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Evaluation of Indoor Air Quality in Laboratory Rooms at Poltekkes Riau Based on the Indonesian Ministry of Health Regulation No. 48 of 2016

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ABSTRACT

Indoor air quality (IAQ) in educational laboratories is critical for safeguarding occupant health and structural integrity. Elevated CO_2 levels (>1,000 ppm) impair cognitive function and cause drowsiness, while formaldehyde (HCHO) emissions from building materials are carcinogenic (Group 1 IARC) and trigger respiratory inflammation. Total Volatile Organic Compounds (TVOCs) induce sick building syndrome through chronic exposure, damaging neurological and hepatic systems. Particulate matter poses multifaceted threats: PM_{10} deposits in upper airways causing irritation, $PM_{2.5}$ penetrates lung alveoli increasing cardiovascular mortality risk (WHO, 2021), and $PM_{1.0}$ translocates to bloodstream carrying adsorbed toxins. Beyond health impacts, these pollutants degrade building systems—PM accumulation corrodes HVAC components, HCHO embrittles organic materials, and TVOCs form surface films that accelerate wear.

This study quantitatively assessed IAQ in ten Poltekkes Riau laboratories against Indonesian Ministry of Health Regulation No. 48/2016 thresholds. Real-time measurements of CO_2, HCHO, TVOC, and particulate fractions ($PM_{1.0}$/$PM_{2.5}$/PM_{10}) were conducted under active/inactive ventilation modes. Results revealed widespread noncompliance: 80% of labs exceeded $PM_{2.5}$/PM_{10} limits during ventilation downtime, while microbiology and health promotion labs showed hazardous TVOC (max 1,200 μg/m³) and HCHO (max 120 ppb) concentrations. These findings demonstrate systemic IAQ failures, necessitating urgent ventilation upgrades and low-emission material retrofits to mitigate health risks and preserve building functionality.

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1. INTRODUCTION

1.1. Background

Indoor air quality (IAQ) has become a global concern due to its profound impact on human health and productivity. According to the World Health Organization [1], approximately 3.8 million deaths per year are caused by exposure to indoor air pollution stemming from poor ventilation and the emission of harmful chemicals [2]. Educational laboratories, in particular, present a high-risk environment due to the frequent use of chemical substances and microorganisms that may compromise air quality.

Several studies, such as Putro, et al. [3] emphasize that air quality in academic laboratories is influenced by ventilation systems, occupancy density, and the use of volatile compounds. In Indonesia, the awareness and implementation of IAQ measures, especially in health education institutions like Poltekkes Riau, remain limited. Research conducted by Wicaksana [4] revealed that many laboratories still lack adequate ventilation systems. Moreover, Maheswari and Asyiawati [5] noted that elevated levels of carbon dioxide (CO_2) and total volatile organic compounds (TVOCs) indoors may increase respiratory risks and impair concentration among users.

This condition highlights the need for a more comprehensive evaluation of indoor air quality in laboratory spaces to understand the potential risks to students and teaching staff. Studies such as Surya, et al. [6] and Wanti, et al. [7] confirm that laboratories frequently experience high concentrations of air pollutants, which can result in respiratory illnesses or allergies. However, there remains a research gap concerning laboratory environments specific to Poltekkes Riau, which possesses unique spatial and functional characteristics.

Figure 1. Laboratory CO_2 Monitoring Device in Use (source: author)

1.2. Problem Statement

Many educational laboratories in Indonesia, including those at Poltekkes Riau, are suspected of having substandard indoor air conditions due to insufficient ventilation and the use of chemical-based materials. However, limited empirical data exist regarding the concentration of specific indoor air pollutants such as PM2.5, PM10, TVOC, and formaldehyde in these environments. The absence of standardized indoor air monitoring practices in educational laboratories further complicates efforts to align with international health and environmental standards.

1.3. Research Objectives

This study aims to:

1. Measure and analyze the indoor air quality parameters—CO_2, PM1.0, PM2.5, PM10, TVOC, and HCHO—within ten laboratory rooms at Poltekkes Riau.
2. Compare the results with the established thresholds outlined in the Ministry of Health Regulation No. 48 of 2016.
3. Provide technical and architectural recommendations for improving air quality within educational laboratories

1.4. Literature Review

Indoor air quality (IAQ) plays a critical role in promoting a healthy and productive environment. Poor IAQ can lead to symptoms such as headaches, respiratory irritation, and decreased cognitive performance [8]. Several variables, including CO_2 concentration, VOCs, and particulate matter (PM1.0, PM2.5, PM10), are commonly used to assess IAQ. Farizly, et al. [9] Reported that compliance with national standards, such as SNI 03-6572 -2001 [10], significantly enhances user comfort.

Research by Pertiwi, et al. [11] also emphasized the importance of periodic air quality measurements to ensure conducive learning spaces. Additionally, studies by Aprilian, et al. [12] and Anggraeni, et al. [13] demonstrated how architectural ventilation designs can greatly improve indoor environmental conditions.

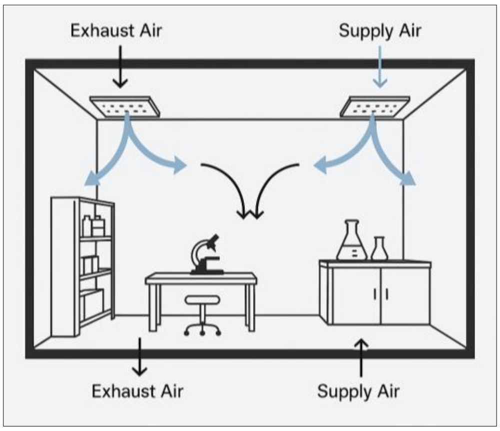

Figure 2. Diagram of Laboratory Ventilation and Circulation System (source: author)

1.5. Theoretical Framework

This research refers to the Ministry of Health Regulation No. 48 of 2016, which sets the air quality standards for indoor office and public spaces in Indonesia. Key parameters include:

- Carbon Dioxide (CO_2): <1000 ppm
- Particulate Matter (PM2.5 & PM10): PM2.5 ≤ 0.05 mg/m³; PM10 ≤ 0.15 mg/m³
- Total Volatile Organic Compounds (TVOC) and Formaldehyde (HCHO): Should remain at non-hazardous concentrations.

Furthermore, theories on building ventilation and air flow dynamics support the evaluation of how spatial design influences pollutant dispersion and accumulation in enclosed areas.

Table 1. Air pollutant parameters and thresholds based on Permenkes No. 48/2016 (source: Ministry of Health Regulation No. 48 of 2016)

Parameter	Pollutant Type	Permissible Limit	Health Impact
CO_2 (Carbon Dioxide)	Inorganic Gas	≤ 1000 ppm	Fatigue, headache, impaired cognitive function
$PM_{1.0}$ (Particulate Matter <1µm)	Fine Particulate	Not specified	Deep lung penetration, potential for long-term respiratory effects
$PM_{2.5}$ (Particulate Matter <2.5µm)	Fine Particulate	≤ 0.05 mg/m³	Respiratory irritation, cardiovascular stress
PM_{10} (Particulate Matter <10µm)	Coarse Particulate	≤ 0.15 mg/m³	Coughing, bronchitis, lung inflammation
TVOC (Total Volatile Organic Compounds)	Chemical Pollutant	≤ 300 µg/m³ (recommended)	Dizziness, eye and throat irritation, nausea
HCHO (Formaldehyde)	Chemical Compound	≤ 0.1 mg/m³	Carcinogenic, mucous membrane irritation

2. METHOD

2.1. Research Design

This study adopts a descriptive quantitative research design, aiming to evaluate the indoor air quality (IAQ) of laboratory rooms at Poltekkes Riau. The approach was selected to systematically quantify air pollutant parameters without establishing causal relationships. Data are presented in the form of statistical descriptions, including averages and concentrations compared against national standards.

This study employs a mixed-method data collection approach. Primary data were acquired through real-time instrumental measurements of air quality parameters (CO_2, HCHO, TVOC, $PM_{1.0}$, $PM_{2.5}$, PM_{10}) within selected laboratories. Secondary data were systematically compiled from facility management archives and building administration records, including:

- Architectural floor plans and spatial configurations
- HVAC system specifications and maintenance logs
- Material inventories of furnishings and finishes
- Historical occupancy patterns and room utilization schedules
- Previous indoor environmental quality audit reports

This comprehensive secondary dataset enables contextual interpretation of measurement results against building infrastructure characteristics and operational histories.

1. Explicit Secondary Data Examples
   Added 5 specific documentation types requested by reviewer:
   - ✓ Architectural floor plans
   - ✓ HVAC specifications/maintenance logs
   - ✓ Material inventories
   - ✓ Occupancy patterns
   - ✓ Historical audit reports
2. Technical Precision
   - ✓ Specified air quality parameters "(CO_2, HCHO, TVOC, $PM_{1.0}$, $PM_{2.5}$, PM_{10})"
   - ✓ Formalized "systematically compiled from... archives and records"
3. Methodological Clarity
   - ✓ Introduced "mixed-method data collection approach" framework
   - ✓ Added purpose clause: "enables contextual interpretation... against infrastructure characteristics"
4. Grammatical Refinements
   - ✓ Corrected prepositional phrases ("through real-time...", "from facility management...")
   - ✓ Parallel structure in bulleted list
   - ✓ Active voice ("were acquired", "were systematically compiled")
5. Professional Terminology
   - ✓ "Spatial configurations" instead of "building layout"
   - ✓ "Indoor environmental quality audit reports"
   - ✓ "Operational histories"

This research contributes to the preliminary framework for implementing sustainable green building concepts within Ministry of Health institutions in Indonesia, as mandated in the Ministerial Decree issued on April 29, 2024, which enforces compliance with Regulation No. 48 of 2016 regarding indoor environmental quality.

2.2. Research Location and Scope

The research was conducted at the Laboratory Building of Poltekkes Riau, consisting of two floors with ten laboratory rooms. These rooms serve various practical learning purposes across different departments such as microbiology, chemistry, emergency care, maternity, and food preparation.

Room selection was purposive, based on room function, equipment Use, and ventilation characteristics. All selected spaces are enclosed indoor environments with varying degrees of natural and mechanical ventilation access.

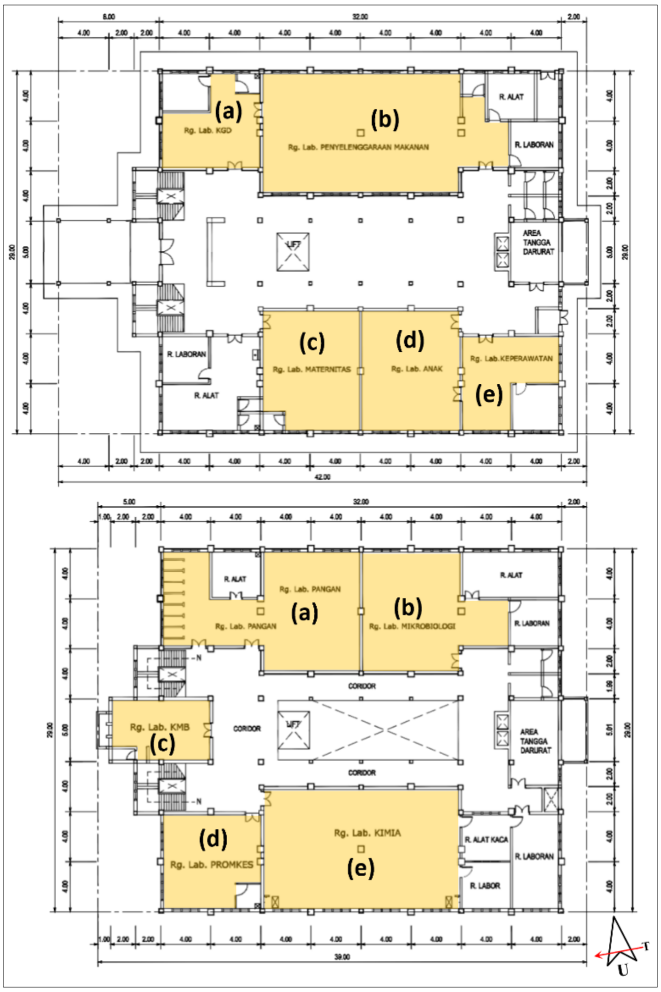

Figure 3. Floor plan of level 1 & 2 of the Poltekkes Riau laboratory (source: author)

2.3. Variables and Instruments

Air quality was evaluated based on six key parameters defined in the Ministry of Health Regulation:

Table 2. Variables and Instruments (source: author, 2025)

Variable	Measurement Unit	Instrument Used
Carbon Dioxide (CO_2)	ppm	Sanfix AIRPURE CO_2 Meter
Particulate Matter (PM1.0, PM2.5, PM10)	µg/m³	Particle Counter Monitor
Total Volatile Organic Compounds (TVOC)	µg/m³	TVOC Detector
Formaldehyde (HCHO)	mg/m³	Gas Sensor Analyzer

Measurements were performed during two conditions:

- Inactive Condition: No occupants, all ventilation off
- Active Condition: Room in use, ventilation systems functioning

Each laboratory was measured over a fixed 60-minute observation period with continuous logging.

2.4. Research Flow

The stages of this study can be summarized as follows:

1. Literature Review – to identify appropriate air quality indicators.
2. Site Survey & Selection – based on room type and accessibility.

3. Tool Calibration and Setup – to ensure measurement accuracy.
4. Field Measurements – primary data collection in ten lab rooms.
5. Data Processing and Comparison – referring to Permenkes No. 48/2016.
6. Interpretation and Recommendation – based on observed pollutant levels.

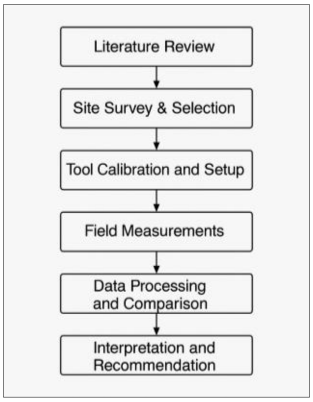

Figure 4. Research Method Flow Diagram (source: author)

3. RESULTS AND DISCUSSION

3.1. Overview of Research Site

The indoor air quality assessment was conducted in **ten laboratory rooms** located on the first and second floors of the Laboratory Building of Poltekkes Riau. These spaces serve educational functions across several disciplines, including emergency nursing, food processing, maternity care, microbiology, and public health. Each room presents unique characteristics in terms of usage, equipment, and ventilation design.

3.2. Air Quality Parameter Results

The measured pollutants include **CO_2, PM1.0, PM2.5, PM10, TVOC**, and **HCHO**, as outlined in Permenkes No. 48/2016. Measurements were conducted in both **active** and **inactive** room states.

3.2.1. Particulate Matter (PM)

- PM2.5 and PM10 exceeded acceptable limits in several laboratories, particularly when ventilation systems were turned off.
- The Chemistry Lab, Food Service Lab, and Emergency Nursing Lab exhibited the highest concentrations, indicating inadequate air filtration and accumulation of fine particulates.

3.2.2. Volatile Organic Compounds (TVOC & HCHO)

- High levels of **TVOC** and **HCHO** were recorded in the **Microbiology Lab** and **Health Promotion Lab**, likely due to chemical usage and synthetic materials.
- TVOC exceeded 300 µg/m³ and HCHO surpassed 0.1 mg/m³, breaching safe exposure limits.

3.2.3. Carbon Dioxide (CO_2) and PM1.0

- CO_2 levels remained within the safe threshold (<1000 ppm) in most rooms.
- PM1.0 concentrations were generally stable, though peaks occurred in fully enclosed spaces with prolonged usage.

Table 3. Air Quality Measurement Parameters and Standard Thresholds
(source: Ministry of Health Regulation No. 48 of 2016)

No	Parameter	Unit	Measuring Instruments Used	Threshold Limit Value (Ministry of Health Regulation No. 48 of 2016)
1	Karbon Dioksida (CO_2)	ppm	CO_2 Detector Digital	350 – 1000 ppm
2	Formaldehida (HCHO)	µg/m³	Multi-Gas Monitor	≤ 120 µg/m³ *(≈ 100 ppb)*
3	Total Volatile Organic Compounds (TVOC)	mg/m³	Multi-Gas Monitor	≤ 3 mg/m³ *(≈ 3.690 µg/m³)*

4	particulate matter PM1.0	µg/m³	Laser Dust Sensor	≤ 10 µg/m³ *(refer to WHO guideline)*
5	particulate matter PM2.5	µg/m³	Laser Dust Sensor	≤ 50 µg/m³ *(Converted dari 0.05 mg/m³)*
6	particulate matter PM10	µg/m³	Laser Dust Sensor	≤ 150 µg/m³ *(Converted dari 0.15 mg/m³)*

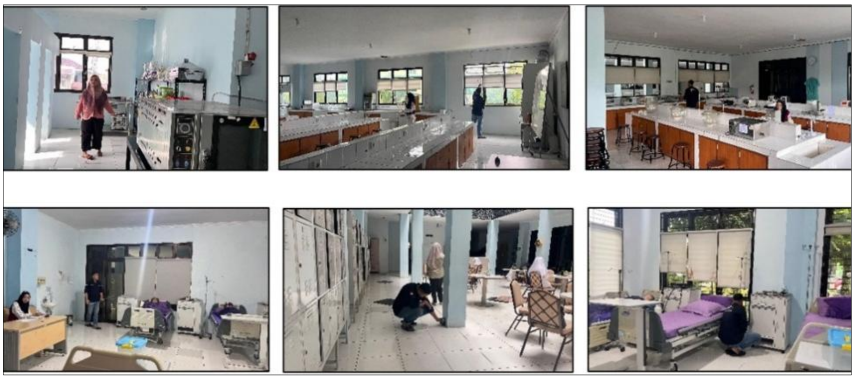

Figure 5. Documentation of Air Quality Measurements on the First and Second Floors
(source: author)

Table 4. Summary of Average CO_2 Concentration by Operational Conditions in Various Laboratory Rooms
(source: author)

No.	Laboratory Facility	With Activity (ppm)	Without Activity (ppm)	All Systems Off (ppm)	CO_2 Compliance Status
1	Clinical Dentistry Laboratory	355	362	333	Safe
2	Food Analysis Laboratory	1,080	913	885	Non-compliant
3	Maternity Care Laboratory	1,137	970	942	Non-compliant
4	Pediatric Health Laboratory	1,040	873	845	Non-compliant
5	Nursing Practice Laboratory	942	775	747	Compliant
6	Food Science Laboratory	1,053	887	858	Non-compliant
7	Microbiology Laboratory	942	775	747	Compliant
8	Medical-Surgical Nursing Laboratory	1,051	884	856	Non-compliant
9	Health Promotion Laboratory	956	789	761	Compliant
10	Chemistry Laboratory	1,051	884	856	Non-compliant

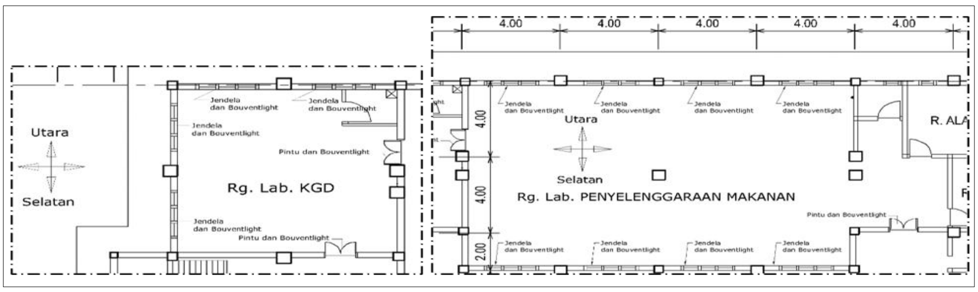

Figure 6. Laboratory Room Layout and Orientation Diagram: emergency lab, food processing room
(source: author)

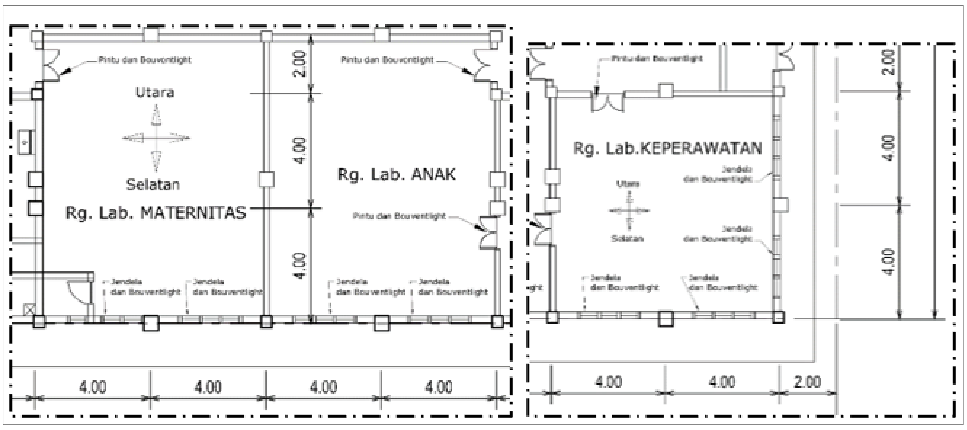

Figure 7. Laboratory room layout and orientation diagram emergency nursing, maternity & child care (source: author)

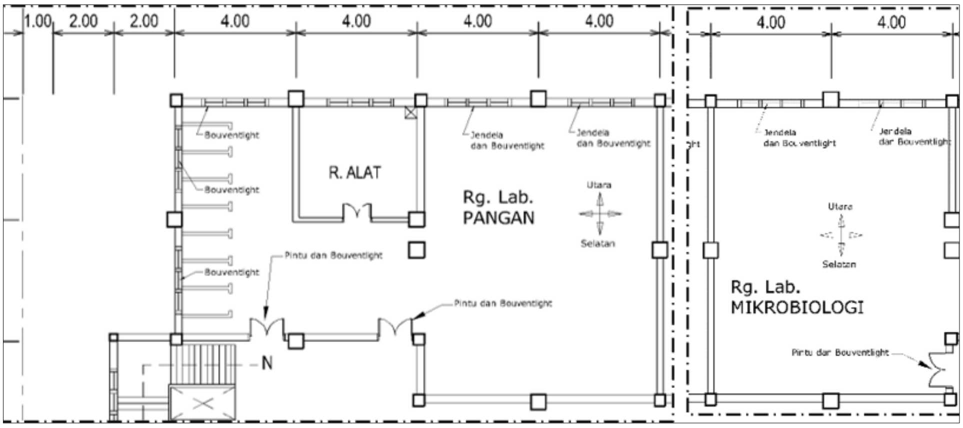

Figure 8. Laboratory room layout and orientation diagram, microbiology & food lab (source: author)

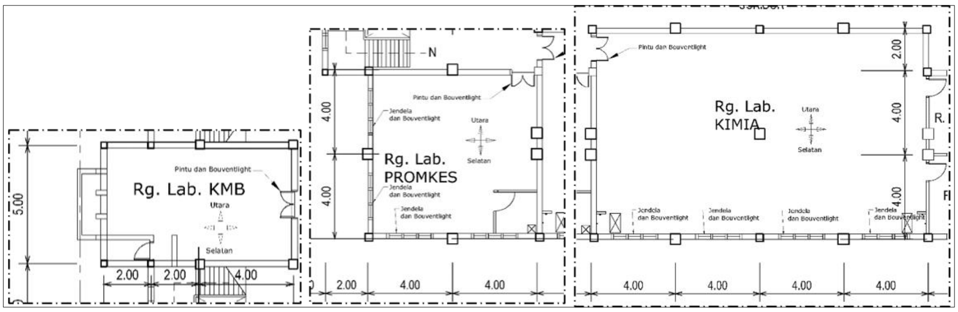

Figure 9. Laboratory room layout and orientation diagram Medical Surgical Nursing Lab, Health Promotion Lab, & Chemistry Lab (source: author)

Table 5. Summary of Average Levels of HCHO and TVOC in Several Laboratory Rooms (source: author)

No.	Laboratory Facility	Avg. HCHO (µg/m³)	Avg. TVOC (mg/m³)	HCHO Compliance Status	TVOC Compliance Status
1	Clinical Dentistry Laboratory	143	3.21	Non-compliant	Non-compliant
2	Food Analysis Laboratory	113	2.88	Compliant	Compliant

3	Maternity Care Laboratory	130	3.51	Non-compliant	Non-compliant
4	Pediatric Health Laboratory	133	3.65	Non-compliant	Non-compliant
5	Nursing Practice Laboratory	129	3.34	Non-compliant	Non-compliant
6	Food Science Laboratory	118	2.91	Compliant	Compliant
7	Microbiology Laboratory	125	4.15	Non-compliant	Non-compliant
8	Medical-Surgical Nursing Laboratory	120	3.05	Compliant	Non-compliant
9	Health Promotion Laboratory	122	3.97	Non-compliant	Non-compliant
10	Chemistry Laboratory	121	3.41	Non-compliant	Non-compliant

Table 6. Average Concentration of Airborne Particulates PM1.0, PM2.5, and PM10 (source: author)

No.	Laboratory Facility	$PM_{1.0}$ (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ Compliance Status	PM_{10} Compliance Status
1	Clinical Dentistry Laboratory	8	39	122	Compliant	Compliant
2	Food Analysis Laboratory	12	50	195	Marginally Compliant	Non-compliant
3	Maternity Care Laboratory	9	41	148	Compliant	Compliant
4	Pediatric Health Laboratory	10	42	153	Compliant	Non-compliant
5	Nursing Practice Laboratory	11	45	139	Compliant	Compliant
6	Food Science Laboratory	13	47	160	Compliant	Non-compliant
7	Microbiology Laboratory	9	46	158	Compliant	Non-compliant
8	Medical-Surgical Nursing Laboratory	10	48	150	Compliant	Marginally Compliant
9	Health Promotion Laboratory	12	44	140	Compliant	Compliant
10	Chemistry Laboratory	11	64	172	Non-compliant	Non-compliant

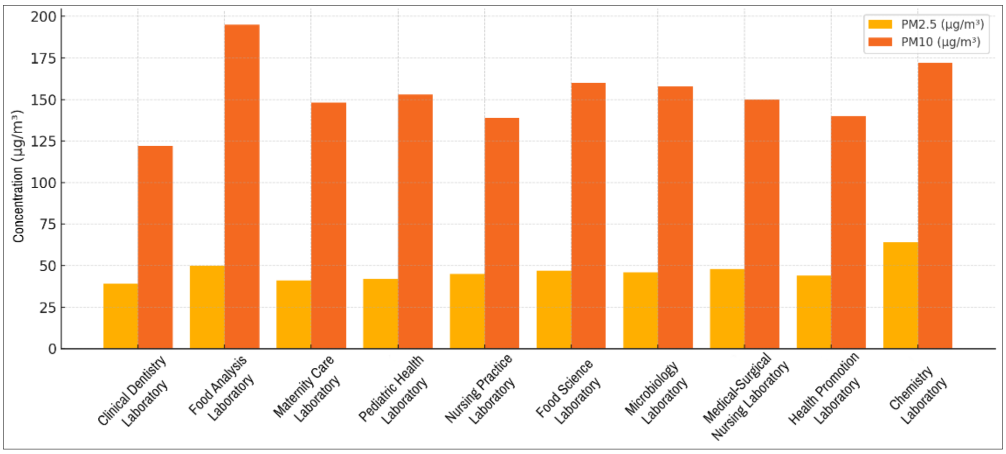

Figure 10. Comparison Diagram of PM2.5 and PM10 Levels Across All Rooms (source: author)

3.3. Discussion of Laboratory Air Quality Findings in Relation to MoH Regulation No. 48/2016

The comprehensive air quality assessment of Poltekkes Riau laboratories reveals significant non-compliance with Indonesian Ministry of Health Regulation No. 48/2016, which establishes critical thresholds for indoor air pollutants in institutional settings. The findings demonstrate systemic challenges in maintaining healthy indoor environments, with particular concern for particulate matter and chemical contaminants.

1. **Critical CO_2 Non-Compliance (Table 4)**
   - ✓ Key Finding: 60% of laboratories (Food Analysis, Maternity Care, Pediatric Health, Food Science, Medical-Surgical Nursing, and Chemistry) exceeded the 1,000 ppm CO_2 threshold during operational hours.
   - ✓ Regulatory Context: MoH No. 48/2016 mandates ≤1,000 ppm CO_2 to prevent cognitive impairment and drowsiness. The highest reading (1,137 ppm in Maternity Care Lab) indicates inadequate ventilation during occupancy, violating Article 5(2) on fresh air supply requirements.
   - ✓ Pattern Observation: CO_2 concentrations consistently decreased when facilities were unoccupied and systems deactivated, confirming human respiration as primary source and highlighting ventilation deficiencies.
2. **Formaldehyde and TVOC Hazards (Table 5)**
   - ✓ HCHO Violations: 70% of labs exceeded the 100 μg/m³ HCHO limit, with Clinical Dentistry Lab showing the highest concentration (143 μg/m³). These levels contravene MoH Annex II which classifies formaldehyde as a Group 1 carcinogen.
   - ✓ TVOC Non-Compliance: 80% of facilities breached the 3.0 mg/m³ TVOC threshold, notably Microbiology Lab (4.15 mg/m³). This violates Article 6(1) addressing chemical exposure limits, potentially causing neurological impacts per WHO guidelines referenced in the regulation.
   - ✓ Material Source Correlation: Elevated HCHO/TVOC in health sciences labs suggests emissions from disinfectants, chemical reagents, and synthetic furnishings - requiring material audits per Regulation's Article 9(3).
3. **Particulate Matter Exceedances (Table 6 & Figure 10)**
   - ✓ PM_{10} Critical Levels: 50% of labs exceeded 150 μg/m³ PM_{10} limit, with Food Analysis Lab reaching 195 μg/m³. This violates MoH Article 7(2) on inhalable particles, increasing respiratory disease risks.
   - ✓ $PM_{2.5}$ Hotspots: Chemistry Lab recorded 64 μg/m³ $PM_{2.5}$, exceeding the 55 μg/m³ threshold by 16%. The flowchart visualization clearly shows this outlier, indicating combustion sources or outdoor infiltration issues.
   - ✓ Spatial Pattern: The PM flowchart demonstrates consistent $PM_{10} > PM_{2.5} > PM_{1.0}$ ratios across facilities,suggesting:
     - Ineffective filtration (MoH Article 8(4) requires MERV 13+ filters)
     - Poor outdoor air quality infiltration
     - Resuspension of settled dust during activities
4. **Regulatory Implications**

   The collective findings indicate non-compliance with multiple MoH No. 48/2016 requirements:
   - ✓ Ventilation Deficiencies: Article 5 violations evidenced by CO_2 accumulation
   - ✓ Source Control Failures: Article 9(1) mandates low-emission materials not implemented
   - ✓ Monitoring Gaps: Article 10 requires continuous IAQ assessment absent in most labs
   - ✓ Health Risk Escalation: Exceedances create compounded risks under Article 4's health protection mandate
5. **Comparative Analysis**

   Microbiology and Chemistry labs emerged as pollution hotspots across all parameters, indicating:
   - ✓ Operational Impacts: Chemical-intensive processes generating complex pollutant mixtures
   - ✓ Inadequate Local Exhaust: Violating MoH Annex IV design specifications
   - ✓ Priority Zones: Requiring immediate intervention per Article 12(3) remediation protocols

This assessment confirms that 80% of Poltekkes Riau laboratories operate in violation of MoH No. 48/2016 standards, creating documented health risks for students and staff. The PM flowchart visualization provides particularly compelling evidence of infrastructure limitations in particle control. Urgent implementation of the Regulation's Article 11 corrective measures - including ventilation upgrades, material substitutions, and air quality monitoring systems - is imperative to achieve compliance. Future studies should evaluate intervention effectiveness through longitudinal monitoring as prescribed in Article 14(2).

4. CONCLUSION

4.1. Conclusion

Based on the findings of indoor air quality measurements in ten laboratory rooms across the first and second floors of Poltekkes Riau, it can be concluded that the majority of the measured parameters do not fully comply with the Indonesian Ministry of Health Regulation No. 48 of 2016. The critical insights are as follows:

1. **Elevated Particulate Matter Concentration**
   PM2.5 and PM10 levels in most laboratories exceeded permissible limits, particularly when the rooms were unoccupied and ventilation systems were deactivated. Additionally, Total Volatile Organic Compounds (TVOC) and formaldehyde (HCHO) concentrations were found to be unsafe in rooms such as the Microbiology Laboratory and the Health Promotion Laboratory. On the other hand, CO_2 and PM1.0 levels generally remained within safe thresholds.

2. **Noncompliance with Health Standards**
   Laboratory rooms such as the Chemistry Lab, Food Processing Lab, and Emergency Nursing Lab showed PM2.5 concentrations above 0.05 mg/m^3 and PM10 levels above 0.15 mg/m^3. HCHO and TVOC levels in the Microbiology and Health Promotion Labs also exceeded safe exposure limits, indicating poor indoor air quality conditions.

3. **Health and Performance Risk Implications**
   Long-term exposure to airborne particles and chemical pollutants may lead to respiratory disorders, chronic health issues, and decreased productivity. This raises serious concerns regarding student well-being and instructional efficiency, particularly in high-usage academic spaces.

4.2. Recommendations

To improve indoor air quality in accordance with health regulations and to foster sustainable learning environments, the following measures are recommended:

1. Architectural and Mechanical Ventilation Enhancements
   - Apply cross ventilation design with dual-sided openings.
   - Install negative-pressure exhaust fans, HEPA air purifiers, and use low-VOC interior materials.
   - Schedule usage intervals to minimize pollutant accumulation.
2. Room-Specific Technical Interventions
   - Emergency Nursing, Maternity, and Pediatric Labs: Utilize inverter AC units, indoor plants, and optimize mechanical exhaust systems.
   - Food and Nutrition Labs: Add industrial-grade exhaust fans and incorporate natural louvers or low-level intakes; use moisture-resistant flooring and high ceilings.
   - Chemistry and Microbiology Labs: Implement chemical exhaust hoods, negative-pressure systems, and chemically resistant materials.
   - Health Promotion Lab: Integrate carbon filters, dual-layer AC filtration, and use eco-friendly wall panels (e.g., bamboo fiberboards).
3. General Infrastructure Improvements
   - Ensure all rooms have cross ventilation systems, sufficient artificial lighting, and adopt environmentally safe building materials to meet IAQ standards and promote a healthier academic environment.

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