Global Journal of Research in
Science and Technology
Journal homepage: https://gsjournals.com/gjrst/
ISSN: 2980-4167 (Online)

(RESEARCH ARTICLE)

SEASONAL PARTICULATE MATTER IN EFFURUN, NIGERIA: REANALYSIS OF FIELD RECORDS AND THE LIMITS OF AIR-QUALITY INFERENCE

Omoko Ejiro Newton *

Department of Geology, Faculty of Science, University of Delta, Agbor, P.M.B. 2090, Agbor, Delta State, Nigeria.
* Corresponding Author

ORCID Details
Omoko Ejiro Newton: https://orcid.org/0009-0008-9727-8995

Global Journal of Research in Science and Technology, 2026, 04(04), 001–009

Publication history: Received on 09 October 2026; revised on 17 November 2026; accepted on 19 November 2026

Article DOI: https://doi.org/10.58175/gjrst.2026.4.4.0094

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

Urban air pollution is an environmental concern in the Warri–Effurun corridor of Delta State, Nigeria, where seasonal changes may influence particulate and gaseous pollutant levels. This study assessed seasonal patterns in air-quality and meteorological records from Effurun and considered their relevance for local monitoring. Dry- and wet-season records (20 and 18 observations, respectively) were audited and analysed using descriptive statistics, record-level distributions, and exploratory Pearson correlations. Pollutant and meteorological summaries were compared by season. The analysis retained available observations and interpreted the results as seasonal sample patterns. Mean $PM_{2.5}$ was 108.20 µg m^{-3} in the dry season and 51.56 µg m^{-3} in the wet season; PM_{10} means were 146.10 and 69.22 µg m^{-3}, respectively. Dry-season means were about 2.1 times wet-season means. Mean CO was 1.80 ppm (dry) and 2.11 ppm (wet), while CO_2 averaged 719.50 and 906.89 ppm. Dry-season records were warmer and had lower mean relative humidity and wind speed. HCHO was higher in the dry-season records, whereas TVOC was higher in the wet-season records. Noise means were 90.06 dBA (dry) and 86.86 dBA (wet). Exploratory correlations varied between seasons. The particulate contrast is consistent with differing seasonal conditions but does not demonstrate causation. Other pollutant indicators showed no common seasonal direction. The findings highlight the value of repeated local observations alongside meteorological measurements. The study provides an audit-based seasonal synthesis of Effurun air-quality records, combines pollutant and meteorological summaries, and identifies particulate matter as the clearest seasonal signal for future monitoring.

Keywords: Effurun; Seasonal air quality; Particulate matter; Data quality

1 INTRODUCTION

Air pollution is an important environmental health concern, with fine particulate matter associated in epidemiological research with respiratory and cardiovascular effects (Pope & Dockery, 2006). In rapidly urbanising African settings, traffic, fuel combustion, industry, waste burning, and resuspended dust can occur together, while routine monitoring remains limited. Local measurements can help identify monitoring priorities, but interpretation depends on pollutant-

specific methods, averaging periods, instrument performance, and the representativeness of sampling (Pope & Dockery, 2006; Cohen et al., 2017; Amegah & Agyei-Mensah, 2017).

Pollutants in a field survey are not interchangeable indicators. $PM_{2.5}$ and PM_{10} represent operational particle-size fractions; CO and CO_2 reflect different aspects of combustion and background exchange; HCHO and total volatile organic compounds (TVOCs) require validated units and, for compound-specific interpretation, chemical identification (Omoko, 2026). Portable sensors can provide useful screening information, but humidity, cross-sensitivity, calibration, and sampling duration affect the values they report (Seinfeld & Pandis, 2016; Morawska et al., 2018).

Seasonal conditions can influence particle concentrations through wet removal, road-surface moisture, resuspension, and atmospheric mixing. These processes occur alongside changes in traffic and other emissions, so a difference between seasonal samples cannot by itself identify a cause. This is especially important for small datasets that lack exact sampling times, continuous rainfall records, or repeated measurements at verified sites (Jacob & Winner, 2009; Tai et al., 2010).

The Niger Delta's urban and industrial settings make location-specific monitoring valuable, but differences in instruments and sampling protocols limit direct comparison between studies. Research in Onne and work on construction-related air quality in Effurun provide relevant regional context (Omoko et al., 2022; Edjere et al., 2025). For Effurun, this study reanalyses the available seasonal records to (1) recalculate descriptive statistics, (2) describe seasonal contrasts without assuming paired sites, and (3) identify data-quality requirements for future monitoring. It does not estimate source contributions, regulatory compliance, or health risk.

1.1 Study Area

Effurun, in Uvwie Local Government Area of Delta State, forms part of the Warri–Effurun urban area in the southern Niger Delta. Residential neighbourhoods, markets, road junctions, workshops, and commercial and industrial activity occur in proximity. The study documentation describes measurements across traffic, commercial, residential, and control settings, but the raw tables do not contain a consistent station key or coordinates. The dry-season table contains 20 records, including duplicate labels 13 and 14; the wet-season table contains 18. We therefore treat observations as season-specific records rather than verified matched locations. Elevations range from 4 to 15 m and are used only as descriptive context.

The study was conducted in Effurun, Uvwie Local Government Area, Delta State, Nigeria, within the approximate coordinate range of 5°30′–5°40′ N and 5°42′–5°50′ E. The dry-season sampling period was 1–14 February 2026, and the wet-season period was 1–14 June 2026, with measurements taken daily from 08:00 to 17:00 West Africa Time (WAT). These two-week windows fall within the seasonal groupings reported for the study.

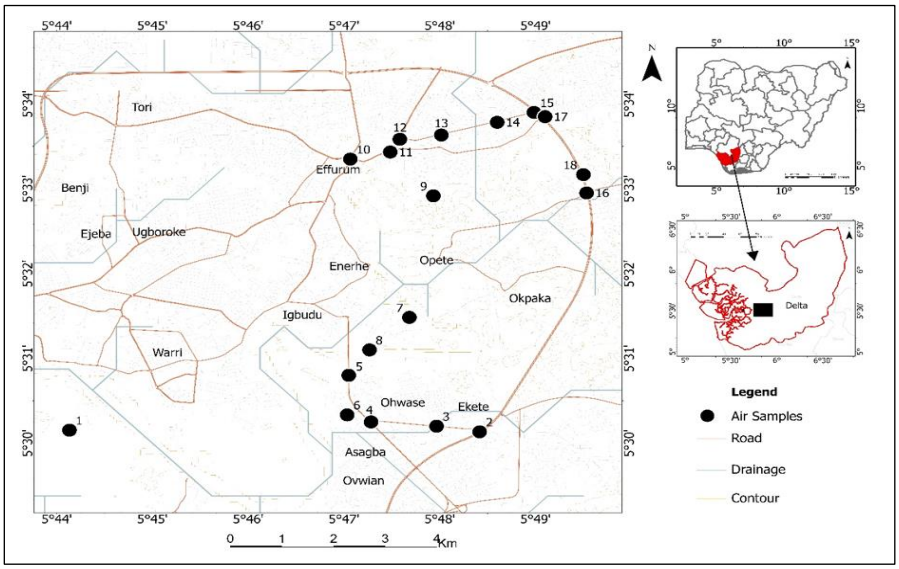

Figure 1: Locator map of Effurun and its environs.

2 METHODOLOGY

This secondary analysis uses the numeric tables and methods description supplied for the Effurun field study. The documentation lists portable air monitors, weather instruments, a sound-level meter, and a handheld GPS. It does not

provide complete field sheets, timestamps, averaging durations, raw instrument exports, calibration records, or a geocoded station register. We distinguish reported procedures from calculations that can be reproduced from the tables. Figure 2 summarises transcription, audit, recalculation, and interpretation. The record counts are 20 in the dry season and 18 in the wet season, despite inconsistent narrative counts of 15 and 18 locations. Because dry-season labels 13 and 14 are repeated and there is no reliable seasonal crosswalk, neutral identifiers were assigned to each row and no one-to-one matching was assumed. All displayed numeric values were retained; potential anomalies were flagged rather than silently corrected, following reproducible data-organisation practice (Broman & Woo, 2018).

Variables include $PM_{2·5}$ and PM_{10} (μg m^{-3}), CO and CO_2 (ppm), temperature (°C), relative humidity (%), wind speed (m s^{-1}), noise (dBA), and elevation (m). HCHO and TVOC units conflict across the source methods, tables, and narrative; those values are reported only as raw numeric outputs and are not compared with guidelines. The unusually high dry-season HCHO value (0.710) was retained, with its influence noted. The documentation reports calibration, but supporting records were unavailable.

For each variable, seasonal record count, mean, standard deviation, median, minimum, and maximum were recalculated from the displayed values. Seasonal contrasts are descriptive; unequal sample sizes and absent site matching do not support paired tests. Pearson correlations are retained only as exploratory summaries because sample size is small and dependence, outliers, and measurement timing are unknown. No causal or predictive interpretation is made. Seasonal AQI categories in the original materials were excluded because the averaging periods and calculation inputs are undocumented; a seasonal mean is not a valid substitute for a pollutant-specific daily AQI.

2.1 Study design and data provenance

The instrument models and software named in the study documentation are not independently verified here. Sensor certification, detection limits, calibration status, zero/span checks, co-location results, sampling duration, and control-site context were not supplied. Portable sensors can support screening when their performance is characterised, but the available records do not establish regulatory-grade accuracy (Snyder et al., 2013; Duvall et al., 2021).

2.2 Variable definitions, units, and screening

2.2.1 Statistical analysis and visualisation

Particulate distributions and selected meteorological variables are shown by season in Figures 3 and 4; Figure 5 displays exploratory correlations. The figures describe the tabulated records and do not represent continuous monitoring or a validated spatial surface. Summary tables report descriptive statistics without significance labels because the sampling unit and independence structure are unknown.

2.3 Quality assurance and interpretive safeguards

All results should be read as screening-level observations. The available tables do not establish 24-hour means, annual averages, legal exceedances, AQI categories, personal exposures, or health outcomes. WHO guideline comparisons require the specified averaging periods and validated measurements; these conditions are not documented here (World Health Organization [WHO], WHO, 2021).

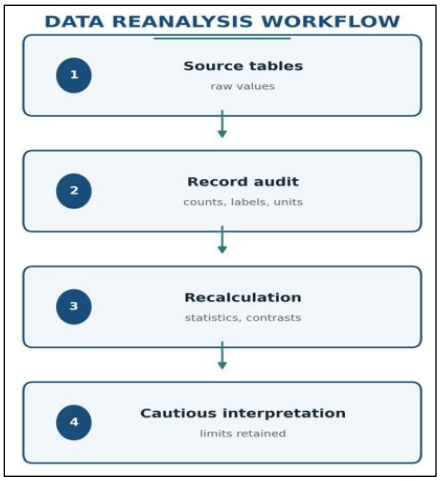

Figure 2: Audit-transparent workflow used to reanalyse the seasonal field records.

3 RESULTS

3.1 Record inventory and data audit

The two seasonal tables contain 38 records in total: 20 dry-season and 18 wet-season. Repeated dry-season labels and conflicting narrative site counts prevent confirmation of the number of unique measured sites. Table 1 summarises the record structure and data-quality flags.

Some distributions are right-skewed: dry-season CO_2 has a mean of 719.50 ppm and median of 471.5 ppm, while wet-season values average 906.89 ppm with a median of 600.5 ppm. Reporting medians and ranges alongside means helps show the influence of high individual readings. The missing timestamps and field notes prevent attribution of these values to persistent locations, brief events, or measurement anomalies.

The ratio of seasonal mean $PM_{2.5}$ to PM_{10} is approximately 0.74 in both seasons. This describes the aggregate size-fraction relationship but does not identify sources, particularly because chemical composition and independent instrument validation are unavailable.

Table 1: Record structure and data-quality audit of the Effurun field records

Audit item	Record status	Interpretive consequence
Dry-season records	20	Data table contains entries numbered 1–18 with duplicate labels 13 and 14.
Wet-season records	18	Data table contains 18 records including a control label.
Coordinates / time stamps	Approximate Effurun reference coordinates: 5.556294° N, 5.784591° E (decimal degrees; approximate town centre). Proposed wet-season period: 1 May–31 October 2026.	Spatial interpolation and temporal averaging cannot be reproduced.
HCHO / TVOC units	$\mu g\ m^{-3}$	Tables and narrative use conflicting unit labels; no conversion or standards comparison.
Instrument quality records	Air Ae Steward six-in-one air-quality monitor, Model JSM-136 (confirm against the instrument label). Serial number and calibration documentation are unavailable.	The model is identified, but the specific unit's identity and calibration cannot be independently verified.
AQI input averaging period	The manuscript does not document the AQI method or the pollutant-specific averaging periods. For reference, NESREA specifies SO_2 and NO_2: 1 hour, 24 hours, and annual; CO: 1 hour and 8 hours; PM_{10}: 24 hours and annual; ozone: 1 hour and 8 hours.	The season-level AQI categories cannot be independently verified as official AQI results. AQI values require pollutant concentrations calculated over the relevant averaging period and the specified AQI method.

3.2 Particulate matter and seasonal contrasts

Recalculated dry-season $PM_{2.5}$ averaged 108.20 $\mu g\ m^{-3}$ (SD 38.59; median 105; range 41–189), compared with 51.56 $\mu g\ m^{-3}$ (SD 42.64; median 30; range 18–170) in the wet-season records. PM_{10} averaged 146.10 $\mu g\ m^{-3}$ (SD 53.02; median 142; range 52–265) in the dry season and 69.22 $\mu g\ m^{-3}$ (SD 55.27; median 41; range 25–225) in the wet season. The dry-to-wet mean ratios are 2.10 for $PM_{2.5}$ and 2.11 for PM_{10}. Individual records overlap, especially in the wet season. Table 2 and Figure 3 show the recalculated summaries and distributions.

Table 2: Recalculated descriptive statistics for pollutant records by season

Pollutant	Reported unit	Dry mean	Dry SD	Dry median	Dry range	Wet mean	Wet SD	Wet median	Wet range
PM2.5	μg m^{-3}	108.200	38.593	105.000	41.000–189.000	51.556	42.636	30.000	18.000–170.000
PM10	μg m^{-3}	146.100	53.015	142.000	52.000–265.000	69.222	55.266	41.000	25.000–225.000
CO	ppm	1.800	0.616	2.000	0.000–3.000	2.111	0.963	2.000	1.000–5.000
CO2	ppm	719.500	602.806	471.500	407.000–2962.000	906.889	588.249	600.500	440.000–2378.000
HCHO	μg m^{-3}	0.084	0.150	0.058	0.003–0.710	0.049	0.019	0.057	0.005–0.068
TVOC	μg m^{-3}	0.311	0.192	0.307	0.022–0.634	0.346	0.242	0.330	0.037–0.971

$PM_{2·5}$ was below PM_{10} in every listed record. A reported dry-season PM_{10} value of 999 μg m^{-3} does not occur in the numeric table and was not used. Means and ranges were recalculated from the rows provided. No source attribution is possible without timestamps, field logs, or chemical measurements.

3.3 Gaseous and organic pollutant indicators

The dry-season CO mean was 1.80 ppm (median 2; range 0–3), compared with 2.11 ppm (median 2; range 1–5) in the wet season. CO_2 averaged 719.50 ppm (median 471.5; range 407–2,962) in the dry season and 906.89 ppm (median 600.5; range 440–2,378) in the wet season. The CO_2 means exceeded the medians in both seasons, as did the wet-season CO mean, suggesting that higher readings influenced these averages. The available records cannot determine whether the observed concentrations were persistent or representative of Effurun as a whole because background measurements, verified sampling times and station coordinates, and instrument-validation records are unavailable.

HCHO averaged 0.0836 in the dry-season records and 0.0488 in the wet-season records, in unresolved raw units; one dry-season reading of 0.710 strongly influenced the dry-season mean. TVOC averaged 0.3112 and 0.3464 in the dry- and wet-season records, respectively, with maxima of 0.634 and 0.971; its units are also unverified. Because the units are unresolved and TVOC is not chemically speciated, these results cannot be compared reliably with health guidelines or interpreted as compound-specific exposure.

3.4 Meteorology, noise, and exploratory associations

Mean temperature was 34.90 °C in the dry-season records and 33.95 °C in the wet-season records. The ranges overlapped (32.00–37.00 °C and 33.40–35.00 °C), so the higher dry-season mean does not indicate that every dry-season observation was warmer. Relative humidity showed a clearer separation: the dry-season range was 30–50%, compared with 62–88% in the wet-season records.

Table 3: Meteorological, elevation, and noise summaries by season

Variable	Unit	Dry mean	Dry SD	Dry range	Wet mean	Wet SD	Wet range
Noise	dBA	90.06	5.46	81.00–99.00	86.86	10.60	60.30–99.20
Temp	°C	34.90	1.33	32.00–37.00	33.95	0.44	33.40–35.00
RH	%	41.95	4.51	30.00–50.00	73.94	7.08	62.00–88.00
Wind	m s^{-1}	1.50	0.57	0.25–2.54	3.61	1.26	1.12–6.13
Elevation	m	9.25	2.38	4.00–15.00	9.17	2.50	4.00–15.00

Mean wind speed was also higher in the wet-season records (3.61 m s^{-1}) than in the dry-season records (1.50 m s^{-1}), although their ranges overlapped. As shown in Figure 4, these measurements describe warmer, drier, and slower-wind

conditions in the dry-season sample. Missing sampling dates and station logs mean that the distributions cannot be assessed for representativeness across Effurun or across each season.

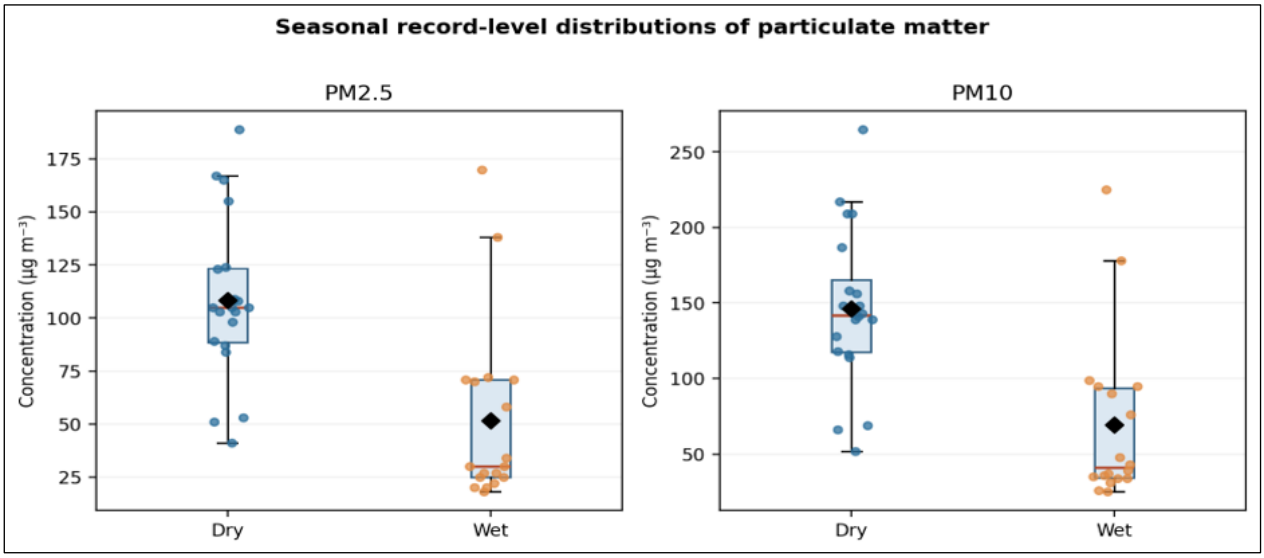

Figure 3: Dry- and wet-season record-level distributions of $PM_{2.5}$ and PM_{10}.

Noise averaged 90.06 dBA in the dry-season records and 86.86 dBA in the wet-season records. The wet-season readings varied more widely (SD 10.60 dBA; range 60.30–99.20 dBA) than the dry-season readings (SD 5.46 dBA; range 81.00–99.00 dBA). However, because the acoustic metric, instrument details, and measurement duration are unspecified, these values do not support formal noise classification or a firm seasonal comparison. Mean elevation was nearly identical in the two groups (9.25 m dry and 9.17 m wet), and both covered the same 4–15 m range. Wind direction was mostly recorded as southwesterly, but the limited observations do not establish a seasonal transport pattern.

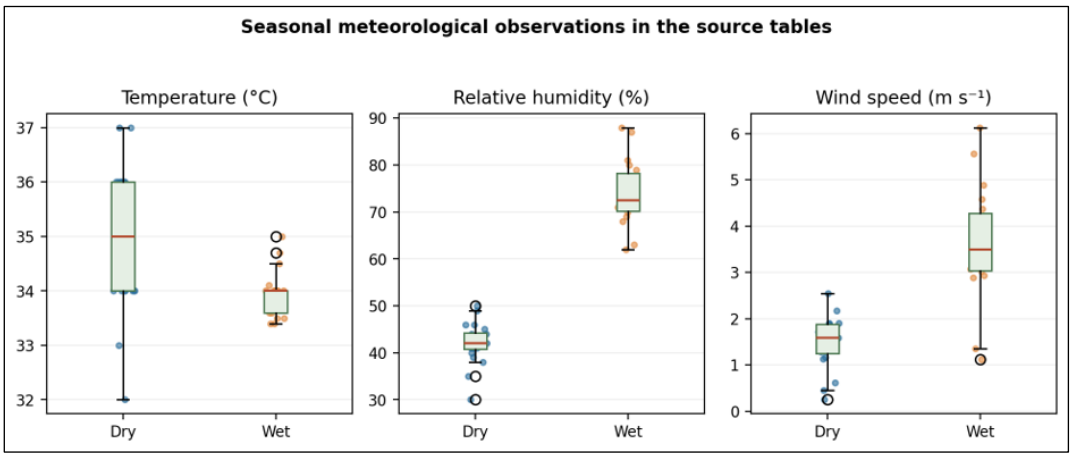

Figure 4: Seasonal distributions of temperature, relative humidity, and wind speed.

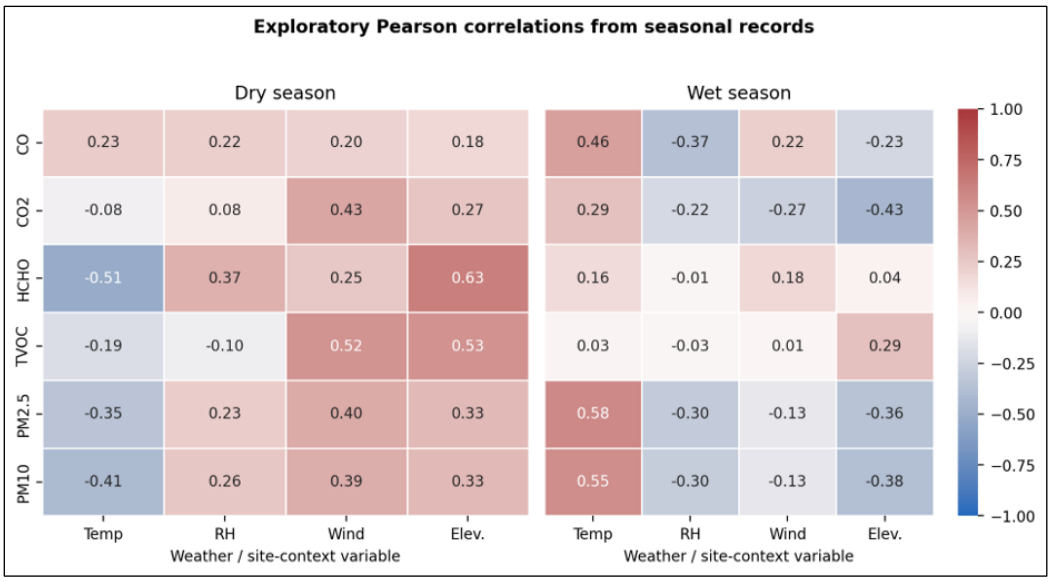

Figure 5: Exploratory Pearson correlations between pollutant records and meteorological or elevation variables.

Figure 5 presents exploratory Pearson correlations rather than evidence of causal relationships. In the dry-season records, HCHO was negatively correlated with temperature ($r = -0.52$) and positively correlated with elevation ($r = 0.63$). The elevation association is particularly sensitive to the high HCHO reading of 0.710, so it should be interpreted cautiously. In the wet-season records, $PM_{2.5}$ and PM_{10} were positively correlated with temperature ($r = 0.58$ and 0.55) and weakly negatively correlated with relative humidity (approximately $r = -0.30$). These associations may guide future investigation, but the small, unmatched samples, missing timestamps, and lack of rainfall and station-level records prevent assessment of their stability or causal interpretation.

4 DISCUSSION

The clearest result is the approximately twofold difference between dry- and wet-season mean particulate records. $PM_{2.5}$ averaged 108.20 µg m^{-3} in the dry season and 51.56 µg m^{-3} in the wet season; PM_{10} averaged 146.10 and 69.22 µg m^{-3}. The distributions overlap, so the result indicates a seasonal contrast in the records rather than uniform conditions at every site. Nigerian studies also report seasonal and site-level variation in particulate matter, but differences in instruments, sampling windows, and site selection make direct ranking across studies inappropriate (Owoade et al., 2021; Wambebe & Duan, 2020).

The contrast is consistent with processes that can reduce suspended particles during wetter periods, including wet deposition and dampened road-dust resuspension. The wet-season records also had higher humidity and wind speed. These factors provide context, but the dataset has no matched rainfall measurements, verified dates, traffic counts, or repeated readings at known sites. Changes in construction, fuel use, traffic, and sensor response could also contribute. The study therefore cannot estimate the share of the difference attributable to rainfall or any other mechanism. Seasonal weather and emissions interact, and local correlations cannot separate their effects (Jacob & Winner, 2009; Tai et al., 2010).

The other pollutant indicators do not follow one common seasonal pattern. Wet-season mean CO and CO_2 were higher, while TVOC averages were similar and HCHO values were strongly affected by one dry-season observation. Inconsistent HCHO/TVOC units prevent comparison with guidelines; aggregate TVOC readings do not identify individual compounds. These columns are best treated as device outputs requiring verification rather than as evidence of exposure levels. Likewise, the particulate means cannot be classified as guideline exceedances because the averaging duration and monitor performance are undocumented (WHO, 2021; Morawska et al., 2018).

The most consequential limitation is the record structure: unmatched seasonal sample sizes, duplicate dry-season labels, contradictory site counts, absent coordinates and timestamps, and unavailable calibration files. These gaps prevent paired inference, defensible spatial interpolation, source apportionment, and health-risk estimation. The descriptive approach avoids overstating precision, but it cannot correct incomplete field metadata. A future campaign should use persistent site identifiers, publish coordinates and dates, specify pollutant-specific averaging periods, retain raw instrument files, and report quality flags. Repeated measurements across sites, days, and times would allow spatial and temporal variation to be distinguished.

Quality assurance should include documented zero and span checks for gas sensors, co-location of portable particle monitors with a reference instrument under local humidity conditions, and records of sampling height, inlet placement, instrument settings, and nearby activity. A fixed-site monitor combined with repeated mobile measurements would help separate background changes from local peaks. Coordinates and a station register are prerequisites for mapping; any interpolated surface should be validated and presented as an estimate rather than a measurement (Crilley et al., 2018; Duvall et al., 2021). The next study should also retain exact timestamps, observation duration, instrument settings, and contemporaneous records of rainfall, traffic, road condition, and nearby activities. This information would make it possible to test whether seasonal contrasts persist after accounting for site and time, and to distinguish brief peaks from sustained concentrations. An open, machine-readable dataset with clear units and quality flags would let independent analysts check each summary and compare Effurun with other Niger Delta locations. These steps are more useful than adding additional index values to the current incomplete record because they improve the evidence needed for interpretation and practical decisions.

The practical implication is to strengthen local monitoring before making site-specific claims or selecting interventions on the basis of these records alone. Dust suppression, road maintenance, construction controls, reduced open burning, and vehicle maintenance are plausible measures, but their local effect should be evaluated with repeated measurements. Particulate matter remains a reasonable monitoring priority because of the broader health evidence, yet this study measured neither personal exposure nor health outcomes. Communication should describe the observed seasonal contrast and its uncertainty, not imply demonstrated disease or a quantified population risk (Pope & Dockery, 2006; Amegah & Agyei-Mensah, 2017). Noise readings also warrant a separate survey because the current records lack defined acoustic metrics and measurement intervals.

5 CONCLUSION

This study provides a seasonal assessment of air-quality records from Effurun, Delta State, Nigeria. The clearest pattern was the higher particulate matter recorded during the dry season. Mean $PM_{2.5}$ was 108.20 μg m^{-3} in the dry-season records and 51.56 μg m^{-3} in the wet-season records. Mean PM_{10} was 146.10 μg m^{-3} and 69.22 μg m^{-3}, respectively. Both particulate means were approximately twice as high in the dry-season sample. The record-level distributions also show variation within each season, indicating that measurements differed among observations rather than following one uniform pattern across Effurun.

The gaseous and organic indicators showed differing seasonal patterns. Mean CO was 1.80 ppm in the dry-season records and 2.11 ppm in the wet-season records. CO_2 averaged 719.50 ppm in the dry season and 906.89 ppm in the wet season, with higher readings influencing the seasonal averages. The recorded HCHO mean was higher in the dry-season sample, while TVOC averaged higher in the wet-season sample. These results indicate that the measured pollutant groups did not all change in the same direction between the two seasonal datasets.

The meteorological observations provide context for the seasonal particulate pattern. Dry-season records were warmer and had lower relative humidity and wind speed on average than wet-season records. Mean temperature was 34.90 °C in the dry season and 33.95 °C in the wet season; relative humidity averaged 41.95% and 73.94%, while wind speed averaged 1.50 and 3.61 m s^{-1}, respectively. Noise readings averaged 90.06 dBA in the dry-season records and 86.86 dBA in the wet-season records. The figures present these seasonal distributions and help show the range of observations around each reported mean.

The exploratory correlations identify relationships that can guide further investigation. In the dry-season records, HCHO was negatively correlated with temperature and positively correlated with elevation. In the wet-season records, $PM_{2.5}$ and PM_{10} were positively correlated with temperature and negatively correlated with relative humidity. These patterns point to useful questions about how meteorological conditions and local characteristics vary alongside measured pollutant concentrations in Effurun. They should be considered associations within the available observations rather than evidence that one variable caused changes in another.

Overall, particulate matter provides the strongest seasonal contrast in the records, while the gaseous, organic, meteorological, and noise indicators show distinct patterns. Continued air-quality monitoring across Effurun can build on these findings by comparing observations across seasons, locations, and times of day. Such monitoring can help identify where elevated particulate readings recur and support the evaluation of practical measures, including road-dust control, improved road maintenance, construction-dust management, and vehicle-emission reduction. The study contributes a local seasonal profile and a basis for further investigation of air-quality conditions in the Warri–Effurun urban area.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

REFERENCES

[1] Amegah, A. K., & Agyei-Mensah, S. (2017). Urban air pollution in Sub-Saharan Africa: Time for action. Environmental Pollution, 220, 738–743. https://doi.org/10.1016/j.envpol.2016.09.042

[2] Broman, K. W., & Woo, K. H. (2018). Data organization in spreadsheets. The American Statistician, 72(1), 2–10. https://doi.org/10.1080/00031305.2017.1375989

[3] Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K., Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., Feigin, V., Freedman, G., Hubbell, B., Jobling, A., Kan, H., Knibbs, L., Liu, Y., Martin, R., Morawska, L., ... Forouzanfar, M. H. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution. The Lancet, 389(10082), 1907–1918. https://doi.org/10.1016/S0140-6736(17)30505-6

[4] Crilley, L. R., Shaw, M., Pound, R., Kramer, L. J., Price, R., Young, S., Lewis, A. C., & Pope, F. D. (2018). Evaluation of a low-cost optical particle counter (Alphasense OPC-N2) for ambient air monitoring. Atmospheric Measurement Techniques, 11, 709–720. https://doi.org/10.5194/amt-11-709-2018

[5] Duvall, R. M., Long, R. W., Beaver, M. R., Kronmiller, K. G., Wheeler, M. D., & Szykman, J. J. (2021). Performance evaluation and community application of low-cost sensors for ozone and particulate matter. Atmospheric Environment, 256, 118445. https://doi.org/10.1016/j.atmosenv.2021.118445

[6] Edjere, O., Ibezute, A. C., Ekuvero, O., Urhibo, V. O., & Okpan, O. (2025). Spatiotemporal variations in ambient air quality during flyover construction in Effurun Metropolis, Delta State, Nigeria: Implications for urban public health. European Journal of Innovative Studies and Sustainability, 1(6), 89–105. https://doi.org/10.59324/ejiss.2025.1(6).08

[7] Jacob, D. J., & Winner, D. A. (2009). Effect of climate change on air quality. Atmospheric Environment, 43(1), 51–63. https://doi.org/10.1016/j.atmosenv.2008.09.051

[8] Morawska, L., Thai, P. K., Liu, X., Asumadu-Sakyi, A., Ayoko, G., Bartonova, A., Bedini, A., Chai, F., Christensen, B., Dunbabin, M., Gao, J., Hagler, G. S. W., Jayaratne, R., Kumar, P., Lau, A. K. H., Louie, P. K. K., Mazaheri, M., Ning, Z., Motme, M., ... Williams, R. (2018). Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? Environment International, 116, 286–299. https://doi.org/10.1016/j.envint.2018.04.018

[9] Omoko, E. N., Onyekuru, S. O., Opara, A. I., Usen, O. S., Ukpong, A. J., & Adikwu, S. O. (2022). Air quality assessment in parts of Onne, Rivers State, southeastern Nigeria. Heliyon, 8(2), e08952. https://doi.org/10.1016/j.heliyon.2022.e08952

[10] Omoko, E. N. (2026). Wet-season co-occurrence of ambient air pollutants and environmental noise in Ughelli, Nigeria: A spatial screening study. GPH-International Journal of Applied Science, 9(10), 39–65. https://doi.org/10.5281/zenodo.23686028

[11] Owoade, O. K., Abiodun, P. O., Omokungbe, O. R., Fawole, O. G., Olise, F. S., Popoola, O. O. M., Jones, R. L., & Hopke, P. K. (2021). Spatial-temporal variation and local source identification of air pollutants in a semi-urban settlement in Nigeria using low-cost sensors. *Aerosol and Air Quality Research, 21*(10), Article 200598. https://doi.org/10.4209/aaqr.200598

[12] Pope, C. A., III, & Dockery, D. W. (2006). Health effects of fine particulate air pollution: Lines that connect. Journal of the Air & Waste Management Association, 56(6), 709–742. https://doi.org/10.1080/10473289.2006.10464485

[13] Seinfeld, J. H., & Pandis, S. N. (2016). Atmospheric chemistry and physics: From air pollution to climate change (3rd ed.). Wiley. https://doi.org/10.1002/9781118947401

[14] Snyder, E. G., Watkins, T. H., Solomon, P. A., Thoma, E. D., Williams, R. W., Hagler, G. S. W., Shelow, D., Hindin, D. A., Kilaru, V. J., & Preuss, P. W. (2013). The changing paradigm of air pollution monitoring. Environmental Science & Technology, 47(20), 11369–11377. https://doi.org/10.1021/es4022602

[15] Tai, A. P. K., Mickley, L. J., & Jacob, D. J. (2010). Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2.5 to climate change. Atmospheric Environment, 44(32), 3976–3984. https://doi.org/10.1016/j.atmosenv.2010.06.060

[16] Wambebe, N. M., & Duan, X. (2020). Air quality levels and health risk assessment of particulate matters in Abuja Municipal Area, Nigeria. Atmosphere, 11(8), 817. https://doi.org/10.3390/atmos11080817

[17] World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. https://doi.org/10.2471/B09333