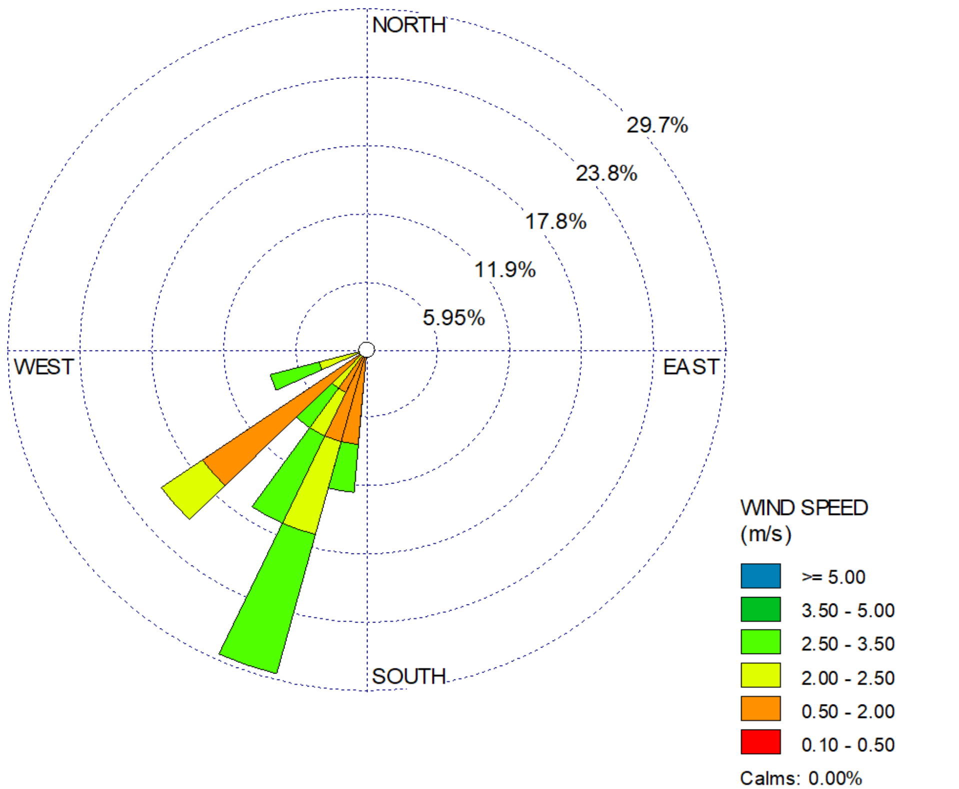

Figure 5: Wind Rose of field meteorological data (July 3 – July 20, 2023)

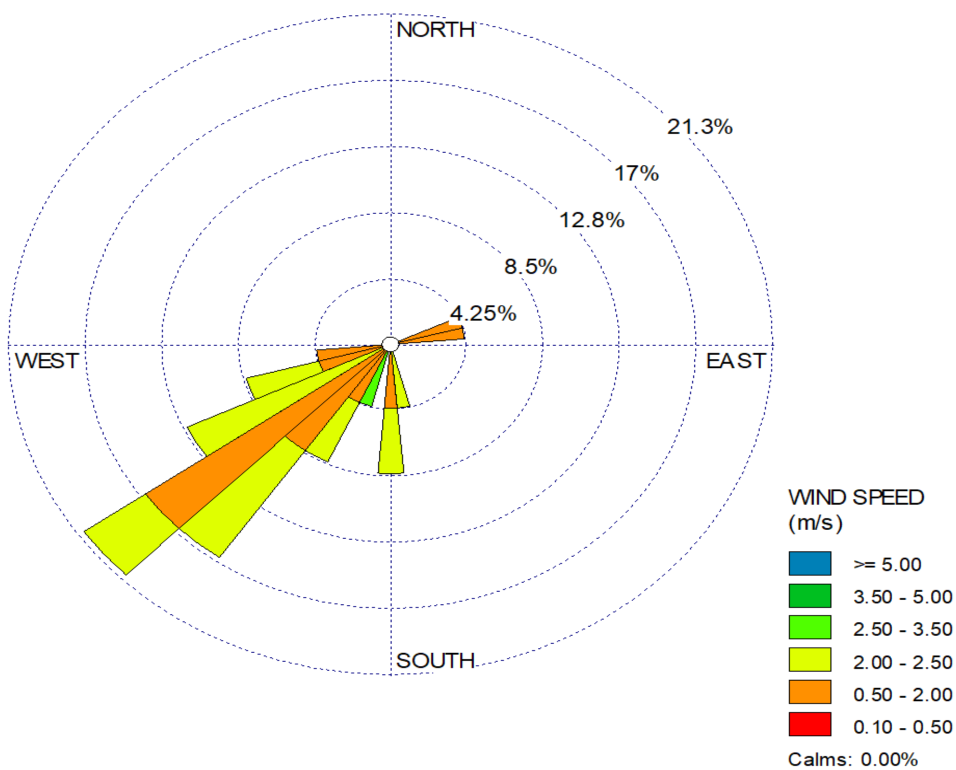

Figure 6: Wind rose of secondary meteorological data (2018 – 2022)

4.2 Temperature

The field result obtained during site monitoring (Table 2) indicates that temperature levels around the project site vary from 23.60^0C to 29.32^0C with a mean deviation of 25.81 ± 1.22^0C. Similarly, analysis of the five years secondary data (Table 3) also indicates that temperature levels ranged from 22.55^0C to 33.54^0C with a mean deviation of 28.76 ± 0.96^0C. Monthly analysis of five years secondary data (Table 3) indicates that mean temperature was minimum (27.71^0C) in August and maximum (30.42^0C) in February. Similarly, Yearly analysis of secondary data (Table 4) indicates that mean temperature was minimum (28.68^0C) in 2021 and maximum (28.9^0C) in 2020. The monthly average climate trend for 30 years as shown in Table 5 indicates that the months of July-September recorded lower temperatures (28^{o}C) due to rainy periods while the months of November to March recorded higher temperatures (32-34^{o}C) due to increased solar radiation with low cloud cover dominant during the dry season.

Temperature is an important weather variable because it determines the movement of water vapour, which brings precipitation. The time variations of diurnal mean temperature levels at the project site are shown in Figure 7. Temperature affects the chemistry of air pollutants as well as their emissions. The moderate levels of temperature observed in the area may result in the formation of small amount of photochemical oxidants such as ground-level ozone. However, the formation of ground-level ozone may increase during periods of high sunshine (high sun intensity) which often take place in the dry season due to thermal convection of solar radiation.

The ambient temperature is depending on the number of solar radiations reaching the surface of the earth and this affects the boundary layer stability condition of micro-meteorological atmospheric environment. Factors such as cloud cover and humidity also affect atmospheric temperature levels. The project area exhibits the characteristics of an unstable atmospheric condition, which prevents temperature inversion and favours air pollutants dispersion. The field data, secondary (NASA and NiMet) data show similar temperature levels in the proposed project area.

4.3 Relative humidity

The diurnal relative humidity measured during field monitoring of the proposed project site (Table 2) ranged from 70.0% to 98.12% with a mean deviation of 92.69 ± 6.17. Similarly, analysis of the secondary data (Table 3) also indicates that relative humidity ranged from 60.12% to 96.12% with a mean deviation of 88.92±4.98%. Monthly analysis of secondary data (Table 3) indicates that mean relative humidity was minimum (82.97%) in January and maximum (91.58%) in September. Similarly, Yearly analysis of secondary data (Table 4) indicates that mean relative humidity was minimum (88.50%) in 2020 and maximum (89.6%) in 2021. In a similar study in Eleme where the proposed project is to be sited, Yorkor et al. (2017) reported an annual mean relative humidity of 80%.

Relative humidity plays important roles in pollutants' wash-out and acid rain formation. When relative humidity (the percentage value of water vapour in the air) rises above some critical point during rainy season, atmospheric SO_2 and NO_2 including suspended particles become soluble and are wash out from the atmosphere (Yorkor et al., 2017). Relative humidity was high in the rainy season months and low in the dry season months. Relative humidity was high when there was overcast cloud and low when it was sunny. Humidity values oscillate in tandem with air temperature, but as opposite fluxes as shown in Figure 7 (Yorkor et al., 2017). High relative humidity of this nature is expected in the project environment due to continuous complete cloud cover and prolong heavy precipitation in the rainy season (Yorkor et al., 2017). The variation of mean relative humidity in project area during field measurement is shown in Figure 7.

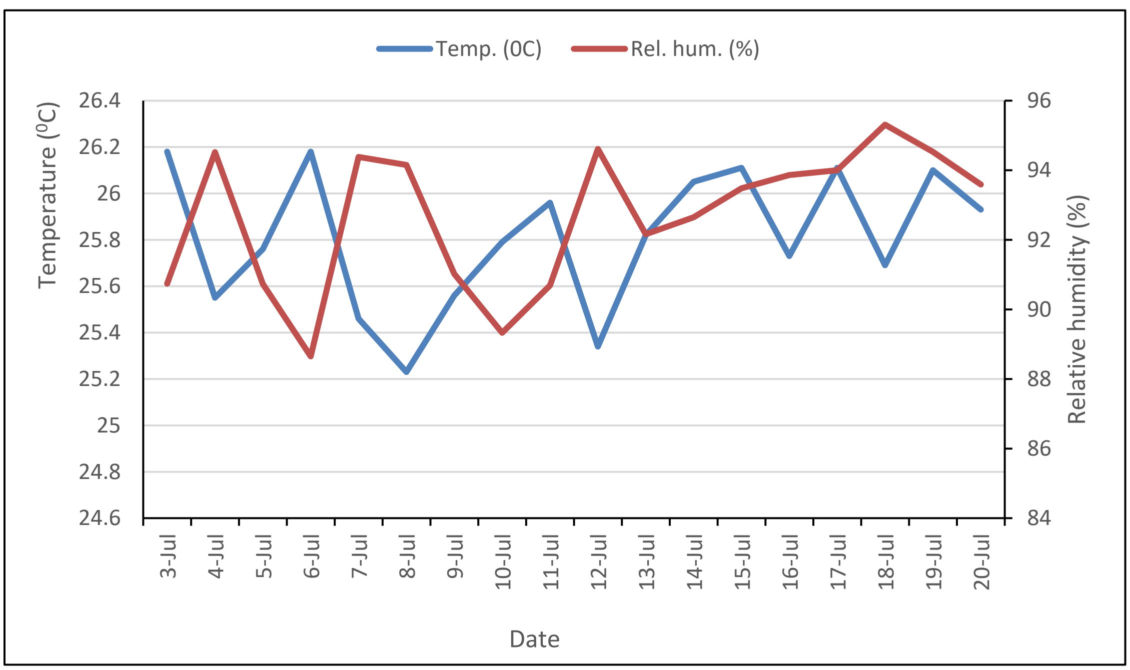

Figure 7**:** Trend in daily average diurnal temperature and relative humidity (July 3 – July 20, 2023)

4.4 Barometric air pressure

The diurnal barometric air pressure measured at the proposed project site (Table 2) ranged from 100.89kPa to 101.56kPa with a mean deviation of 101.21±0.14kPa. Similarly, analysis of the secondary data (Table 3) also indicates that barometric air pressure ranged from 100.58kPa to 101.48kPa with a mean deviation of 101.02±0.16kPa. Monthly analysis of secondary data (Table 3) indicates that mean barometric air pressure was minimum (100.88kPa) in January and March, and maximum (101.22kPa) in July and August. Similarly, Yearly analysis of secondary data (Table 4) indicates that mean barometric air pressure was minimum (1001.00kPa) in 2018 and 2022, and maximum (101.1kPa) in 2019 and 2020. These results fall within the normal range of the barometric air pressure of the earth (97.0kPa to 105.0kPa). Figure 8 shows the variation of diurnal mean barometric air pressure in project area during field measurement.

Barometric air pressure was lower in the dry season months compared to the rainy season months. The atmospheric pressure an area usually determines its wind and weather pattern across the area. The atmosphere exerts more pressure at the earth's surface than it does at higher elevations. Wind speed is in part a function of the steepness of the atmospheric pressure. The winds flow from the higher-pressure areas to the lower pressure areas resulting in unequal heating across the earth's surfaces. The wind speed is zero at the ground surface and rises with elevation to near the speed imposed by the atmospheric pressure gradient (Davis and Masten, 2004). The project area frequently experiences low pressure in the rainy season, which is associated with clouds, high winds, warm air, precipitation, and tropical storms. Contrarily, the project area experiences high pressure in the dry season, which is associated with clear sky and high long wave solar radiation or insolation.

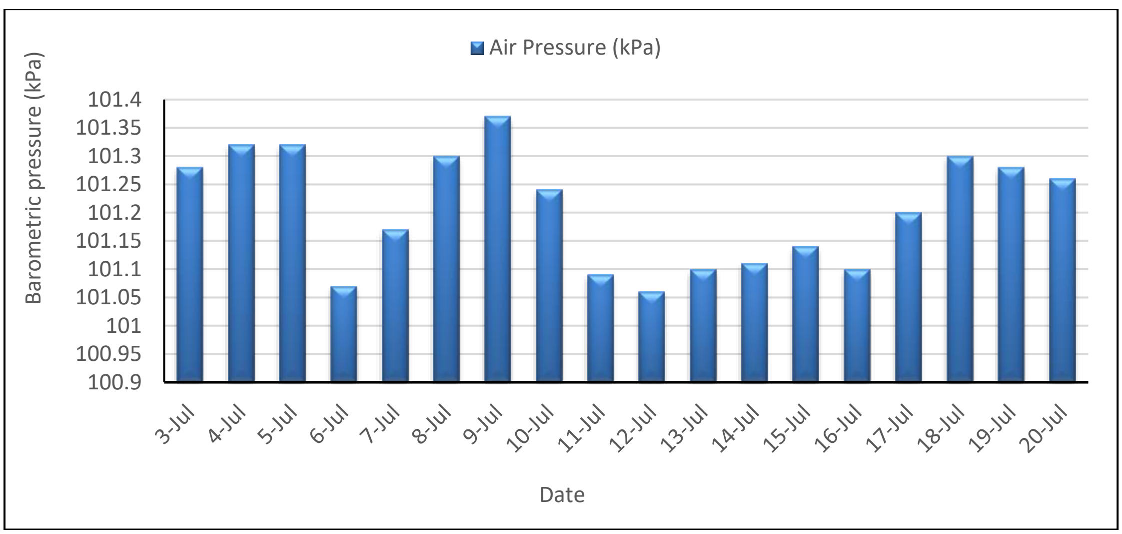

Figure 8**:** Trend in daily average diurnal barometric air pressure (July 3 – July 20, 2023)

4.5 Cloud Cover

A cloudy weather condition was observed in the proposed project area during the period of field monitoring in day hours. The observed cloud covers ranged between 5 and 8 Oktas, with average values between 6 and 7.5Oktas. A lofty cloudy weather of this nature is a common characteristic of the proposed project area during the months of rainy season. Elevated cloud cover causes the temperature of the atmosphere to fall at a rate greater than adiabatic lapse rate. This tends to suppress unstable atmosphere which enhances air emission dispersions. Sunny days are observed during the dry season and hence minimal cloud cover. Lower cloud cover in the dry season encourages unstable atmospheric conditions that promotes atmospheric emission dispersions.

4.6 Rainfall

Some rainfalls were observed during the period of field monitoring. The daily mean values of rainfall measured at the proposed project area ranged from 0.3mm to 3.2mm with an overall daily mean value of 1.0±1.7mm. Similarly, analysis of the secondary data (Table 3) also indicates that the monthly mean values of the secondary data ranged from 21.44mm to 431.34mm with an overall monthly mean of 223.10±155.62mm. Monthly analysis of the five years secondary data (Table 3) indicates that mean rainfall was minimum (21.44mm) in December and maximum (431.34mm) in September. Similarly, Yearly analysis of secondary data (Table 4) indicates that total rainfall was minimum (2723.46mm) in 2022 and maximum (4053.66mm) in 2020. The next highest rainfall was obtained in 2021 with a total rainfall of 4005.21mm. The monthly, mean rainfall distribution of 30 years (1990-2020) for the area is shown in Table 5. Average highest rainfall peaks were attained in September (374mm), July (368mm) and August (325mm). Lowest rainfall values were attained in January (17.2mm) and December (20.4mm). The 30 years (1990-2020) secondary data of the proposed project area shows that monthly rainfall between May and October averages over 300 mm, while the monthly averages for the months of dry season are below 40 mm.

The average amount of rainfall recorded in the project area during field measurement and the average amount of rainfall obtained in December corroborated the study by Ofomata (1975). This study indicates that the Niger delta region where the proposed project will be sited is a very wet region, with monthly mean rainfall ranging between 218.28mm and 408.25mm. The maximum amount of average rainfall occurs in the months of June, July, August and September indicating the periods of peak rainfall in the Onne, Eleme area, while the minimum average rainfall occurs in the months of December and January.

Rainfall in the project area begins in late March and ends in November due to the environment's closeness of the area to tropical wet maritime air mass of the Atlantic Ocean. The field data, secondary (NASA and NiMet) data show similar rainfall pattern in the proposed project area. The amount and distribution of rainfall in the area is such that it plays a vital role in atmospheric wash-out of air pollutants from the atmosphere to other areas of the environment. Rainfall plays a very significant role in environmental and air pollution studies because of its ability to cause wet deposition resulting in pollutants' wash-out from the atmosphere onto land and water. Rainfall has the ability to dissolve pollutants such as NO_2, CO and SO_2 to form acidic compounds resulting in the formation of acid rain, which could be hazardous to humans, plants, animals and the environment in general.

5. Identification of likely Climate Impacts

Analysis of micro-meteorological data showed that the proposed project area exhibits the characteristics of very unstable to slightly unstable atmospheric condition according to Pasquill-Gifford Stability Classes (Davis and Masten, 2004). Atmospheric stability is important as it influences the rate of dispersion of pollutants. Increased amounts of turbulence atmospheric conditions will cause air pollutants to be dispersed more rapidly than with more stable atmospheric conditions. Both the field data and the secondary data indicated three main wind class of the project area ranging from 0.5 to 3.5 m/s (Classes A, B and C), suggesting unstable atmosphere. The climatic condition indicates that the atmosphere will be unstable throughout the year. However, July and August would experience slightly unstable atmosphere.

The project area is dominated by the tropical maritime air-mass from the Atlantic Ocean most time of the year. Air pollutants would be dispersed towards the northern direction in the rainy season and towards the southern direction in the dry season. Temperature levels observed in the area may result in the formation of photochemical oxidants. Rainfall and relative humidity may dissolve pollutants such as NO_2, CO and SO_2 to form acidic compounds resulting in the formation of acid rain. Generally, the proposed project is expected to have negligible impacts on the local climate.

6. Conclusion

Moderate mean wind speed and mean temperature and high mean relative humidity are common characteristics of the proposed project area. Wind speed showed no period of clam atmosphere. Prevailing wind directions were north-easterly in the dry season and south-westerly in the rainy season. Air pollutants would be dispersed towards the northern direction in the rainy season and towards the southern direction in the dry season. The moderate levels of temperature observed in the area may cause the formation of small amount of photochemical oxidants such as ground-level ozone. The project area exhibits the characteristics of an unstable atmospheric condition, which prevents temperature inversion and favours air pollutants dispersion. High levels of relative humidity and rainfall in the project area may result in atmospheric wash-out of dissolved air pollutants during construction and operations. The proposed project is expected to have negligible impacts on the local climate.

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