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Air Quality Analysis in the Vicinity of Tanjung Lesung Beach, Banten

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Abstract

Beaches are among the most popular recreational destinations for the public. This study aims to evaluate the air quality in the Tanjung Lesung coastal area, Pandeglang, Banten, by collecting air samples followed by laboratory analysis. The air pollutants measured in this study include Total Suspended Particulate (TSP), Sulfur Oxides (SO_x), and volatile organic compounds such as Benzene, Toluene, and Xylene (BTX). Sampling methods were the impinger method for SO_x, High Volume Air Sampler (HVAS) for TSP and Pb, and activated carbon and XAD adsorbents for BTX. The results showed that the concentration of TSP reached 421.08 µg/m³, exceeding the national ambient air quality standard of 230 µg/m³. The concentration of SO_x was recorded at 0.7837 ppm, which remains within the permissible limit. Meanwhile, BTX compounds were not detected in the air samples, likely due to very low concentrations. These findings suggest that although the coastal air is relatively free from volatile organic compounds, a high level of particulate pollution was observed, which is suspected to originate from nearby industrial activities. Regular air quality monitoring is essential to ensure public health and maintain the comfort of tourist environments.

Keywords: air quality, total suspended particulate (TSP), Sulfur Oxides, BTX (benzene, toluene, xylene), Tanjung Lesung Beach

Introduction

Ambient air, as defined by the Government Regulation of the Republic of Indonesia No. 22 of 2021, refers to free air in the outdoor environment that is associated with air quality and may affect the health of humans and other living organisms. Based on this definition, it is evident that ambient

air quality must be continuously monitored due to its direct impact on public health and the environment. Air quality is assessed by comparing pollutant concentrations with national ambient air quality standards. According to Government Regulation No. 41 of 1999 on Air Pollution Control, ambient air quality standards represent the threshold levels or concentrations of substances, energy, and/or components that should or may be present, and tolerated pollutants in the ambient air. These standards are established to prevent air pollution and protect both human health and the environment.

Both natural and anthropogenic factors. Natural factors include volcanic activity, whereas anthropogenic sources such as transportation and industrial activities are considered the most dominant contributors (Agista, 2020). The regulated parameters for ambient air quality under Article 174, Paragraph (1), Annex VII of Government Regulation No. 22 of 2021 include the concentration of sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), photochemical oxidants (O₃), non-methane hydrocarbons (NMHC), airborne particulate matter (TSP, PM₁₀, PM_{2.5}), and lead (Pb).

Although ambient air quality monitoring is commonly conducted in densely populated or industrial areas, it is also crucial to perform such tracking in tourism areas. Beaches are among the popular tourist destinations in Indonesia. On the island of Java, many coastal attractions are located in Banten Province, such as Anyer Beach, Sawarna Beach, and Tanjung Lesung Beach. Monitoring air quality in these tourist areas is particularly important, given that Banten is a province with both active tourism and significant industrial development. According to 2023 data from the Banten Statistics Agency (banten.bps.go.id), 3,399 large and medium-scale industries operating in the region. Some of these industrial activities emit gases that can cause environmental pollution (Tinambunan, 2022). There are five major industrial facilities located near coastal areas in Banten known for emitting high levels of pollutants, mainly due to chimney height and fuel type, including PT Krakatau Steel, PT Krakatau Daya Listrik, PT Chandra Asri, Ciogading Power Plant, and PT Indonesia Power (Guntara, 2024; Dianti, 2017). As reported by CNN Indonesia, on Saturday, January 20, 2024, a flaring event at PT Chandra Asri Petrochemical impacted 360 individuals who required medical attention.

Given these considerations, this study was conducted to assess air quality in the Tanjung Lesung coastal area of Banten Province. The focus was on measuring levels of Total Suspended Particulate (TSP), sulfur oxides (SO_x), and benzene, toluene, and xylene (BTX), and comparing the results to national air quality standards in Indonesia.

Methods

SO_x Sampling and Determination

Sulfur oxide (SO_x) sampling used an impinger method with hydrogen peroxide (H₂O₂) as the absorbing solution (Biasioli, 2021). Before sampling, the H₂O₂ solution was prepared and stored in a dark glass bottle. Air from the Tanjung Lesung coastal area was drawn through the impinger at a flow rate of 1 L/min for a minimum of 12 hours to ensure sufficient absorption of SO_x gases. After sampling, the absorbing solution was collected and stored for laboratory analysis.

For analysis, 1 mL of the collected absorbing solution was mixed with 5 mL of a 1000 ppm barium ion (Ba²⁺) solution in a 10 mL volumetric flask, resulting in a final Ba²⁺ concentration of 500 ppm. The solution was analyzed using Atomic Absorption Spectrophotometry (AAS) to quantify unreacted Ba²⁺ (Ulliyah, 2024). A calibration curve was constructed using Ba²⁺ standard solutions of 50, 100, 150, 200, and 250 ppm, each spiked with 1 mL of 50 ppm SO₄²⁻ standard and one drop of 6 M hydrochloric acid (HCl). The mixtures were then left to stabilize without forming precipitates before AAS measurement. The residual Ba²⁺ concentration, determined via the calibration curve, was used to quantify the sulfate content, and indirectly the concentration of absorbed SO_x gases.

Determination of Total Suspended Particulate (TSP) and Lead (Pb)

Particulate matter was collected using a High Volume Air Sampler (HVAS) for 12 hours at a 40–60 ft³/min suction rate onto chromatographic filter paper (USEPA, 1999). After sampling, the filter paper was cut into small pieces, placed into a crucible, and ashed in a furnace at 900°C until only residue remained. The ash was digested using a microwave digestion system for approximately 2 hours. A few drops of concentrated nitric acid (HNO₃) were added to the residue, and the solution was diluted to a final volume of 50 mL using demineralized water.

Standard solutions of lead (Pb) with varying concentrations were prepared to establish calibration curves using AAS. The concentration of Pb in the sample was then determined based on the resulting calibration equation.

BTX (Benzene, Toluene, Xylene) Sampling and Analysis

BTX compounds were collected using activated carbon and XAD adsorbents. After sampling, each adsorbent was extracted with chloroform (CHCl₃) in a 10 mL volumetric flask. Two standard BTX solutions were prepared: the first consisted of 1 mL each of benzene, toluene, and xylene in equal ratios, while the second included the same mixture diluted with CHCl₃ to 10 mL.

Gas Chromatography (GC) was used for BTX analysis (Kristi, 2021). Before sample injection, the syringe was cleaned with acetone. A 1 µL aliquot of each standard solution and each extracted sample was injected into the GC system. In addition to the two standards and samples, a blank CHCl₃ solution was also analyzed for comparison.

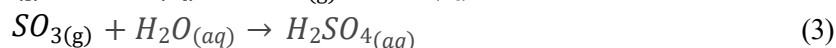
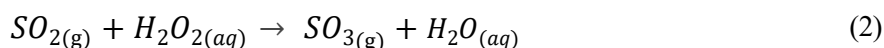
Result and Discussion

The emission of sulfur oxide gases (SO_x) in ambient air, particularly in coastal areas, can undergo oxidation to form sulfur trioxide (SO₃), which subsequently reacts with abundant atmospheric water vapor to produce sulfuric acid (H₂SO₄). This process contributes to acid rain, degrading the surrounding area's environmental quality (Hapsauqi *et al.*, 2024).

The presence of sulfur trioxide (SO₃) in its gaseous form is only possible when atmospheric water vapor concentration is extremely low. However, under sufficient humidity, sulfur trioxide readily reacts with water vapor to form sulfuric acid droplets through the following reaction:



The concentration of sulfur oxide gases (SO_x) in the atmosphere can be determined using an impinger containing hydrogen peroxide (H₂O₂) as the absorbing solution. The reaction between SO_x and H₂O₂ results in the formation of sulfuric acid (H₂SO₄) and water. In this process, hydrogen peroxide (H₂O₂) oxidizes sulfur dioxide (SO₂) into sulfur trioxide (SO₃), which then reacts with water to form sulfuric acid (H₂SO₄) (Wijaya, 2020), as shown in the following reactions:



An indirect determination of sulfur oxides (SO_x) can be carried out using Atomic Absorption Spectroscopy (AAS) by measuring the concentration of residual barium ions (Ba²⁺) after their interaction with sulfate ions (SO₄²⁻), which are the oxidation products of sulfur dioxide (SO₂) gas. This method aligns with the principles of AAS commonly applied in heavy metal analysis, as demonstrated in the study by Ulliyah (2024), which quantified mercury levels in river water using standard series and calibration curves as quantitative references for analyte concentration. AAS offers highly sensitive detection of metal ions in solution, making it a suitable technique for indirectly monitoring secondary reactions between airborne pollutants such as SO_x and other compounds present in the environment (Zare-Dorabei *et al.*, 2018).

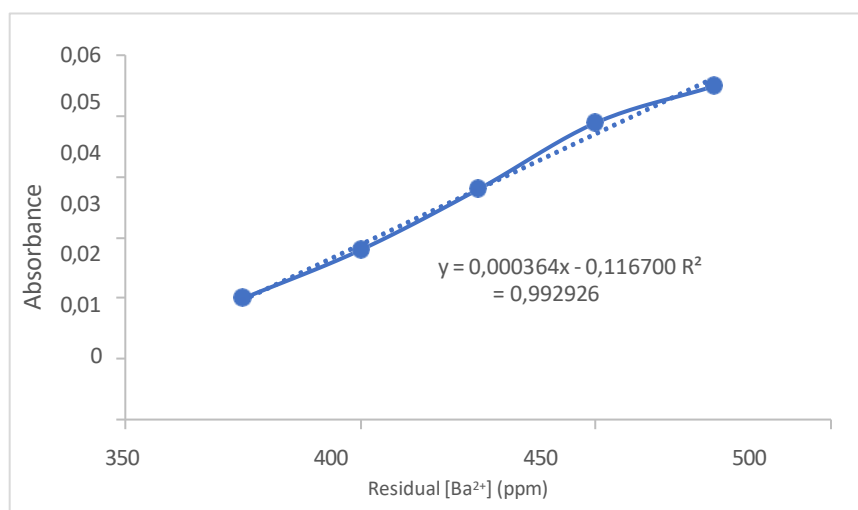


Fig.1. Residual Ba²⁺ Concentration vs. Absorbance Curve

Based on **Fig.1**, a linear regression equation was obtained: $y = 0.000364x + 0.1167$, with a coefficient of determination $R^2 = 0.9829$. An R^2 value close to 1 indicates optimal sensitivity and a high degree of accuracy in the measurement (Aryani & Gustian, 2020). Using the regression equation and correcting for the sample volume, the concentration of SO_x was determined to be 0.7837 µg/m³, demonstrating the precision of this method in quantifying ambient air pollutants. The calculation results for Total Suspended Particulate (TSP) showed a particulate concentration of 421.08 µg/m³. This value was obtained based on the difference in the mass of the filter paper before and after sample collection using the High Volume Air Sampler (HVAS) method, corrected for an airflow rate of 20 feet per minute over a 12-hour sampling period. This concentration significantly exceeds the ambient air quality standard for TSP as stipulated in Government Regulation No. 22 of 2021, which is set at 230 µg/m³ as a 24-hour average.

The concentration of Total Suspended Particulate (TSP) measured in this study was notably high, despite being collected over 12-hours. Although this duration is shorter than the standard 24-hour period commonly recommended for ambient air monitoring, it remains within the operational range used in high-volume air sampling, particularly when field limitations such as equipment constraints or environmental conditions are considered (USEPA, 1999; WHO, 2005). This elevated concentration is strongly suspected to be due to the sampling location's proximity to the chimney of an active industrial facility, which serves as a direct source of particulate emissions into the ambient air.

This finding aligns with the study conducted by Nurfadillah (2023), which reported a peak TSP concentration of 397.5 µg/m³ in a limestone mining area of Kelurahan Buliide, Gorontalo City. Although conducted in a different geographic region, the study was performed under comparable environmental conditions, specifically in residential areas situated in close proximity to direct emission sources associated with mining activities. The comparability of both studies underscores the consistent impact of emission source proximity on ambient TSP concentrations, reinforcing the need for localized air quality management strategies in industrial zones.



Fig.2. Sampling location at the coastal area of Tanjung Lesung, Banten Province

Subsequently, a calibration curve method was used to determine the lead (Pb) concentration in the filter paper sample. The curve was constructed using standard Pb^{2+} solutions ranging from 0 to 5 ppm, and absorbance values were measured using AAS. This calibration was then applied to calculate the concentration of Pb in the air sample.

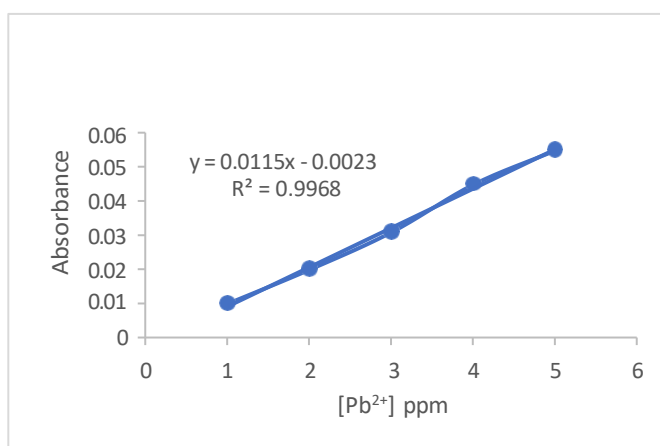


Fig.3. Calibration curve for lead (Pb^{2+}) analysis. The curve was constructed by plotting absorbance values against standard Pb^{2+} concentrations

The measured air sample showed an absorbance value of 0.006. After calculations using the calibration line equation and corrections to the flow rate and volume of filtered air, temperature and actual pressure, the concentration of lead (Pb) in ambient air was obtained at $0.0757 \mu\text{g}/\text{Nm}^3$.

This value was then compared with the national ambient air quality standards stated in the Regulation of the Minister of Environment of the Republic of Indonesia No. 12 of 2010. In this regulation, the maximum limit permitted for lead concentration in ambient air during a 24-hour measurement period is $2 \mu\text{g}/\text{Nm}^3$ (Ministry of Environment, 2010).

The lead concentration in the sample was very low compared to the threshold value. This shows that the air quality at the sampling location still meets environmental health standards. However, even though Pb concentrations are within the safe range according to regulations, the potential for long-term exposure accumulation still needs to be considered, considering that lead is a toxic heavy metal that is bioaccumulative and can cause health impacts, especially in vulnerable groups such as children (Kusuma *et al.*, 2022)

In order to identify and quantify BTX compounds (benzene, toluene, and xylene) in air samples, chromatographic analysis was conducted using both standard mixtures and field-collected samples. Fig.4.1 and 4.2 display the chromatograms of standard BTX mixtures in a 1:1:1 ratio, with and without the addition of chloroform (CHCl_3), respectively. These standards served as references for compound identification based on retention times. Fig.4.3 and 4.4 show the chromatographic

results of air samples collected using XAD resin and activated carbon, respectively. Peaks observed in the sample chromatograms were compared with those of the standard mixtures to confirm the presence of BTX compounds in the ambient air.

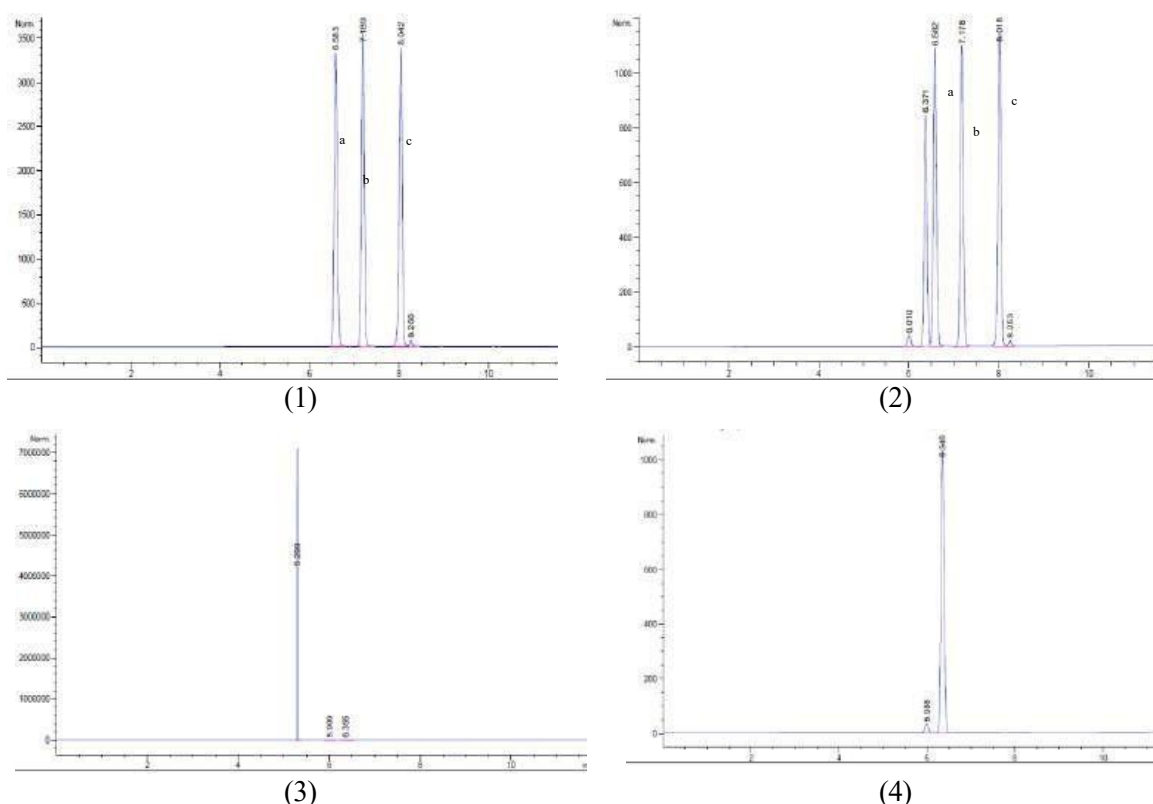


Fig.4. Chromatograms of BTX Standards and Air Samples (1) A standard mixture containing benzene, toluene, and xylene in a 1:1:1 ratio — peaks: benzene (a), toluene (b), xylene (c). (2) A standard mixture containing benzene, toluene, and xylene in a 1:1:1 ratio with the addition of chloroform (CHCl_3) — peaks: benzene (a), toluene (b), xylene (c). (3) BTX compounds in air sampled with XAD resin (4) BTX compounds in air sampled with activated carbon.

Air samples adsorbed on activated carbon and XAD resin did not contain detectable levels of BTX (benzene, toluene, xylene) vapors. This suggests that BTX compounds were absent in the sampled air or at concentrations below the instrument's detection limit.

Conclusion

Air content analysis in Tanjung Lesung Beach, Banten's coastal area, has been successfully carried out using a sampling method using a High Volume Air Sampler, impinger, activated carbon adsorbents, and XAD. The study's results showed that the Total Suspended Particulate (TSP) concentration of

$421.08 \mu\text{g}/\text{m}^3$ exceeded the national ambient air quality standard threshold of $230 \mu\text{g}/\text{m}^3$. The SO_x concentration of 0.7837 ppm was still within acceptable ranges, while the volatile compound BTX (benzene, toluene, and xylene) was not detected, likely due to concentrations below the detection limit of the instrumentation. The high levels of TSP are thought to come from industrial activities around the sampling location. Therefore, routine air quality monitoring is critical to maintain public health and the comfort of the tourist environment.

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