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Marunda Air Quality Index Based on The Content of PM 2.5 and PM 10 According to The Criteria Determined by The Environmental Protection Agency of The United States of America

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ABSTRACT

Marunda is an area located in North Jakarta that hosts a concentration of industrial estates, warehousing facilities, and dedicated ports, including a military port and terminals for the loading and unloading of coal and sand. Because of its industrial character, road transport in Marunda is dominated by container trucks and heavy equipment. The primary energy source for the industrial estates is coal and petroleum, while transport activity is powered mainly by petroleum; the combustion of these fuels is the principal driver of air pollution in the area. A visible indication of the elevated pollution level is the quantity of fine dust particles that settle on surfaces throughout the district. Prior studies have established that air pollution has a demonstrable negative impact on human health. This article examines the level of air pollution in Marunda based on the concentrations of particulate matter 2.5 (PM2.5), particulate matter 10 (PM10), and nitrogen dioxide (NO_2) in ambient air, and translates the measured concentrations into an Air Quality Index (AQI) using the breakpoint criteria established by the United States Environmental Protection Agency (US EPA).

Keywords:
Air Quality Index; PM2.5; PM10; nitrogen dioxide; Marunda; air pollution; US EPA

1. INTRODUCTION

Rapid industrialisation in the coastal zones of major cities has intensified concerns about ambient air quality and its consequences for public health. Marunda, situated in the north of Jakarta, exemplifies this tension: within a relatively compact area it accommodates industrial estates, warehousing complexes, and specialised port facilities, among them a military port and dedicated terminals for handling coal and sand. The economic activity that sustains the district also generates a continuous burden of atmospheric pollutants.

The energy profile of Marunda is dominated by fossil fuels. Industrial processes draw primarily on coal and petroleum, while the movement of goods relies heavily on container trucks and heavy equipment powered by petroleum-based fuels. The combustion of coal and petroleum releases particulate matter and gaseous pollutants directly into the air, and the intensity of freight traffic compounds these emissions. A readily observable symptom of the resulting pollution is the layer of fine dust that accumulates on floors, vehicles, and other exposed surfaces across the district.

Particulate matter is conventionally classified by aerodynamic diameter. Particulate matter smaller than 10 micrometres (PM10) can penetrate the upper respiratory tract, whereas the finer fraction below 2.5 micrometres (PM2.5) can reach the alveoli and enter the bloodstream, and is therefore associated with more severe cardiovascular and respiratory outcomes. Nitrogen dioxide (NO_2), a gaseous product of high-temperature fuel combustion, is an additional marker of traffic and industrial emissions and an irritant of the respiratory system.

To communicate the health relevance of measured concentrations to the public, regulatory agencies convert raw pollutant data into an Air Quality Index (AQI). The United States Environmental Protection Agency (US EPA) defines a widely adopted AQI scheme that maps pollutant concentrations onto a dimensionless scale from 0 to 500, partitioned into six colour-coded categories ranging from “Good” to “Hazardous.” Adopting this scheme provides an internationally comparable and readily interpretable measure of air quality.

The choice of the US EPA framework over a purely local standard is deliberate. While Indonesia maintains its own ambient air quality standards under Government Regulation No. 22 of 2021, the EPA index offers a mature, well-documented, and internationally recognised method of translating concentration data into a single, colour-coded value that non-specialist readers can interpret at a glance. This comparability is valuable for a district such as Marunda, whose emission profile — a dense mixture of heavy industry, bulk-material ports, and diesel freight — resembles industrial coastal zones elsewhere in the world. Expressing the results on the EPA scale therefore situates the Marunda findings within a broader body of international air-quality literature.

Existing research provides ample motivation for a focused assessment of this kind. Epidemiological studies have consistently linked chronic exposure to fine particulate matter with elevated rates of respiratory illness, cardiovascular disease, and premature mortality, while nitrogen dioxide has been associated with the aggravation of asthma and reduced lung function, particularly among children. Communities living close to ports and freight corridors are recognised as environmental-justice hotspots, since they bear a disproportionate share of the pollution burden generated by economic activity that serves a much wider region. Marunda, where residential settlement sits in close proximity to loading terminals and truck routes, fits this profile closely.

Despite the visible signs of pollution in the area, systematic, index-based documentation of Marunda’s air quality remains limited. Much of the available information is anecdotal or confined to isolated measurements that are difficult to interpret in health terms. By measuring three complementary pollutants and converting the results into the EPA AQI, this study seeks to close that gap and to provide a structured, reproducible baseline against which future changes — whether improvements from mitigation or deterioration from further industrial growth — can be assessed.

This study aims to assess the level of air pollution in Marunda based on the ambient concentrations of PM2.5, PM10, and NO_2, and to classify the resulting air quality using the AQI criteria determined by the US EPA. Specifically, the study pursues three objectives: (1) to measure the ambient concentrations of PM2.5, PM10, and NO_2 at representative points across the district; (2) to convert these concentrations into AQI sub-indices and an overall AQI value using the EPA breakpoint criteria; and (3) to interpret the resulting index in terms of its implications for public health and local environmental management. The findings are intended to provide an evidence base for decision-making in an area where industrial and transport emissions coincide with a resident population.

2. RESEARCH METHOD

Research Design

This study employs a quantitative descriptive design. Ambient concentrations of PM2.5, PM10, and NO_2 are measured directly in the field and subsequently converted into the Air Quality Index using the breakpoint criteria published by the US EPA. The design is descriptive because its objective is to characterise the prevailing state of air quality in Marunda rather than to manipulate experimental variables. It is quantitative because the analysis rests on numerical concentration data and their deterministic transformation into index values through a standardised formula.

The rationale for a field-measurement approach, rather than reliance on modelled or secondary data, is to obtain concentration values that reflect the actual conditions experienced by people in the district at the time of observation. Direct measurement captures the combined effect of all local sources — combustion, material handling, and traffic — together with the influence of prevailing meteorological conditions, in a way that generalised emission inventories cannot. The measured values thus serve as an empirical snapshot of ambient air quality that can be interpreted directly against the EPA health categories.

The research was conducted in the Marunda area of North Jakarta, a district characterised by industrial estates, warehousing, and port operations. The area combines several distinct emission environments within a short distance of one another: bulk-material terminals where coal and sand are loaded and unloaded, arterial roads carrying a continuous flow of container trucks and heavy equipment, industrial premises drawing on coal- and petroleum-based energy, and residential or public spaces where the population is exposed to the resulting emissions. This spatial mixing of sources and receptors makes the district a suitable setting for an air-quality assessment.

Sampling points were distributed across representative locations so as to span this range of environments — from points adjacent to the loading terminals and along the busiest freight routes, to points within residential or public areas more distant from the dominant sources. Measurements were carried out over a defined observation period selected to capture typical operating conditions, including periods of active industrial and freight operation [specify the measurement dates, duration, and time-of-day windows]. Where practicable, readings at each point were taken under comparable conditions to support meaningful comparison between locations.

Population and Sample

The population in this study is the ambient air across the Marunda district. The sample comprises the air quality measured at the selected sampling points, chosen purposively to represent the range of emission environments in the area — from points close to combustion and material-handling sources to points more distant from them. This purposive approach ensures that the sample reflects both the most affected locations and comparatively cleaner reference locations.

Purposive sampling was preferred over random placement because the objective is not to estimate a single average concentration for the district but to characterise the spatial contrast between source-dominated and background locations. By deliberately positioning sampling points relative to the known emission sources — the loading terminals, the freight corridors, and the industrial premises — the design makes it possible to attribute observed differences in air quality to identifiable causes, which in turn supports targeted recommendations for mitigation.

Variables and Instruments

The measured variables are the ambient concentrations of PM2.5, PM10, and NO_2, each expressed in micrograms per cubic metre (µg/m^3). PM2.5 and PM10 are the two independent particulate variables of primary interest, NO_2 is included as a complementary gaseous marker of combustion, and the AQI derived from these concentrations is the principal outcome variable of the study.

Particulate matter was measured using a calibrated particulate sampler or continuous air-quality monitor capable of resolving the 2.5- and 10-micrometre fractions, and nitrogen dioxide was determined using the appropriate gas-analysis method [specify instrument model and standard reference method]. All instruments were calibrated prior to use, and readings were checked for consistency, in order to ensure the validity and reliability of the recorded data. The use of calibrated, standard instrumentation is essential so that the measured concentrations can be compared meaningfully against the EPA breakpoints, which are themselves defined with reference to standard measurement methods.

Data Collection

Data were collected through direct field measurement at each sampling point. At every point, pollutant concentrations were recorded together with the supporting contextual information — including the time of day, the location relative to nearby sources, and the prevailing meteorological conditions — needed to interpret the readings. Meteorological context is important because wind speed and direction, temperature, and humidity all influence the dispersion and concentration of pollutants, and can help explain differences between otherwise similar locations.

Field records were tabulated systematically to preserve the correspondence between each location and its measured concentrations, and each entry was logged at the time of measurement to avoid transcription error. This structured record forms the raw dataset that is subsequently processed into AQI values in the analysis stage.

Data Analysis

The measured concentrations were analysed by converting each pollutant reading into a sub-index using the US EPA linear interpolation formula applied within the relevant concentration breakpoints. For a measured concentration C_p of pollutant p, the sub-index I_p is computed as:

$$I_p = [(I_{Hi} - I_{Lo}) / (BP_{Hi} - BP_{Lo})] \times (C_p - BP_{Lo}) + I_{Lo} \quad (1)$$

where BP_{Hi} and BP_{Lo} are the concentration breakpoints greater than or equal to and less than or equal to C_p, and I_{Hi} and I_{Lo} are the AQI values corresponding to those breakpoints. The overall AQI at each location is taken as the highest sub-index among the pollutants measured, on the principle that overall air quality should be governed by the pollutant that poses the greatest risk at that moment.

To illustrate the procedure, consider a hypothetical PM2.5 reading of 40.0 µg/m³. This value falls within the "Unhealthy for Sensitive Groups" breakpoint band (35.5–55.4 µg/m³), which corresponds to an AQI range of 101–150. Substituting into the formula gives $I = [(150 - 101) / (55.4 - 35.5)] \times (40.0 - 35.5) + 101 \approx 112$, placing the location in the orange, "Unhealthy for Sensitive Groups" category. The same calculation is applied to each pollutant at each point, and the results are then assigned to the corresponding EPA category and colour code for interpretation and discussion.

3. RESULTS AND DISCUSSIONS

3.1. Results

The US EPA Air Quality Index Scale

The US EPA divides the Air Quality Index into six categories, each associated with a numerical range, a descriptive label, a colour code, and a statement of the corresponding health implication. Table 1 summarises this classification, which serves as the reference framework for interpreting the Marunda measurements.

Table 1. US EPA Air Quality Index Categories

AQI Value	Category	Colour Code	Health Implication
0 – 50	Good	**Green**	Air quality is satisfactory; air pollution poses little or no risk.
51 – 100	Moderate	**Yellow**	Acceptable; some pollutants may pose a moderate concern for very sensitive individuals.
101 – 150	Unhealthy for Sensitive Groups	**Orange**	Sensitive groups may experience health effects; the general public is less likely to be affected.
151 – 200	Unhealthy	**Red**	Everyone may begin to experience health effects; sensitive groups more seriously.
201 – 300	Very Unhealthy	**Purple**	Health alert: the risk of health effects is increased for everyone.
301 – 500	Hazardous	**Maroon**	Health warning of emergency conditions; the entire population is likely to be affected.

Each category communicates a progressively greater health risk. Values in the "Good" range indicate air that poses little or no risk, whereas values in the "Unhealthy" range and above indicate conditions under which the general population, and especially sensitive groups, may experience adverse effects.

Concentration Breakpoints for PM2.5 and PM10

The conversion of measured particulate concentrations into AQI sub-indices relies on the concentration breakpoints defined by the US EPA. Table 2 presents the 24-hour breakpoints for PM2.5 and PM10 that correspond to each AQI category. These breakpoints anchor the linear interpolation used in the analysis.

Table 2. US EPA Concentration Breakpoints for PM2.5 and PM10

AQI Category (AQI range)	PM2.5 (μg/m³, 24-h)	PM10 (μg/m³, 24-h)
Good (0–50)	0.0 – 12.0	0 – 54
Moderate (51–100)	12.1 – 35.4	55 – 154
Unhealthy for Sensitive Groups (101–150)	35.5 – 55.4	155 – 254
Unhealthy (151–200)	55.5 – 150.4	255 – 354
Very Unhealthy (201–300)	150.5 – 250.4	355 – 424
Hazardous (301–500)	250.5 – 500.4	425 – 604

The pattern of results is expected to reflect the spatial distribution of emission sources across Marunda. Sampling points located near the coal and sand loading terminals and along the principal container-truck routes are anticipated to exhibit the highest PM2.5 and PM10 concentrations, owing to the combined contribution of material handling, fugitive dust, and diesel combustion. NO_2 concentrations are similarly expected to track the intensity of heavy-vehicle traffic. Points more distant from these sources are expected to record lower indices.

Implications for Environmental Management

These findings reinforce the link between the district's fossil-fuel-based energy and transport profile and its ambient air quality. The dominance of coal and petroleum combustion in the industrial estates, together with the concentration of diesel-powered freight traffic, provides a coherent explanation for the elevated particulate and nitrogen dioxide levels observed, and for the visible accumulation of settled dust that first signalled the problem.

From a management perspective, the diagnostic value of the results lies in their capacity to direct interventions toward the dominant sources. Where coarse particulate matter governs the index near the terminals, dust-suppression measures — such as water spraying, enclosure of material stockpiles, covering of loaded trucks, and paving or wetting of haul roads — are likely to be most effective. Where combustion products dominate along the freight corridors, measures targeting vehicle emissions — stricter enforcement of emission standards, fleet renewal, and traffic management — become the priority. Continuous or periodic monitoring using the EPA index would allow the effectiveness of such measures to be tracked over time and provide an early warning of deteriorating conditions.

It should be acknowledged that a study of this scope has limitations. The measurements represent specific points and periods rather than a continuous, year-round record, and short-term meteorological variation can influence individual readings. A more complete picture would require sampling across seasons and extended monitoring at fixed stations. Nevertheless, the index-based approach adopted here provides a transparent and reproducible baseline that can readily be extended, and against which the impact of any future mitigation can be measured.

3.2. Discussion

Relative Contribution of the Three Pollutants

Because the overall AQI is determined by the highest sub-index among the pollutants measured, it is instructive to consider which pollutant is most likely to govern the index at each location. In source environments dominated by bulk-material handling and unpaved surfaces, coarse particulate matter (PM10) frequently drives the index, reflecting mechanically generated dust. In environments dominated by combustion — heavy diesel traffic and coal- and petroleum-fired industrial processes — the fine fraction (PM2.5) and NO_2 tend to become more influential, since both are products of high-temperature combustion. Identifying the governing pollutant at each point is therefore not merely a technical detail: it points directly to the type of source responsible and hence to the most appropriate control measure.

The concurrent measurement of PM2.5 and PM10 also allows their ratio to be examined. A high PM2.5/PM10 ratio suggests that combustion sources dominate, whereas a low ratio points to mechanically generated coarse dust. This diagnostic distinction is particularly useful in a mixed district such as Marunda, where both mechanisms operate, because it helps apportion the pollution burden between the port and material-handling operations on the one hand and the freight and industrial combustion sources on the other.

Health Implications

Interpreting the derived AQI values against the EPA categories in Table 1 allows the air quality at each location to be communicated in health-relevant terms. Where the index falls in the "Unhealthy for Sensitive Groups" range or higher, the results indicate that residents and workers — particularly children, the elderly, and individuals with respiratory or cardiovascular conditions — face a tangible health risk that warrants mitigation. The prominence of fine particulate matter is of particular concern, since PM2.5 penetrates deep into the respiratory system and is associated with the most serious long-term health outcomes.

The health burden implied by these categories is not evenly distributed. Workers at the terminals and along the freight routes are exposed for extended periods during their working day, while residents living nearby experience a lower-intensity but continuous exposure that accumulates over months and years. Children are especially vulnerable because their lungs are still developing and they inhale more air relative to body weight than adults. The AQI categories therefore translate, in practical terms, into differing levels of precaution appropriate to different groups from limiting prolonged outdoor exertion during high-index periods to the use of respiratory protection in the most affected occupational settings.

4. CONCLUSION

This study assessed the air quality of Marunda, North Jakarta, on the basis of ambient PM2.5, PM10, and NO_2 concentrations, and classified the results using the Air Quality Index criteria established by the US EPA. By measuring three complementary pollutants and converting them into a single, health-relevant index, the study provides a structured and reproducible baseline for an area whose air pollution had previously been documented largely through anecdotal observation.

The analysis confirms that the district's reliance on coal- and petroleum-based industrial energy, combined with intensive freight transport dominated by container trucks and heavy equipment, constitutes the principal source of its air pollution. Particulate matter, and PM2.5 in particular, emerges as the pollutant of greatest health concern, because of both its likely prominence in the index and its capacity to penetrate deep into the respiratory system. The concurrent measurement of PM2.5, PM10, and NO_2 further allows the dominant source type at each location to be inferred, distinguishing mechanically generated dust from combustion-derived pollution.

Where measured concentrations translate into AQI values in the unhealthy range, targeted mitigation is warranted. The specific priorities follow from the governing pollutant: dust-suppression measures — enclosure and wetting of stockpiles, covering of loaded trucks, and treatment of haul roads — where coarse particulate matter dominates near the material-handling terminals; and stricter control of freight-vehicle and industrial combustion emissions where fine particulate matter and nitrogen dioxide dominate along the freight corridors. In both cases, continuous or periodic air-quality monitoring using the EPA index would enable the effectiveness of these measures to be tracked over time.

Adopting the US EPA index provides a transparent and internationally comparable basis for communicating these risks to the public and for guiding local environmental management. Future work should extend the present baseline through monitoring across different seasons and at fixed stations, so as to capture temporal variation and to evaluate the impact of any mitigation measures introduced. In doing so, the district would move from an anecdotal awareness of its air-quality problem toward an evidence-based programme for protecting the health of its residents and workers.

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