

Ambient PM₁₀ levels in selected Bicol cities: A comparative study of highly urbanized and developing areas, 2024

Parde, Gia Joy B. ✉

Central Bicol State University of Agriculture, Philippines (giajoy.parde@cbsua.edu.ph)

Pacala, Ruthie M.

Central Bicol State University of Agriculture, Philippines (ruthie.pacala@cbsua.edu.ph)

Ela Avellana, Joseph Clarence A.

Central Bicol State University of Agriculture, Philippines (josephclarence.ela-avellana@cbsua.edu.ph)



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Abstract

Ambient particulate matter (PM₁₀) is a critical air pollutant associated with respiratory and cardiovascular health risks. This study evaluated and compared annual PM₁₀ concentrations in selected highly urbanized (Naga and Legazpi Cities) and developing (Iriga and Ligao Cities) urban areas of the Bicol Region, Philippines, for 2024. Secondary air quality data from the Department of Environment and Natural Resources – Environmental Management Bureau Region V were analyzed using descriptive statistics to determine annual mean concentrations and assess compliance with the Philippine National Ambient Air Quality Guideline Value (60 µg/Ncm). The annual mean PM₁₀ levels ranged from 21 µg/Ncm in Legazpi City to 36 µg/Ncm in Naga and Iriga Cities, with an overall regional mean of 30.75 µg/Ncm. Group analysis revealed that developing cities exhibited a higher mean concentration (33 µg/Ncm) compared to highly urbanized cities (28.5 µg/Ncm), although all areas remained within the “Good” air quality category. Variations in PM₁₀ levels were attributed to local factors such as road dust resuspension, construction activities, and infrastructure development, rather than urban classification alone. These findings emphasize the need for sustained monitoring and proactive air quality management in developing urban centers to prevent deterioration as urban growth continues. The study provides insights for environmental policy planning and the prioritization of interventions to maintain public health protection under the Philippine Clean Air Act.

Keywords: PM₁₀, ambient air quality, urbanization, Bicol Region, Philippines, particulate matter

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1. Introduction

Ambient air pollution continues to pose serious environmental and public health risks worldwide. Exposure to particulate matter, particularly PM₁₀, has been associated with respiratory illnesses, cardiovascular diseases, and premature mortality (World Health Organization [WHO], 2021). Urbanization often intensifies pollutant emissions due to increased vehicular traffic, construction activities, commercial expansion, and industrial operations. In the Philippines, air quality management is governed by Republic Act No. 8749, which establishes National Ambient Air Quality Guideline Values (NAAQGV) to protect public health and environmental integrity. The annual standard for PM₁₀ is set at 60 µg/Ncm. Monitoring and regulatory enforcement are implemented by the Department of Environment and Natural Resources (DENR) through its Environmental Management Bureau (EMB). While highly urbanized cities are commonly assumed to exhibit higher pollution levels, recent research suggests that particulate concentrations may also be elevated in developing cities due to infrastructure transitions, road dust resuspension, and limited emission control mechanisms (WHO, 2021). Within the Bicol Region, both established urban centers and rapidly developing cities coexist under similar climatic conditions, providing a suitable context for comparative analysis.

This study therefore aims to assess and compare ambient PM₁₀ levels between selected highly urbanized and developing cities in the Bicol Region for 2024 and evaluate their compliance with national standards.

1.1 Objectives of the Study

Generally, the study aims to assess and compare ambient PM₁₀ concentrations in selected highly urbanized and developing cities in the Bicol Region for 2024. Specifically, the objectives of the study are:

1. To describe the annual mean PM₁₀ concentrations of the selected cities.
2. To compare PM₁₀ levels between highly urbanized and developing cities.
3. To evaluate compliance with the National Ambient Air Quality Guideline Value.

1.2 Scope and Limitations

The study only focuses on the PM₁₀ data of year 2025 within the selected four cities (Naga, Iriga, Ligao, and Legazpi cities) in the region. PM_{2.5} data is not included in the scope of study.

2. Methodology

This study employed a descriptive research design using secondary ambient air quality monitoring data for the year 2024 from DENR EMB-Region V which provided monthly PM₁₀ concentrations for each study site. The goal is to assess the ambient air quality status of selected highly urbanized and developing cities in the Bicol Region, with specific focus on particulate matter with aerodynamic diameter of ten micrometers or less (PM₁₀). The study areas included Naga City and Legazpi City, classified as highly urbanized cities, and Ligao and Iriga cities classified as developing urban areas based on administrative status and population characteristics. The selection was guided by administrative classification and spatial comparability. Naga and Iriga cities are both located in Camarines Sur, while Legazpi and Ligao are in Albay. Each highly urbanized city was paired with a developing city within the same province to control large-scale geographic and climatic variations. This provincial pairing strengthens internal validity by minimizing confounding environmental factors such as regional wind

systems, topography, and seasonal meteorological influences.

Although inter-city distances vary moderately, all cities share similar regional atmospheric conditions characteristic of the Bicol Region. This spatial framework enables comparison based primarily on urban development intensity rather than broad geographic differences.

The collected data were organized and summarized using descriptive statistics to determine the annual PM₁₀ levels per city and the mean concentrations for each urbanization group. Comparative analysis was conducted to examine differences in PM₁₀ levels between highly urbanized and developing cities. To assess regulatory compliance, the observed annual mean PM₁₀ concentrations were compared with the Philippine National Ambient Air Quality Guideline Value of 60 µg/Ncm as prescribed under the Implementing Rules and Regulations of Republic Act No. 8749 (Philippine Clean Air Act of 1999). Results were presented using tables and graphical illustrations to facilitate interpretation of spatial variation and urbanization-based comparison. All data processing and visualization were performed using Microsoft Excel. As the study relied solely on secondary environmental monitoring data, no human subjects were involved.

3. Results

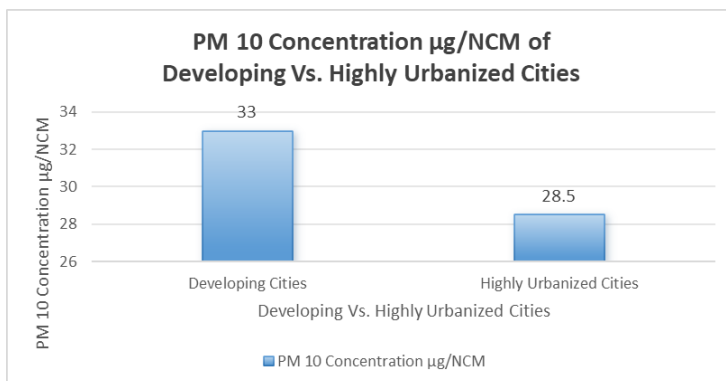
The annual mean PM₁₀ concentrations for selected cities and municipalities in the Bicol Region in 2024 are presented in table 1. Among the cities, PM₁₀ levels ranged from 21 µg/Ncm in Legazpi City to 36 µg/Ncm in Iriga and Naga city, while Ligao City recorded 30 µg/Ncm. The annual mean of all cities in Bicol region are 30.75 µg/Ncm.

Table 1
PM₁₀ Concentration of Bicol region in 2024

City	Classification	PM ₁₀ (µg/Ncm)	Classification	Compliance
Naga City	Highly Urbanized	36	Good	Compliant
Legazpi City	Highly Urbanized	21	Good	Compliant
Iriga City	Developing	36	Good	Compliant
Ligao City	Developing	30	Good	Compliant

When grouped according to level of urbanization, the developing cities of Iriga and Ligao showed a combined mean PM₁₀ concentration of 33 µg/Ncm, likewise with the highly urbanized cities (Naga City and Legazpi City) registered a group mean of 28.5 µg/Ncm that shows in figure 1.

Figure 1: Shows the PM₁₀ Concentration of cities grouped into Highly urbanized and Developing cities in Bicol Region



Comparison with the DENR National Ambient Air Quality Standard for annual PM₁₀ (60 µg/Ncm) indicates that all selected cities remained within the allowable limit for the year 2024. No exceedance of the national guideline value was observed across both highly urbanized and developing areas. Based on Part II, Rule VII, Section 4 (air quality indices) of the Implementing Rules and Regulations of RA 8749 (Philippine Clean Air Act of 1999), the following shall describe the six (6) levels of air quality for Particulate Matter 10 (PM₁₀).

Table 2
PM10 – (24-hour Average)

Air Quality index	Concentration Level
Good	0 – 54 µg/NCM
Fair	55 – 154 µg/NCM
Unhealthy for sensitive groups	155 – 254 µg/NCM
Very Unhealthy	255 – 354 µg/NCM
Acutely unhealthy	355 – 424 µg/NCM
Emergency	425 – 504 µg/NCM

All observed annual mean PM₁₀ concentrations were substantially below the Philippine National Ambient Air Quality Guideline Value of 60 µg/Ncm. Based on the Air Quality Index classification, all selected cities fell under the “Good” air quality category, signifying minimal health risk associated with PM₁₀ exposure during the study period. No exceedance of regulatory limits was recorded in either highly urbanized or developing areas.

4. Discussion

Population Density - Naga City is a 1st class independent component city with a land area of 77.40 square kilometers which constitutes 1.40% of Camarines Sur's total area which represents 10.11% of the total population of Camarines Sur province, or 3.44% of the overall population of the Bicol Region (PhilAtlas). It has a total population of 209,170. (2020 Census, PSA). Legazpi City, a 1st class coastal city of Albay province with land area of 161.61 square kilometers which comprises 6.28% of Albay's total area and accounts 15.24% of the total population of the province, or 3.45% of the overall population of the Bicol Region. 2024 Census of PSA, the city has a total of 210,616 population. Ligao city, a 4th class city in Albay with a land area of 246.75 square kilometers, and 9.58% of Albay's total area. It represents 8.59% of the total population of Albay province, or 1.94% of the overall population of the Bicol Region. It has 119,779 population as of 2024 Census of PSA. Iriga city, a 3rd class city of Camarines Sur has a land area of 137.35 square kilometers. Its population as determined by the 2020 Census was 114,457, which represents 5.53% of the total population of Camarines Sur province, or 1.88% of the overall population of the region. Based on the population per city, Naga City and Legazpi City accounts for the increasing population than Iriga and Ligao City. Specifically, Legazpi City has a population of 210, 616 population which can be considered as highly dense population considering 50% of the city's population residing within the compact, urbanized coastal zones commonly resulting in intense urbanization, high-rise living, and increased strain on infrastructure which relatively has an effect in the air quality within the city.

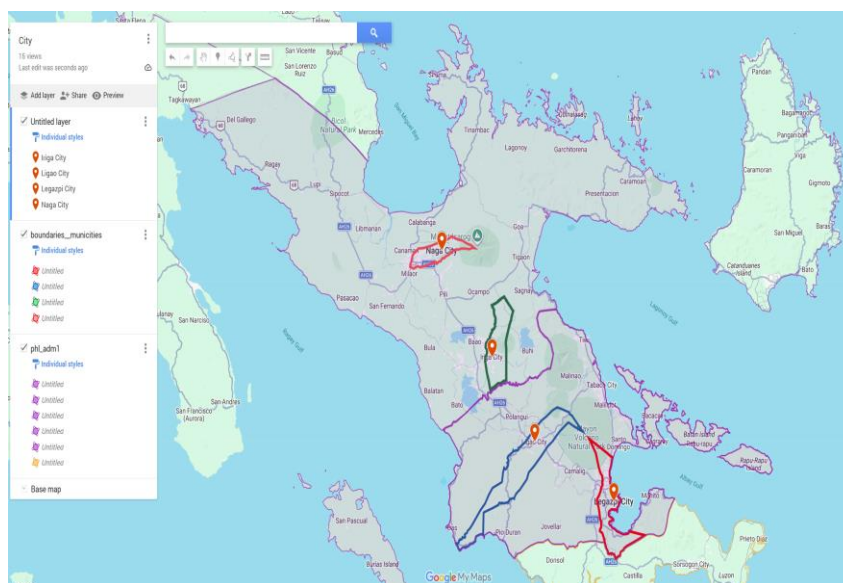


Figure 2: Map and geographical location of Naga City, Iriga City, Ligao City, and Legazpi City

Particulate Matter 10 (PM₁₀) - Department of Environmental and Natural Resources (DENR) through Environmental Management Bureau (EMB) monitors particulate matter (PM₁₀, PM_{2.5}) in Bicol region. PM₁₀ (Particulate Matter ≤ 10 micrometers), refers to particles 10 micrometers (µm) or smaller. These are coarse particles, about 1/7 the width of a human hair. Common sources of these are road dust, construction activities, quarrying mining, wind-blown soil, agricultural activities, and volcanic ash especially those with volcanoes within the area. PM₁₀ can trigger health effects such as nose, throat, and upper airways irritation, can trigger asthma and can cause coughing and breathing discomfort caused by the deposits in the upper respiratory tract.

The results reveal that all selected cities in the Bicol Region maintained annual mean PM₁₀ concentrations well below the Philippine standard of 60 µg/Ncm in 2024. However, a notable trend emerged, developing cities recorded a higher group mean (33 µg/Ncm) compared to highly urbanized cities (28.5 µg/Ncm). In 2024, Naga City air quality monitoring highest monthly average for PM₁₀ is 39 µg/NCM for the months of March, April, and June 2024. According to DENR-EMB region 5, these concentrations could be attributed to prevailing weather conditions, wind speed/direction, dumping activities, and construction of buildings and roads operations that was conducted in the area. However, this accounts generally for a good air quality index. The same year, Legazpi City air quality monitoring highest monthly average for PM is 35 µg/NCM for the month of June, July, August 2024 which attributed to wind speed and direction, traffic congestions and provincial activities in the region.

On the other hand, Iriga City air quality monitoring highest monthly average for PM₁₀ is 39 µg/NCM for the months of June, July, August 2024 and still under good air quality category. Moreover, the results aligned to wind speed and direction at the surface atmosphere, traffic, building and road constructions in the city. In Ligao City, the quarterly average concentration of PM₁₀ peaked at 2nd quarter of 2024 which is 42 µg/NCM. This result may be attributed to the observed road construction near the station and the prevailing weather condition were fair and sunny as recorded throughout the 2nd quarter which was considered as the dry season. The findings challenge the conventional assumption that highly urbanized cities inherently exhibit poorer air quality while urban centers often have greater vehicular density and commercial activity. They may also benefit from better infrastructure, paved road networks, traffic management systems, and stricter environmental enforcement mechanisms.

In contrast, developing cities such as Iriga and Ligao may experience elevated particulate levels due to ongoing infrastructure expansion, road construction, unpaved surfaces, and dust resuspension. Transitional urban areas may lack fully developed emission control systems, contributing to increased ambient particulate concentrations despite lower overall population density. Iriga City recorded one of the highest PM₁₀ concentrations (36 µg/Ncm) annually, equivalent to Naga City, suggesting that localized sources and land use activities play a critical role in particulate generation. Meanwhile, Legazpi City exhibited the lowest concentration (21 µg/Ncm), possibly influenced by its coastal geographic setting, which promotes atmospheric dispersion through stronger wind circulation.

These results underscore that urban classification alone does not determine air quality outcomes. Instead, infrastructure quality, environmental governance, traffic patterns, construction activities, and geographic conditions collectively shape ambient particulate levels. Although all cities were compliant with national standards and classified under “Good” air quality, the relatively higher levels observed in developing cities highlight the need for preventive measures to avoid future deterioration as urban growth continues.

Weather Condition Effects to PM₁₀ Health Impacts - Weather conditions significantly influence PM₁₀ concentration and its health impacts, especially in tropical areas like the Philippines. DENR-EMB Region 5 incorporates meteorological variables such as rainfall, temperature, wind speed, and atmospheric stability into particulate matter monitoring and predictive modeling frameworks. Higher or increased PM₁₀ levels were generally observed during sunny and dry periods, and this often leads to dust resuspension from roads and bare soil, construction and quarry dust airborne longer, agricultural field dust during dry periods, volcanic ash suspension. Lesser moisture in the air, particles remain suspended longer while concentrations decreased during rainy conditions. This pattern is consistent with established atmospheric processes governing particulate matter behavior.

During strong sunlight, surface heating can create thermal inversions especially early morning and weak wind conditions can trap pollutants near ground level which in turn can increase ground-level PM₁₀ concentration, worsening air quality from the surface atmosphere or near the ground where people breathe. Higher PM₁₀ during dry weather may cause increased asthma attacks, eye and throat irritation, most probably more outpatient respiratory cases. In this season urban building and road construction frequently operate. During rainy season, rain helps remove PM₁₀ (rain washout effect) from the air through wet scavenging (process where raindrops capture particles), and surface washing where dusts on roads is naturally removed causes a sudden or rapid drop of PM₁₀ concentrations. Moreover, during extreme weather events such as Tropical Cyclone, strong winds before or after rain may temporarily increase dust, and flood-dried sediments after heavy rain can later become new dust sources. In areas experiencing land conversion or soil disturbance, this rebound effect may be more pronounced.

5. Conclusion

This study assessed and compared ambient PM₁₀ concentrations in selected highly urbanized and developing cities of the Bicol Region for 2024. All cities recorded annual mean concentrations ranging from 21 to 36 µg/Ncm, well below the national standard of 60 µg/Ncm. Developing cities exhibited a higher group mean (33 µg/Ncm) than highly urbanized cities (28.5 µg/Ncm), suggesting that development phase and infrastructure conditions may influence particulate levels more significantly than urban classification alone. While current air quality remains satisfactory, sustained monitoring and proactive environmental management are essential to maintain compliance amid ongoing urban expansion.

Practical Educational Implications - The findings of this study have important implications for practitioners, teachers, students, and schools. Although all selected cities in the Bicol Region recorded PM₁₀ concentrations within the “Good” air quality category and remained compliant with the Philippine National Ambient Air Quality Guideline Value, the higher average PM₁₀ levels observed in developing cities suggest the need for early environmental awareness and preventive action. The results show that developing cities had a higher mean PM₁₀ concentration than highly urbanized cities, indicating that construction activities, road dust, infrastructure development, traffic, and local environmental conditions may influence air quality more than urban classification alone.

For **teachers and educational practitioners**, the findings can be used as a practical basis for integrating local environmental issues into science, health, social studies, and values education lessons. Teachers may use the study as a local example to help students understand air pollution, particulate matter, environmental monitoring, and the relationship between urban development and public health. Instead of teaching air pollution only as a general or textbook concept, teachers can connect lessons to familiar cities such as Naga, Legazpi, Iriga, and Ligao. This makes environmental education more meaningful, contextualized, and relevant to learners’ everyday experiences.

For **students**, the findings highlight the importance of environmental responsibility and health awareness. Since PM₁₀ particles may come from road dust, construction, traffic, and dry weather conditions, students can be encouraged to observe environmental conditions in their own communities and reflect on how human activities affect air quality. Schools can also involve students in simple environmental monitoring activities, such as observing dust-prone areas, documenting traffic congestion near school zones, identifying construction-related dust sources, and participating in clean-up or greening activities. These activities can help develop scientific literacy, civic responsibility, and environmental stewardship.

For **schools**, the study suggests the need to strengthen school-based environmental health practices. Even though the air quality levels were classified as “Good,” schools should not be complacent, especially those located near roads, construction sites, transport terminals, or developing urban areas. School administrators may consider practical measures such as maintaining green spaces, planting trees or vegetation barriers, minimizing dust from school grounds, improving classroom ventilation, and monitoring outdoor activities during dry and dusty periods. Schools may also coordinate with local government units, DENR-EMB, and community organizations to promote

clean air campaigns and environmental awareness programs.

The findings are also significant for **school health and safety planning**. Since PM₁₀ exposure may irritate the nose, throat, and upper airways and may trigger asthma or breathing discomfort, schools should be attentive to learners with respiratory conditions. Teachers and school health personnel may monitor students who are sensitive to dust or pollution, especially during dry months or periods of nearby road construction. Schools may also develop simple advisories on when to limit outdoor activities if dust levels are visibly high or if construction activities are occurring near the campus.

At the broader institutional level, the study supports the role of schools as partners in **community-based environmental protection**. The finding that developing cities had relatively higher PM₁₀ levels suggests that schools in growing urban areas can serve as important centers for environmental advocacy. Through student projects, parent involvement, school-community campaigns, and partnerships with local agencies, schools can help raise awareness about dust control, proper waste management, road cleanliness, responsible construction practices, and clean transportation.

Overall, the study implies that maintaining good air quality is not only the responsibility of environmental agencies but also of educational institutions. By translating local air quality findings into classroom instruction, student activities, school health practices, and community engagement, teachers and schools can contribute to the prevention of future air quality deterioration while promoting environmental awareness and public health protection among learners.

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