Breath Interrupted Amidst Pollution: The Impact of PM2.5 on Pneumonia in Toddlers in Jakarta

June 2025

About the Collaboration between Nafas, DBS Foundation and the Faculty of Public Health, University of Indonesia (FKM UI)

This collaboration is a synergy of three stakeholders: **Nafas Indonesia,** a technology platform for real-time, data-driven air quality monitoring; the **Faculty of Public Health, University of Indonesia (FKM UI),** a leading academic institution in the field of public health; and **DBS Foundation,** a purpose-driven partner championing innovation for sustainability and community well-being.

United by a shared commitment to environmental health, this partnership aims to:

- Build evidence-based policymaking and public interventions to mitigate the effects of air pollution on vulnerable groups, particularly young children.
- Raise public awareness and shift mindsets on the importance of clean air as a fundamental right for community well-being and sustainable development.
- Strengthen cross-sector partnerships between technology, academia, and the social sector to drive innovative, data-driven solutions for public health challenges.

Roles of Each Partner:

- **FKM UI** contributed scientific rigor and epidemiological expertise in assessing pneumonia prevalence in toddlers.
- **Nafas Indonesia** provided the network of real-time PM2.5 sensors deployed across 10 sub-districts in Jakarta.
- **DBS Foundation** supported this initiative as part of its mission to foster sustainable and innovative solutions that create lasting positive impact. By empowering social enterprises and businesses driving meaningful change, DBS Foundation leverage its ecosystem and network to tackle pressing environmental and social challenges, serving as a catalyst for scalable, sustainable solutions that build community resilience.

Through this collaboration, we champion the spirit of **"Data for Health",** paving the way to:

- Advocate for the integration of environmental data into public health policy.
- Elevate public understanding about the urgency of clean air for child development.
- Promote clean air as a fundamental right.

Contributors:

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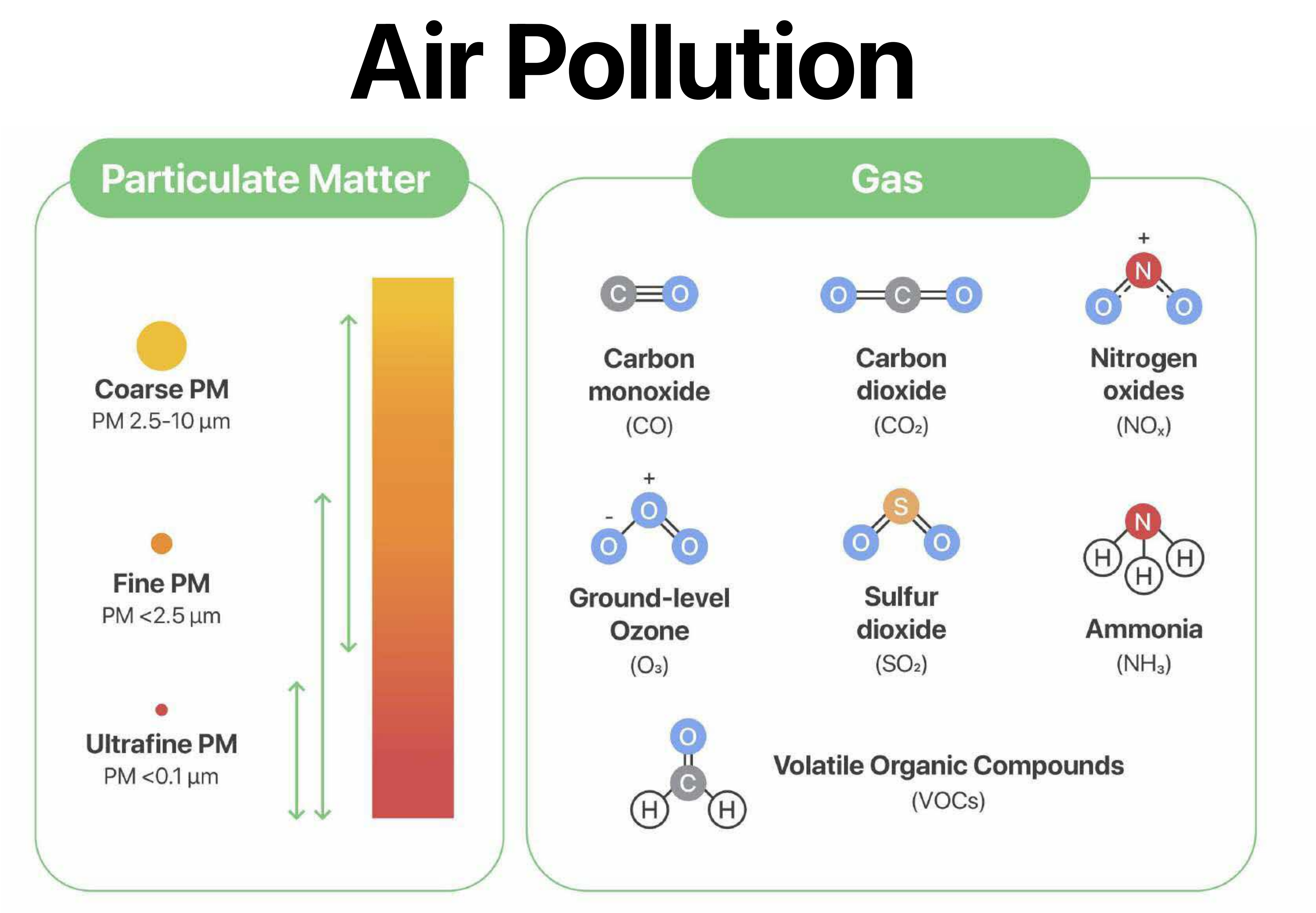
67 premature deaths per 100,000 people caused by air pollution

Indonesia is now facing an air crisis that is no longer local but global in scale. In 2023, Indonesia was one of a handful of countries contributing up to three-quarters of the global air pollution burden. Furthermore, the Special Capital Region of Jakarta (DKI Jakarta) was recorded as the seventh most polluted city in the world in the same year. Jakarta Province suffers the highest impact among all provinces in Indonesia, with an estimated 67 premature deaths per 100,000 people attributed to air pollution, according to Global Burden of Disease data.

The threat is real. In 2022, the life expectancy of the Indonesian population could decrease by an average of 2.2 years if they continue to be exposed to unhealthy air pollution. Harmful particles and gases such as PM2.5, O3, SO2, NO2, and CO enter through breathing, invisible yet deeply felt.

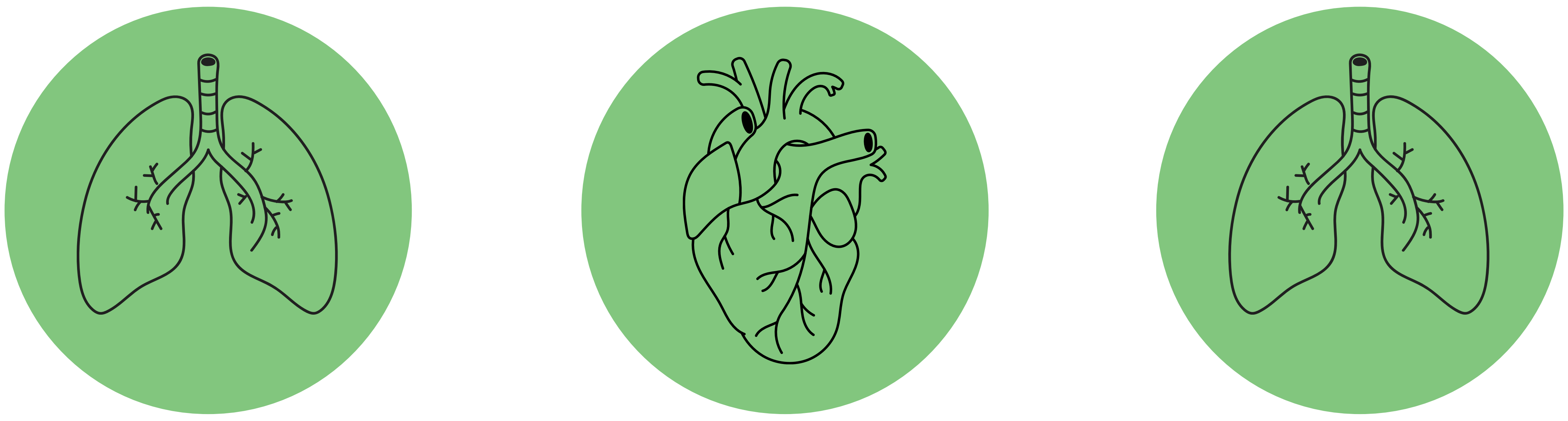


Grafik 1: Rincian polusi udara

The World Bank in 2021 explained that for decades, many global studies have shown that particulate air pollution is very dangerous for humans.

The World Health Organization (WHO) stated that air pollution is responsible for 7 million deaths globally each year, with fine particulate matter PM2.5 being the primary actor. More than half of deaths due to chronic obstructive pulmonary disease (COPD), as well as one-third of deaths due to respiratory tract infections and ischemic heart disease, are now directly linked to air pollution. Specifically, air pollution is responsible for 48% of deaths from Chronic Obstructive Pulmonary Disease (COPD), 30% of deaths from lower respiratory infections, and 28% of deaths from ischemic heart disease.

Air pollution is responsible for



30% of deaths from lower respiratory infections.

28% of deaths from ischemic heart disease.

48% of deaths from chronic obstructive pulmonary disease.

Graphic 2: Health effect on air pollution overview

Unfortunately, public access to air quality data remains very limited. The scarcity of local research further weakens policy advocacy and public awareness. This highlights the need for real-time data-driven studies and a contextual scientific approach.

One such initiative is the research conducted by the Faculty of Public Health, University of Indonesia (FKM UI) in collaboration with Nafas Indonesia. This study examines **the relationship between PM2.5 exposure and the incidence of pneumonia and asthma in toddlers in the Jabodetabek region during the COVID-19 pandemic.** The results showed a significant correlation, with the highest values found in Depok City (Haryanto et al. 2025).

Why is this important? Pneumonia accounts for 14% of all global child deaths, killing more than 800,000 toddlers. Nearly 2,200 toddlers die every day. In Jakarta, the annual PM2.5 concentration reaches 40 µg/m³ – far above the WHO standard of 15 µg/m³. The question now is no longer whether polluted air impacts our children, but how much it impacts them—and what we can do to prevent it.

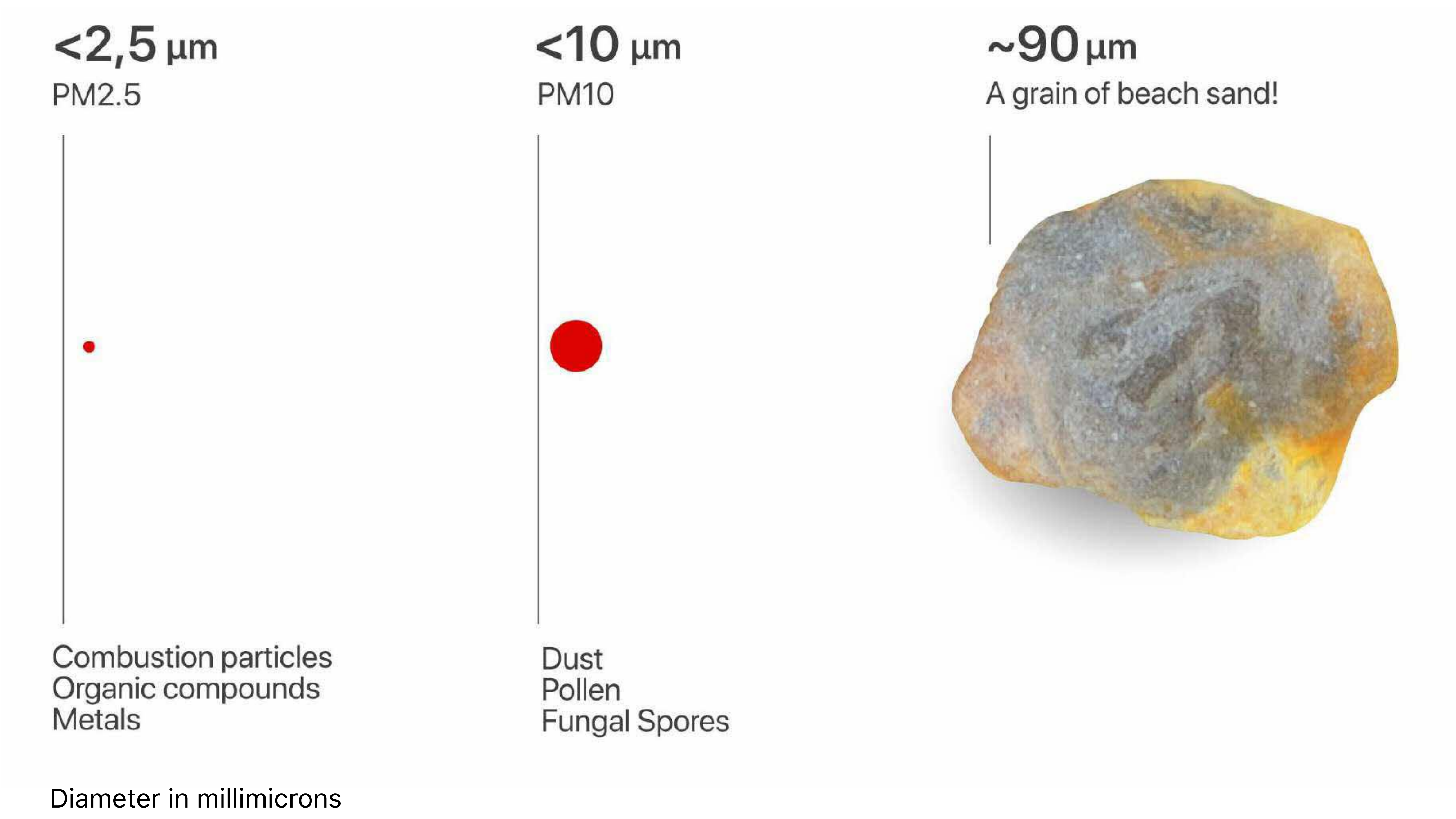
1.1

Dangers of Air Pollution to Child Health

Air Pollution and PM2.5

Air pollution is an invisible crisis, yet its impacts are felt deep within human lungs, especially children's lungs. Pollution exists in two main forms: **particles (particulate matter/PM)** and **harmful gases** like ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO).

One of the most dangerous forms of pollution is **Particulate Matter 2.5 (PM2.5)** – extremely small particles measuring less than 2.5 micrometers, or **about 36 times smaller than a grain of sand**. Their microscopic size allows PM2.5 to penetrate deep into the respiratory tract, bypassing the body's natural filtering system, and directly **enter the bloodstream**.



Graphic 3: Illustration of PM2.5 size

Why is PM2.5 Dangerous?

PM2.5 not only irritates the lungs, but also:

- Causes **chronic inflammation** and **oxidative stress**
- Weakens the local immune system in the respiratory tract

- Increases the risk of lower respiratory tract infections (such as pneumonia)
- It is associated with **heart disease, stroke, lung cancer, and even pregnancy complications and stunting in children**

The most affected groups are **children, the elderly, pregnant women, and individuals with chronic diseases.** When air quality worsens, these groups are often the first—and most severely—affected victims.

How Bad is the Situation in Jakarta?

The WHO has set PM2.5 thresholds as follows:

- **5 µg/m³ for annual average**
- **15 µg/m³ for daily average**

However, based on Nafas sensor network data from 2024, **the annual average PM2.5 in Jakarta reaches 35 µg/m³, it is 7 times higher than the safe WHO threshold**. This positions Jakarta as a city with a high exposure burden, even in a global context.

Where Does PM2.5 Come From?

PM2.5 sources are divided into two categories:

- **Natural:** soil dust, volcanic eruptions, and forest fires.
- **Anthropogenic (human-made):** including the combustion of fossil fuels, motor vehicles, industrial activities, and waste.

How we move

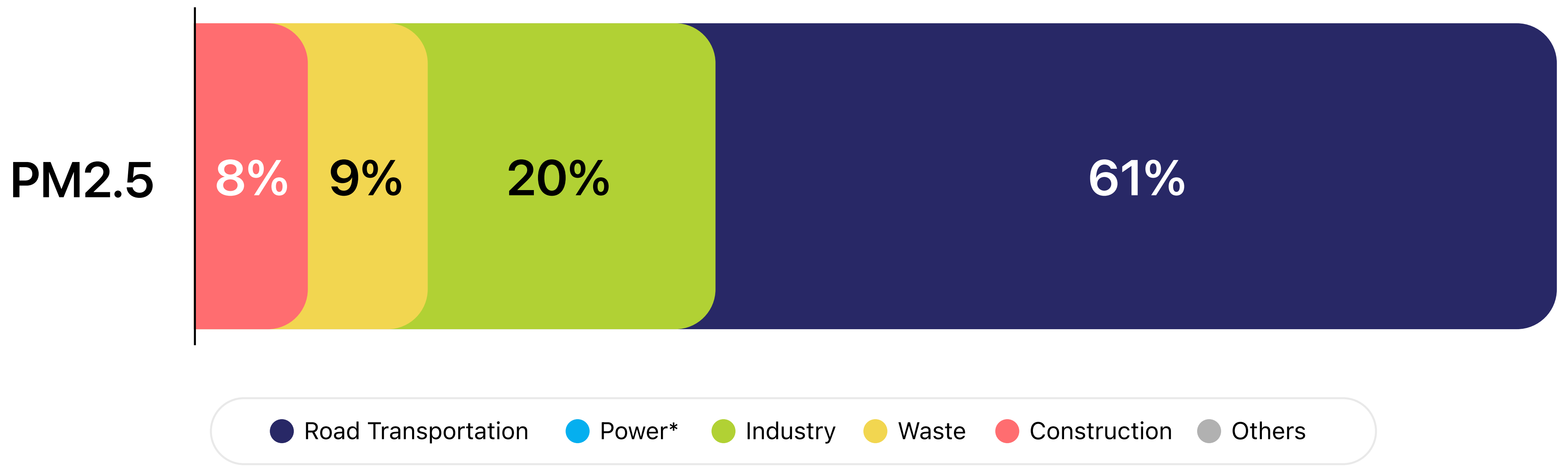
How we manage waste

How we produce

How we produce energy

However, there are also those that come from nature

A study by Systemiq, ITB, and Climate Foundation (2025) found that in DKI Jakarta, **transportation is the primary contributor to PM2.5 emissions**, particularly from fossil-fueled vehicles and incomplete combustion.



Graphic 4: Source of air pollution overview

Impact of PM2.5 in Numbers

- Every **1 in 5 global deaths** is linked to air pollution.
- **709,000 children under 5 years old** died from air pollution-related diseases in 2021 (State of Global Air).
- **PM2.5 is the second leading risk factor for child mortality globally**, after malnutrition.

Symptoms Caused by PM2.5 Exposure:

- **Short-term:** coughing, sneezing, watery eyes, shortness of breath, acute respiratory infections (ISPA).
- **Long-term:** chronic asthma, pneumonia, lung cancer, cardiovascular disorders, and even premature death.

Based on several studies conducted over the short term, each 10 µg/m³ increase in PM2.5 is associated with increased risk of respiratory diseases as follows:

Asthma	→ 1.7% increase in emergency visits for adult asthma and 3.6% in children (Fan et al., 2015)
Rhinitis	→ 0.47% increase in outpatient visits for allergic rhinitis on the same day (Wang et al., 2020)
COPD (Chronic Obstructive Pulmonary Disease)	→ 2.5% increased risk of hospital admission due to COPD, and 3.1% increase in mortality (Li et al., 2016)
Bronchitis	→ 15–32% increase in medical visits for lower respiratory tract infections in bronchitis patients (Horne et al., 2018)
URTI (Upper Respiratory Tract Infection)	→ **Sinusitis** • 0.48% increase in outpatient visits and hospitalizations due to chronic sinusitis among children under 15 years old (Lu et al., 2020) → **Influenza** • 14.7% increase in "Influenza-like illness within 6 days" (Zhang et al., 2022) • 16% increase in "Influenza-like illness" in weekly average (Toczylowski et al., 2021)

Several studies also indicate that each 10 µg/m³ increase in PM2.5 is associated with:

Lung Diseases & Disorders	→ 6.5% increase in risk of death due to lung cancer (Yang et al., 2023) → 34% increased risk of lung cancer (Miller et al., 2016) → 4.47% decrease in lung vital capacity (Chen et al., 2019)
Tuberculosis	→ 0.9% increase in TB case numbers after three months of exposure (Yang et al., 2020)

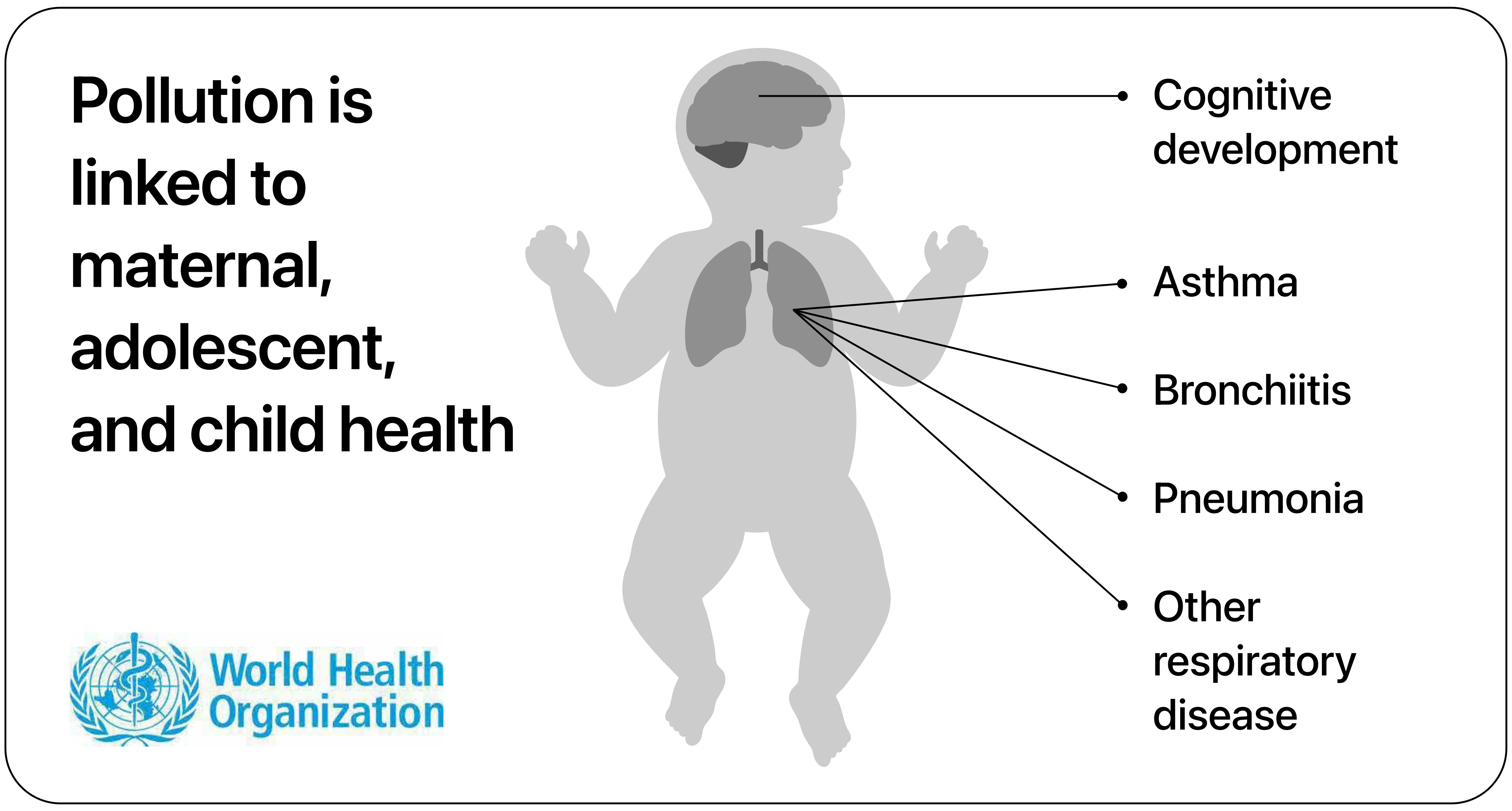
Several studies indicate that for every 10 µg/m³ increase in PM2.5, the following may be affected:

Cardiovascular Disease	→ **12–14%** increased risk of cardiovascular disease (Goldberg et al., 2008)
	→ **3%** increase in risk of cardiovascular disease related to stroke, heart disease, and ischemic heart failure (Lai et al., 2021)
	→ **23%** increase in risk of heart disease, 13% in stroke, and 8% in heart failure in the elderly (Xuewei et al., 2021)
Pregnancy	→ **48.4 grams** reduction in baby's birth weight during pregnancy (Savitz et al., 2014)
	→ **11%** increase in risk of miscarriage from secondhand exposure during pregnancy (Xue et al., 2022)
	→ **26%** increased risk of preterm birth during pregnancy (Zhang et al., 2020)
Children	→ **Stunting** • **19%** increased risk of stunting in children under five (Rani et al., 2021)
	→ **ADHD** *(attention-deficit hyperactivity disorder)* • **19%** increased risk of ADHD in children aged ten and above (Wang et al., 2023)
Skin Diseases	→ **5.1%** increase in medical visits for atopic dermatitis for every 10 µg/m³ increase in PM2.5 (Fadadu et al., 2023)
	→ **2.71%** increase in outpatient visits for eczema per month (Park et al., 2023)
	→ **1.71%** increased risk of acne vulgaris (pimples) in 120,842 patients in Chongqing (Jing et al., 2017)

1.2

Pneumonia: A Silent Threat to Indonesian Children's Breathing

Pneumonia is a contagious infectious disease that affects the lungs and spreads through the air—often unseen, yet highly deadly. It is caused by various microorganisms, including bacteria like *Streptococcus pneumoniae, Haemophilus influenzae, Haemophilus parainfluenzae*, Human bocavirus, Parainfluenza virus, Respiratory Syncytial Virus (RSV), Human metapneumovirus, Rhinovirus, Adenovirus, and Influenza.



Graphic 5: Air pollution effect to children's health visual

How Does PM2.5 Increase the Risk of Pneumonia?

PM2.5 particles are extremely small (<2.5 micrometers) and can penetrate the respiratory tract to the **alveoli**, where oxygen exchange occurs in the lungs. When continuously inhaled:

- PM2.5 triggers chronic inflammation and oxidative stress in lung tissues.
- Weakens the local immune system in the respiratory tract.
- Increases the body's susceptibility to attacks from microorganisms that cause pneumonia.

Vulnerable groups like children, the elderly, and individuals with chronic diseases are at **higher risk of contracting pneumonia due to high PM2.5 exposure**.

Why Are Toddlers So Vulnerable?

Toddlers (children under 5 years old) are considered a vulnerable group because:

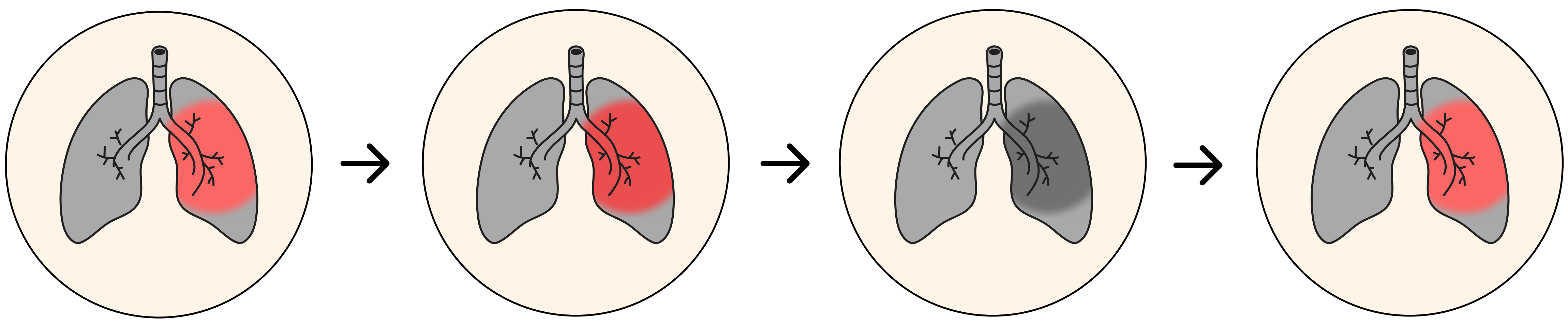
- Their **immune systems are not yet fully developed** to fight complex infections.
- Their **smaller respiratory tracts** cause mild infections to develop into pneumonia more quickly.
- **The air inhaled by toddlers is faster**: 24-40 times per minute, compared to adults who inhale only 12-20 times per minute. This means exposure to air pollution occurs more frequently and deeply.

Symptoms of pneumonia in toddlers include:

- Persistent coughing.
- Rapid or gasping breathing.
- High fever (>39°C).
- Loss of appetite.
- Chest or abdominal pain.
- Vomiting.
- Noisy breathing (*wheezing or grunting*).

If not handled quickly and appropriately, pneumonia can develop into a life-threatening condition—especially in environments with poor air quality.

Stages of pneumonia:



Stage 1	Stage 2	Stage 3	Stage 4
Congestion	**Red Hepatization**	**Grey Hepatization**	**Resolution**
First 24 hours	Days 2-3	Days 4-8	1-2 weeks

Graphic 6: Stages of pneumonia overview | Source: verywell health (2025)

2

Research Methods

Research Design

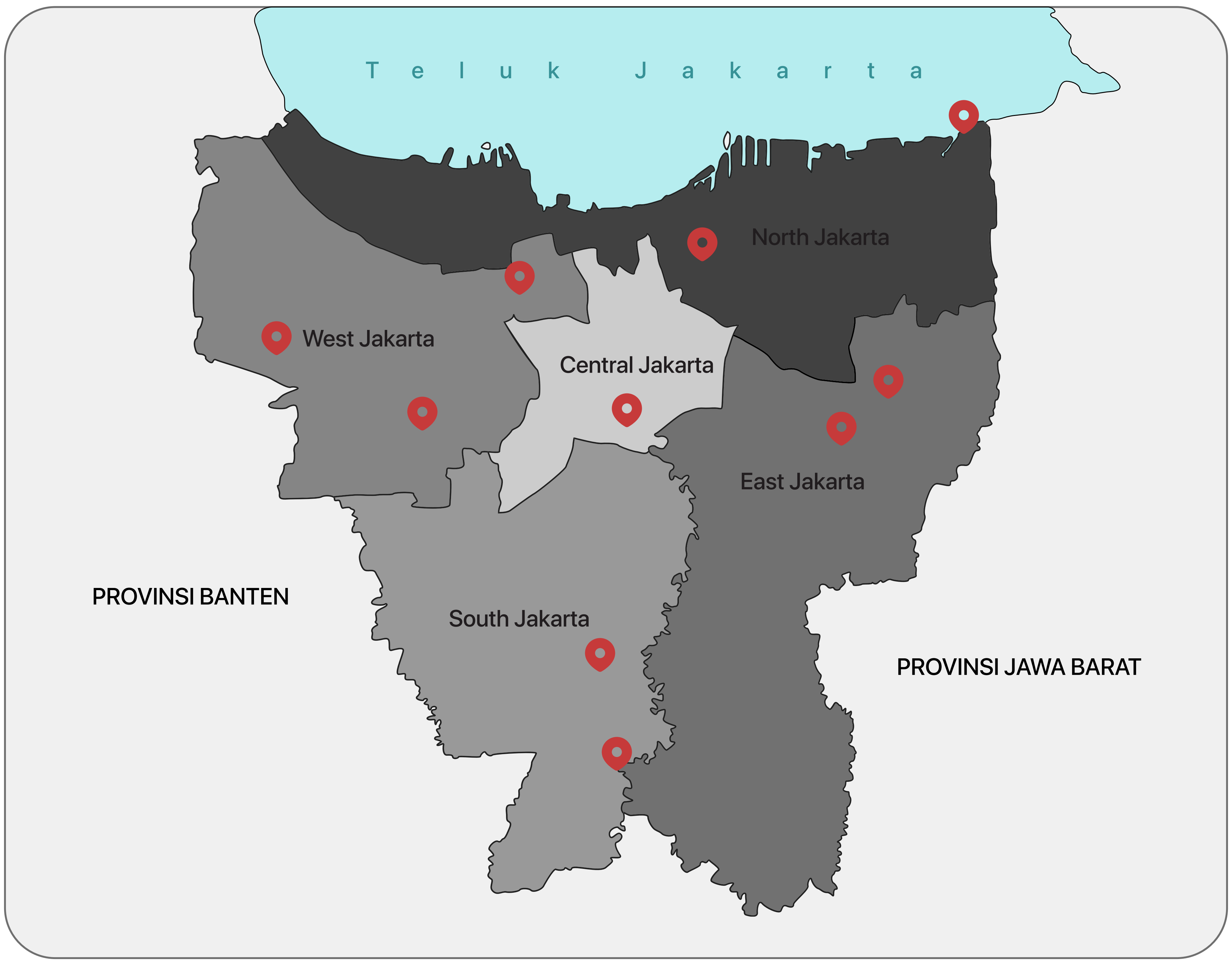
This research utilized a place-based **ecological study design** to analyze the relationship between **PM2.5 concentrations and the incidence of pneumonia in toddlers, the area of study is in DKI Jakarta in 2023**. The study aimed to provide a spatial and temporal overview of the air pollution burden and its impact on child health. It is classified as a multiple-group ecological study, comparing aggregate data across different regions at the same time to broadly analyze spatial relationships between pollution and disease.

Study Location and Source of Data

The study was conducted in **10 sub-districts in DKI Jakarta**, which are equipped with air quality monitoring sensors from **Nafas's sensor network**. These sub-districts were randomly selected from five administrative cities within Jakarta and include Menteng, Cilincing, Tanjung Priok, Kalideres, Kebon Jeruk, Tambora, Pasar Minggu, Jagakarsa, Cakung, and Duren Sawit.

The data used in this study included:

- **Air pollution data:** PM2.5 concentration (µg/m³) obtained from Nafas Indonesia sensors.
- **Number of pneumonia cases in toddlers:** sourced from the DKI Jakarta Provincial Health Agency.
- **Toddler population data:** obtained from the DKI Jakarta Civil Registry and Population Agency.



Graphic 7: Research location

Research Type

This research is categorized as a **multiple-group ecological study**, which compares aggregate data across regions at the same time. With this approach, the spatial relationship between pollution and disease variables can be broadly analyzed, even if not at the individual level.

Measurement and Data Analysis Methods:

1. Prevalence

Calculated to describe the proportion of toddlers with pneumonia in each sub-district. The formula used is

$$Prevalence = \frac{Number\ of\ Pneumonia\ cases\ in\ toddler\ (in\ the\ specific\ place\ and\ time)}{Number\ of\ total\ toddler\ population\ (in\ the\ specific\ place\ and\ time)} \text{ x } 10.000$$

Calculations were performed monthly to observe seasonal trends and per region for geographical comparison.

2. Univariate Analysis

Performed to describe the characteristics of each variable (PM2.5 concentration and pneumonia prevalence) independently, with visualizations in the form of **time trend graphs** and **scatter plots**.

3. Bivariate Analysis

Conducted to test the relationship between the two main variables: PM2.5 concentration and pneumonia prevalence. This included:

1. **Normality test:**
   a. Using Shapiro-Wilk (for $n < 30$) or Kolmogorov-Smirnov (for $n \geq 30$).
   b. A p-value > 0.05 indicated normal data distribution,
   c. A p-value < 0.05 indicated non-normal distribution.

2. **Correlation test:**
   a. **Pearson's correlation** was used for normal data, and
   b. **Spearman rank correlation** for non-normal data.

P-value interpretation:

P-value	Details
≤ 0,05	Significant relationship
>0,05	Non-significant relationship

Correlation coefficient (r) interpretation:

R value	Details
0,00 – 0,25	Weak correlation
0,26 – 0,50	Moderate correlation
0,51 – 0,75	Strong correlation
0,76 – 1,00	Very strong correlation

4. Linear Regression based on Spearman Correlation

Used to quantify the direct impact of increased PM2.5 concentration on the increase in pneumonia cases in toddlers, once a significant relationship was established through the Spearman correlation test.

The simple linear regression model used was

$$Y=a+bX$$

where:

- **Y** = number of pneumonia cases in toddlers
- **X** = PM2.5 concentration (μg/m³)
- **a** = constant (intercept)
- **b** = regression coefficient (indicating the change in Y for every 1 unit change in X).

Positive b-coefficient → indicates that the higher the PM2.5, the higher the pneumonia cases

Negative b-coefficient → indicates an inverse relationship (not common in this context, but can occur if there are other protective factors)

R^2 value (coefficient of determination) → indicates the percentage of variation in pneumonia cases that can be explained by variations in PM2.5

3

Research Results

Finding 1:

PM2.5 Increase Directly Linked to Pneumonia Surge

Analysis of data, particularly in Menteng Sub-district—which showed the highest correlation in this study—revealed that **every 10 µg/m³ increase in PM2.5 could lead to a twofold surge in pneumonia prevalence**. This finding strongly suggests that PM2.5 exposure significantly contributes to the increase in lower respiratory tract infections, especially in toddlers.

For instance, **the baseline PM2.5 concentration in Central Jakarta was 26 µg/m³**, categorized as a **moderate level** and representing the average PM2.5 in the area. At this level, pneumonia prevalence was recorded at 19 cases per 10,000 population. However, when PM2.5 increased to 56 µg/m³, the prevalence surged to 92 cases per 10,000 population—**nearly 5 times higher than the initial baseline**.

PM2.5 (µg/m³)	**Prevalensi Pneumonia** (per 10.000 penduduk)
26	19
36	43
46	67
56	92

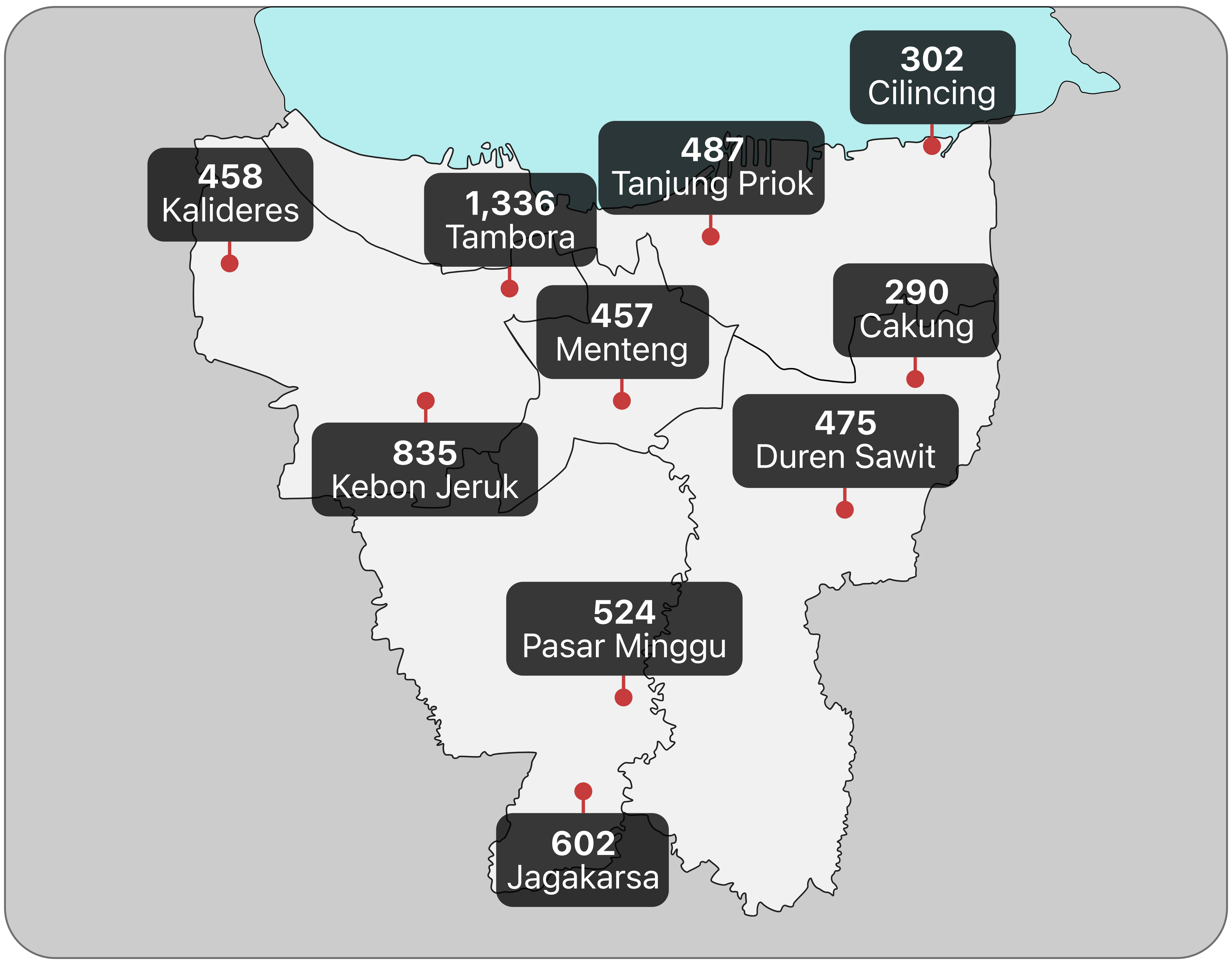
Table 1: Increase correlation between PM2.5 and Pneumonia prevelance

This **consistent linear pattern** between fine particulate exposure and disease burden reinforces findings from other studies, such as Wang et al. (2021), which concluded that every 1 µg/m³ increase in PM2.5 was associated with an increase of approximately 1,316 visits to healthcare facilities for respiratory illnesses. This cumulative data strongly indicates that poor air quality, even at "moderate" levels, can have severe health implications, especially for vulnerable groups like children.

Finding 2:

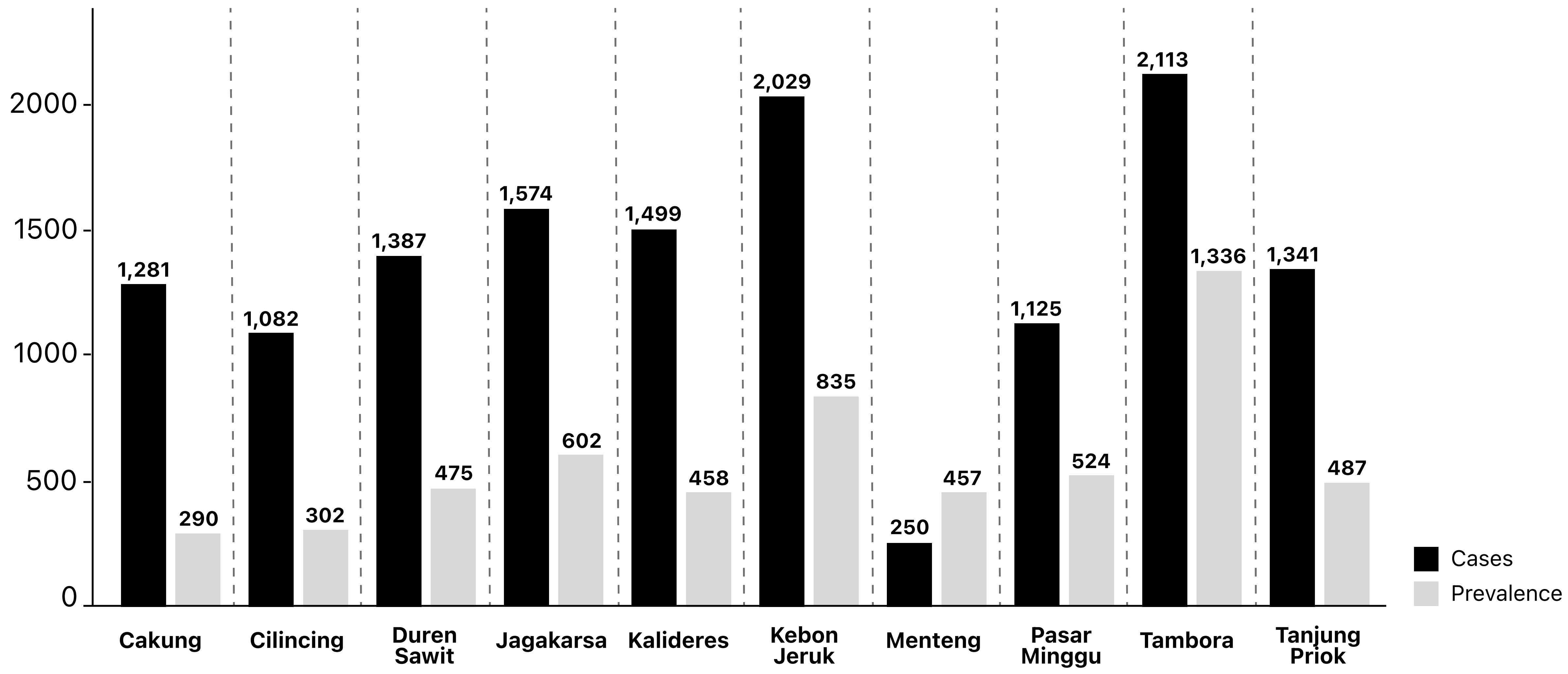
One in Twenty Toddlers in Jakarta Affected by Pneumonia.

Data analysis revealed that in 2023, **1 out of every 20 toddlers in DKI Jakarta suffered from pneumonia**. This indicates a significant and recurring health burden, particularly in densely populated and polluted areas. Pneumonia prevalence is calculated as the number of cases at a specific time and area divided by the toddler population in that area, multiplied by 10,000.



Graphic 8: Map of pneumonia prevalence based on the size in DKI Jakarta

Prevalence of pneumonia in toddlers is calculated by dividing the number of pneumonia cases at a specific time in a specific area by the number of toddlers at that specific time and in that specific area, multiplied by 10,000. **This formula provides an overview of how many toddlers are affected by pneumonia per 10,000 children in the population of a certain area within a specific time period.**



Graphic 9: Graph of the distribution of pneumonia cases and prevalence

This striking difference between regions shows the possibility of **variations in environmental exposure**, air quality, residential density, and unequal access to health services across Jakarta.

- **Tambora Sub-district** recorded the highest prevalence**, at 1,406 cases per 10,000 toddler residents.**
- **Cakung Sub-district** became the area with the lowest burden**, namely 312 cases per 10,000 residents.**

Sub-district	January		February		March		April		May		June	
	Cases	Prevalence	Cases	Prevalence	Kasus	Prevalence	CasesCases	Prevalence	Cases	Prevalence	Cases	Prevalence
Cakung	81	20	61	15	71	17	40	10	38	9	103	25
Cilincing	90	27	99	29	58	17	72	21	109	32	61	18
Duren Sawit	118	43	104	38	111	40	79	29	95	35	111	40
Jagakarsa	122	49	126	51	103	42	131	53	125	51	130	53
Kalideres	121	39	129	41	125	40	123	40	130	42	125	40
Kebon Jeruk	176	76	170	73	185	80	174	75	358	154	56	24
Menteng	10	20	5	10	12	23	10	20	21	41	22	43
Pasar Minggu	89	44	96	47	69	34	69	34	119	58	96	47
Tambora	204	136	189	126	135	90	145	96	180	120	164	109
Tanjung Priok	46	18	61	23	60	23	69	27	78	30	155	60

Sub-district	July		August		September		October		November		December	
	Cases	Prevalence	Cases	Prevalence	Cases	Prevalence	Cases	Prevalence	Cases	Prevalence	Cases	Prevalence
Cakung	75	16	164	36	173	38	211	46	136	30	128	28
Cilincing	146	39	91	24	98	26	101	27	86	23	71	19
Duren Sawit	109	36	126	41	145	47	118	38	111	36	160	52
Jagakarsa	129	47	142	51	140	51	145	52	133	48	148	54
Kalideres	125	36	126	36	127	37	124	36	124	36	120	35
Kebon Jeruk	198	77	165	64	59	23	178	69	178	69	132	51
Menteng	24	42	48	85	28	49	48	85	10	18	12	21
Pasar Minggu	76	34	81	36	161	71	122	54	75	33	72	32
Tambora	190	114	215	129	234	141	176	106	170	102	111	67
Tanjung Priok	116	41	121	42	194	68	102	36	171	60	168	59

Table 2: Monthly pneumonia cases and prevalence

Monthly data shows that **pneumonia prevalence is not constant**, but **fluctuates throughout the year** and **differs between sub-districts**.
For example:

- **The highest monthly prevalence** occurred in **Kebon Jeruk Sub-district in May** (154 per 10,000 population)**.**
- **The lowest monthly prevalence** occurred in **Cakung Sub-district in May as well** (9 per 10,000 population)**.**

This indicates that **seasonal factors such as weather, humidity, and exposure** to air pollution likely contribute to monthly case numbers.

Sub-district	Month		Prevalence	
	Highest	Lowest	Highest	Lowest
Cakung	October	May	46	9
Cilincing	July	March	39	17
Duren Sawit	December	April	52	29
Jagakarsa	December	Maret	54	42
Kalideres	May	December	42	35
Kebon Jeruk	May	September	154	23
Menteng	August and October	February	85	10
Pasar Minggu	September	December	71	32
Tambora	September	December	121	67
Tanjung Priok	September	January	68	18

Table 3: Highest and lowest pneumonia prevalence by month

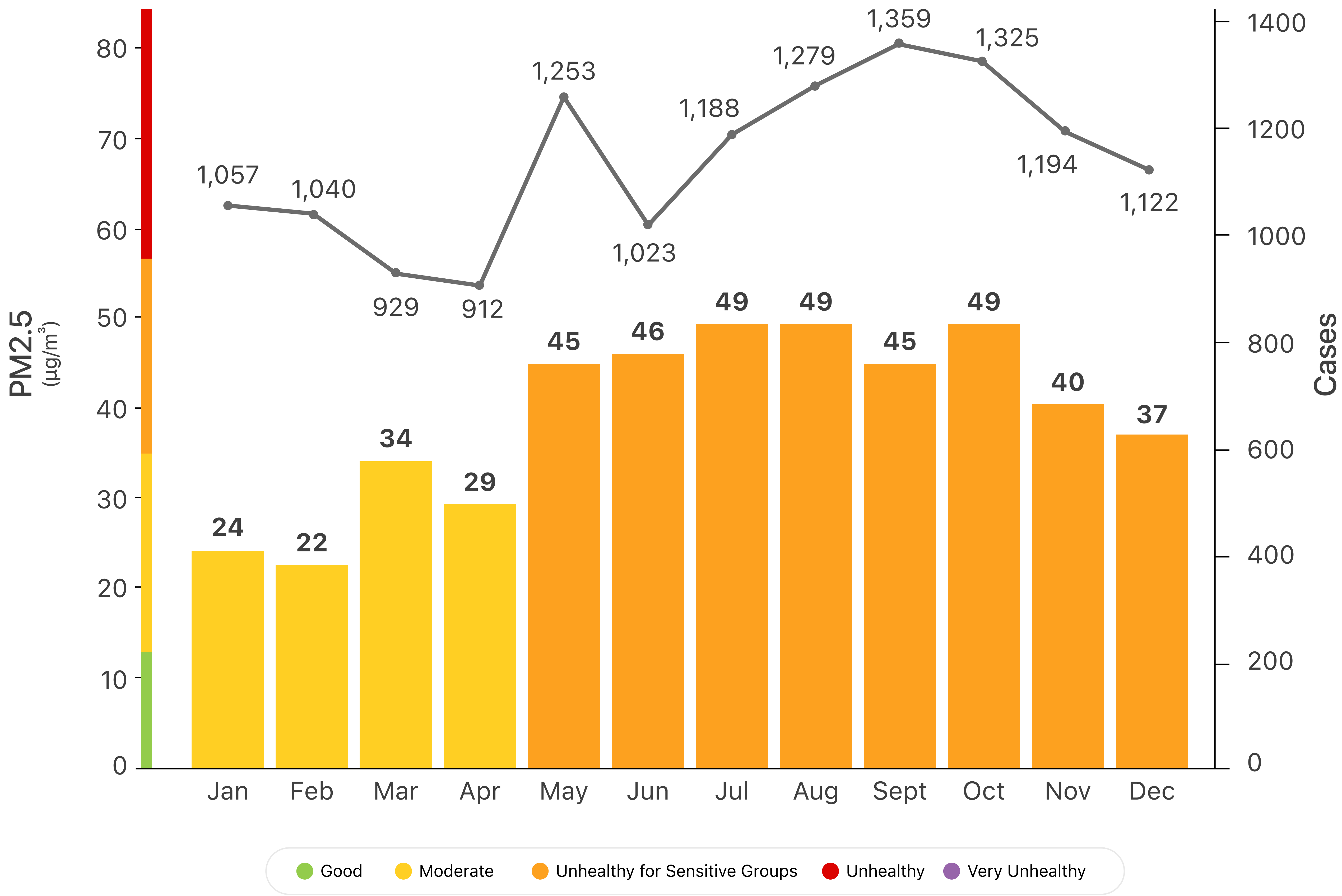
Pneumonia is not just an individual health problem, but also **a reflection of environmental quality**. Disparities between regions strengthen the urgency to:

- Increase access to local air quality monitoring
- Encourage region-based health interventions
- Educate the public about respiratory disease prevention efforts

Finding 3:

Significant Correlation between PM2.5 and Pneumonia in Jakarta Time

Analysis: Cases Surge in Dry Season



Graphic 10: Number of monthly pneumonia case and the monthly average of PM2.5

Monthly trends indicate that pneumonia cases began to surge in **May, peaking between August and October**. This surge coincided with a parallel increase in PM2.5 concentrations during those months.

The average monthly pneumonia cases in 2023 were 1,140. Most months from May to December (excluding June) recorded above-average cases.

Mengapa kasus di bulan Juni turun?

The temporary drop in cases in June could be explained by two hypotheses:

1. **The clinical phases of pneumonia (congestion, hepatization, resolution, and recovery)** mean some cases starting in May might resolve before June ends, or
2. **Dry season conditions make respiratory irritation and symptoms more pronounced,** leading to higher classification as pneumonia by healthcare professionals.

pearman Correlation Analysis was conducted to examine the relationship between PM2.5 concentrations and the number of pneumonia cases in toddlers across the 10 sub-districts equipped with Nafas air quality sensors. The results showed:

Sub-districts	R Value	P Value	Details
Menteng	0,751	0,005*	Strong positive correlation
Cilincing	0,332	0,292	Medium positive correlation
Tanjung Priok	0,622	0,031*	Strong positive correlation
Kalideres	-0,631	0,028*	Strong positive correlation
Kebon Jeruk	-0,259	0,416	Medium positive correlation
Tambora	0,102	0,753	Weak positive correlation
Pasar Minggu	0,140	0,664	Weak positive correlation
Jagakarsa	-0,042	0,897	Weak positive correlation
Cakung	0,405	0,192	Medium positive correlation
Duren Sawit	-0,140	0,664	Weak positive correlation

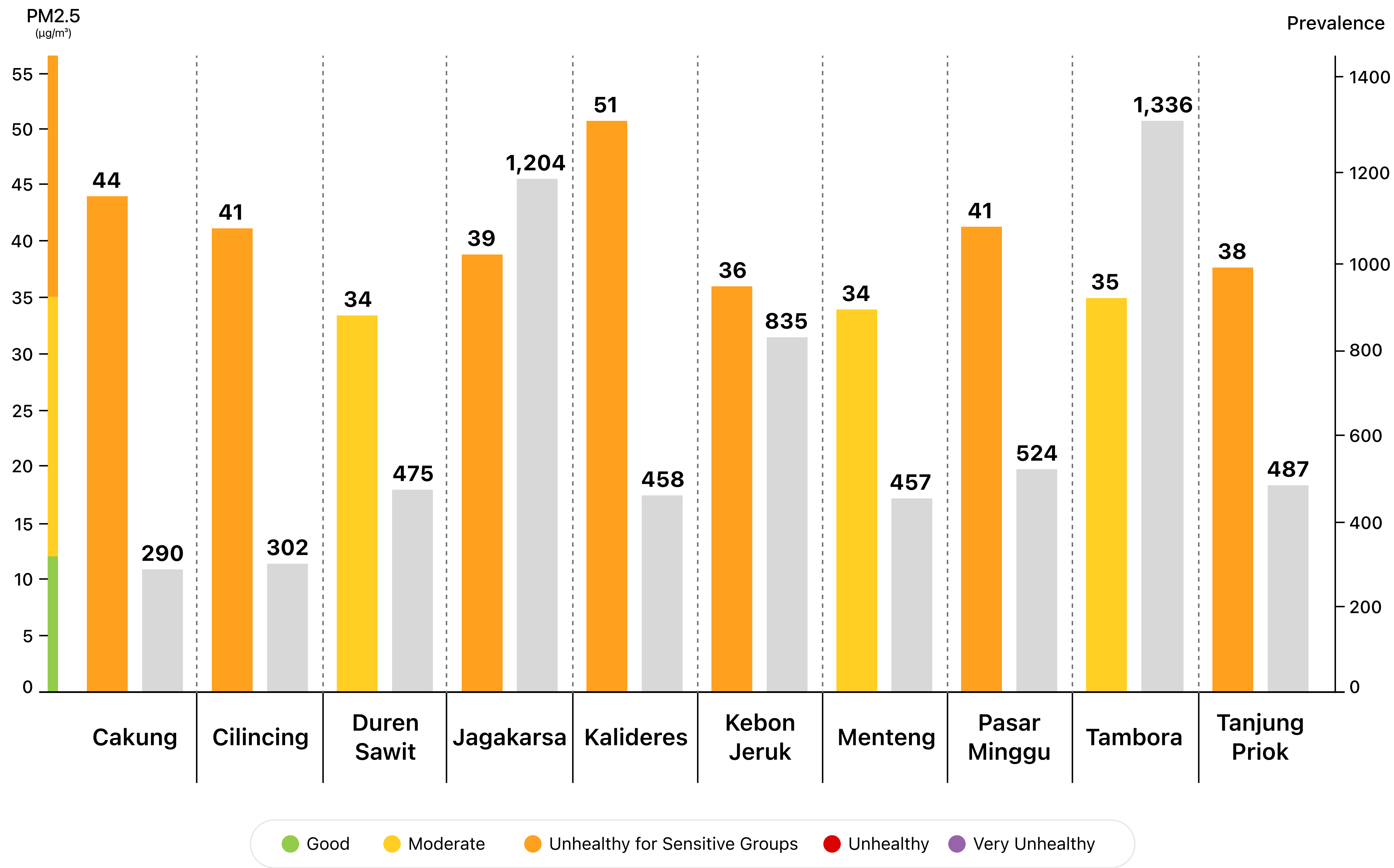
*Have a significant relationship

Table 3: P-Score in each sub-district in DKI Jakarta

- **Three sub-districts had a statistically significant relationship ($p < 0.05$):**
  - **Menteng** ($r = 0.751$; $p = 0.005$) showing a strong positive correlation
  - **Tanjung Priok** ($r = 0,622$; $p = 0,031$) → also shows a strong positive correlation.
  - **Kalideres** ($r = –0,631$; $p = 0,028$) → showing a strong negative correlation.

The meaning of correlation in this context:

- A **positive** correlation (Menteng and Tanjung Priok) indicates that as PM2.5 concentration increases, the number of pneumonia cases also tends to increase.
- A **negative** correlation (Kalideres) suggests that **other factors might be more dominant** in triggering pneumonia in that area, such as housing density, home ventilation, or seasonal infections



Graphic 11: Annual PM2.5 average and total prevalence per sub-district

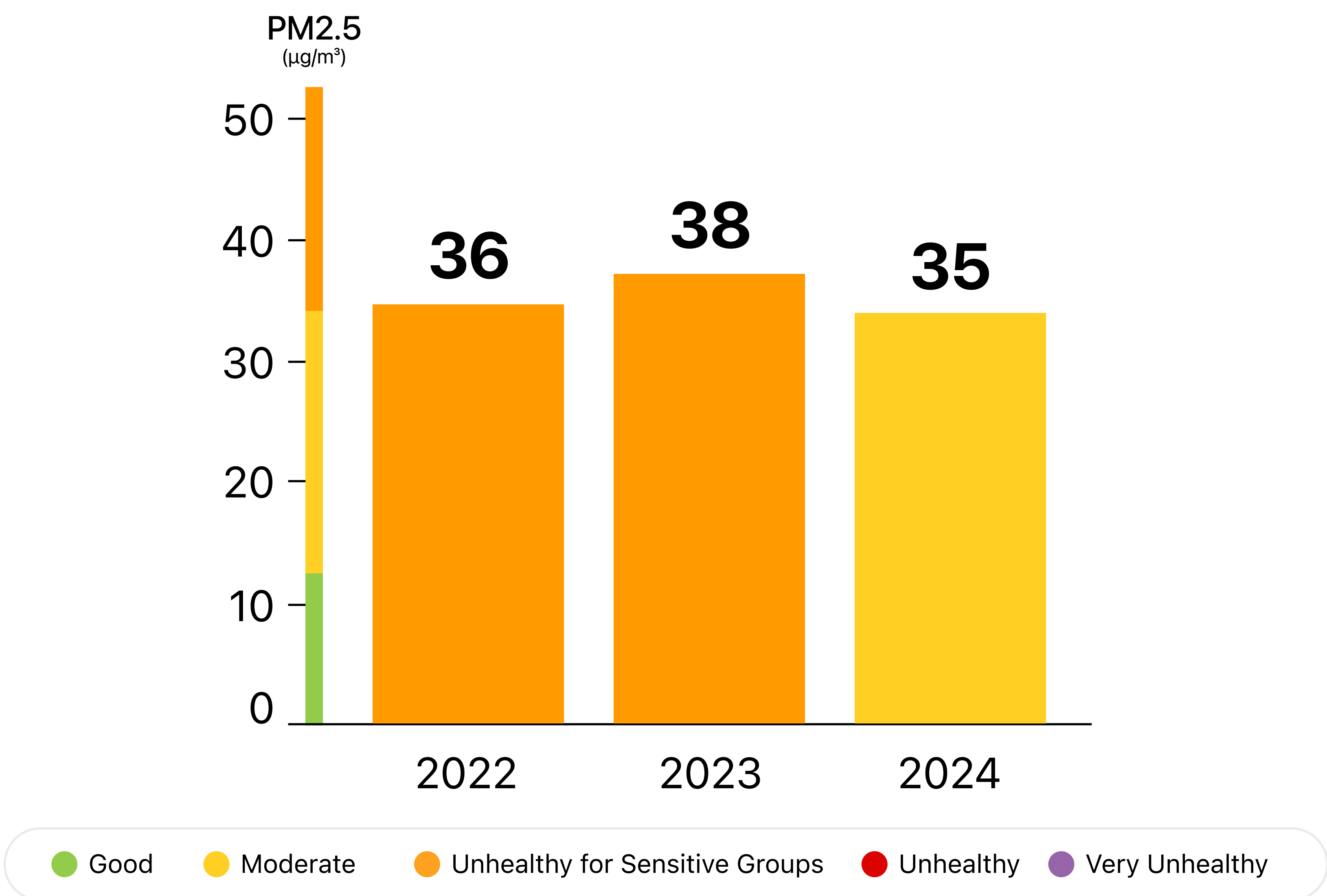
While correlation does not directly imply causation, it provides a strong indication that poor air exposure is linked to high pneumonia cases in parts of Jakarta. These findings are further supported by other research, including a study by Munggaran et al. (2024), which found a significant relationship between particulate matter and pneumonia incidence, and Haryanto et al. (2025), which showed a strong correlation between PM2.5 concentration and pneumonia in toddlers in Depok City. This correlation data emphasizes the importance of air quality monitoring as a crucial component of an early warning system for infectious disease prevention, enabling more targeted public policies to protect vulnerable groups, especially toddlers.

Finding 4:

Jakarta Air Quality Worsened Post-Pandemic

Increase in Average PM2.5 Year-on-Year

The year 2023 was recorded as a year with worst air quality compared to the previous year. According to Nafas sensor monitoring in DKI Jakarta, the annual average PM2.5 increased from 36 µg/m³ in 2022 to 38 µg/m³ in 2023. This reinforces a gradual decline in air quality post-pandemic. Nafas' data for 2024 showed an annual average of 35 µg/m³.

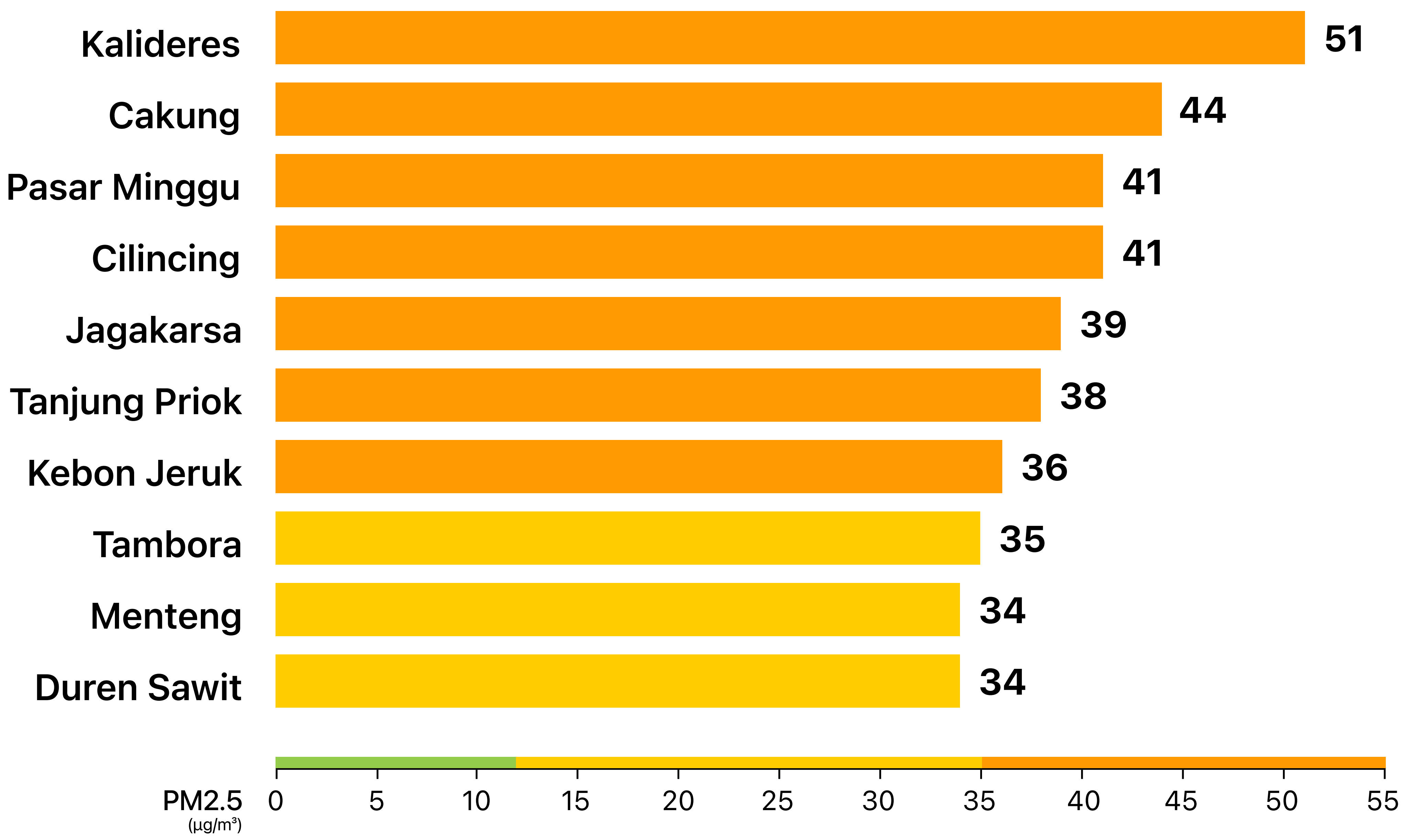


Graph 12: Annual PM2.5 average of PM2.5 in DKI Jakarta

Resumption of Activities = Increased Emissions?

This surge in PM2.5 coincides with a significant event:
June 21, 2023, the Indonesian government officially lifted the COVID-19 pandemic status through **Presidential Decree No. 17 of 2023.**

As the economy, office, transportation, and overall mobility increased, so did pollution sources from vehicles and human activities. This aligns with a study by **Maksum et al.** (2022) that identified motor vehicles as a primary contributor to suspended particulate matter in Jakarta's air.



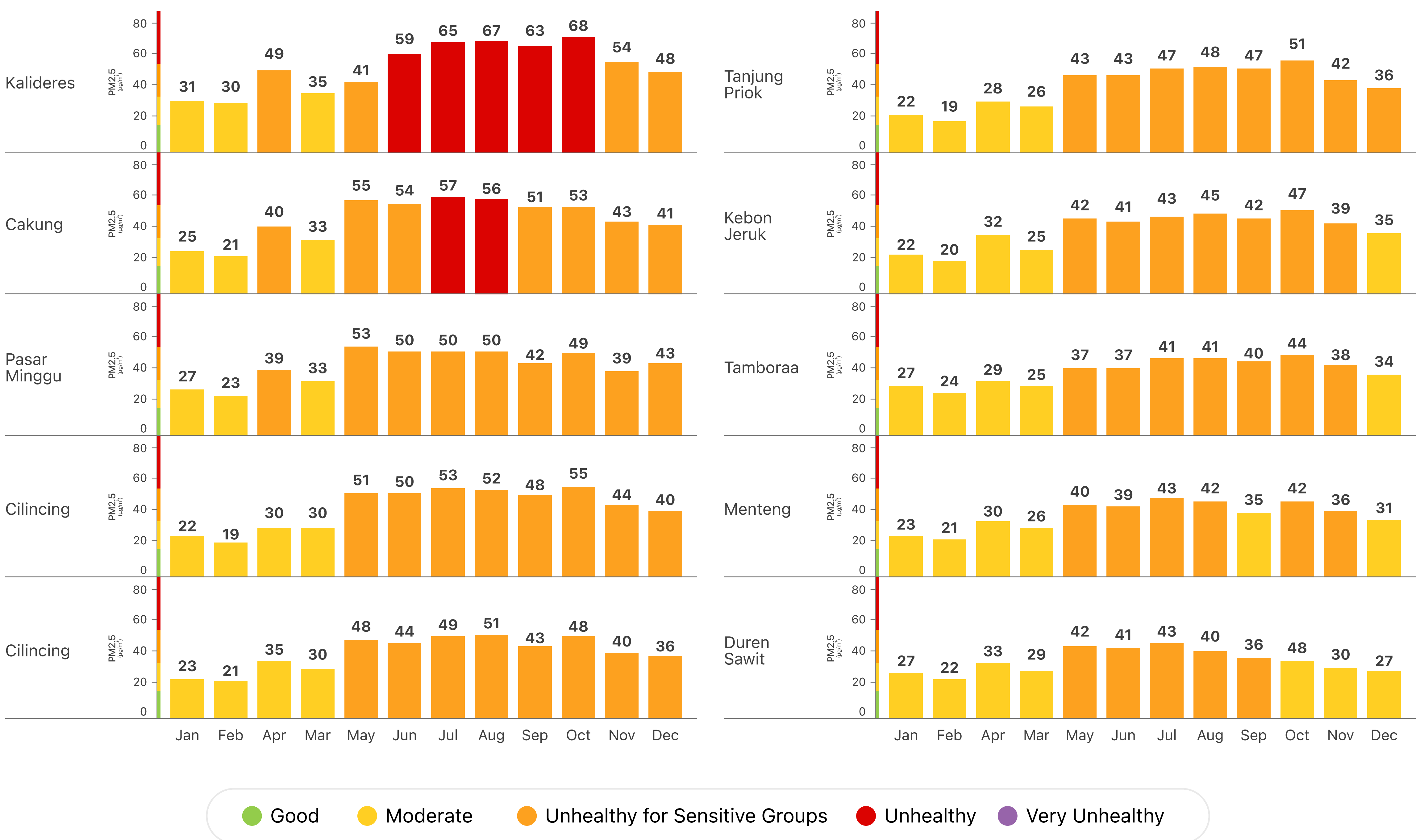
Graphic 13: Annual average of PM2.5 in each sub-district

Differences Between Sub-districts: Not All Exposed Equally

The annual average PM2.5 levels showed significant variation across sub-districts:

- **Kalideres** recorded the highest concentration at **51 µg/m³**
- **Penjaringan** was among the lowest at **33 µg/m³.**

This highlights that **local characteristics** (e.g., vehicle density, building patterns, population density, green spaces) greatly influence air pollution levels.
Even within a single large city like Jakarta, air quality **can vary significantly between neighborhoods.**



Graphic 14: Monthly average of PM2.5 in each sub-district

- **PM2.5 concentrations increased sharply between May and October,** coinciding with the dominant dry season.
- **A decrease was observed from January–March and from November–December,** aligning with the rainy season.

Atmospheric factors such as humidity, precipitation, and wind movement play crucial roles in dispersing or settling pollutant particles.

The rise in PM2.5 after the end of the COVID-19 pandemic indicates that without environmental interventions, economic recovery could compromise air quality and public health. The varying concentrations across regions necessitate localized policies that consider specific conditions. With this data, we can understand not just that pollution is increasing, but also *when, where,* and *how significant* the risks are.

4

Preventive Measures: Protecting Toddlers from Pneumonia

To mitigate the risks of pneumonia, particularly in vulnerable populations like toddlers, several preventive steps are recommended:

1. Use Masks When Outdoors

Exposure to air pollution like PM2.5 can deeply penetrate the lungs and trigger inflammation. Wearing high-filtration masks (e.g., KF94 or N95) can help filter inhaled air and reduce exposure to harmful particles, especially when the air quality index (AQI) is poor.

2. Lengkapi Imunisasi Dasar Balita

Immunization is a primary defense against lower respiratory tract infections such as pneumonia. Two crucial immunizations for pneumonia prevention in toddlers are

- **HiB (Haemophilus influenzae type B)**
- **PCV (Pneumococcal Conjugate Vaccine)**

Graphic 15: Government has established a national immunization schedule through the Ministry of Health

3. Meet Balanced Nutritional Needs

Good nutrition strengthens a toddler's immune system to fight infections. The **"Isi Piringku" (My Plate)** program from the Ministry of Health promotes balanced consumption of staple foods, protein, vegetables, and fruits. It is recommended to be complemented by:

- Drinking at least 8 glasses of water daily,
- Engaging in 30 minutes of physical activity, and
- Handwashing before meals.

Graphic 16: Nutrition meal illustration

4. Practice Regular Handwashing with Soap

Pneumonia can be transmitted through hands contaminated with viruses or bacteria. Toddlers should be taught the **6 Steps of Handwashing with Soap for 60 seconds,** particularly before eating and after playing.

Graphic 17: Guidance on hand washing with soap

5. Protect Toddlers from Exposure to Infected Individuals

Since pneumonia can spread through the air, it's crucial to:

- Avoid direct contact with people who are coughing or have colds.
- Creating a **clean and well-ventilated home environment,**
- Maintaining physical distance and practicing cough etiquette are also important.

Toddlers are a vulnerable group with underdeveloped immune systems. Prevention is better than cure, and these steps represent **a long-term investment in protecting the lung health of future generations. Protecting their small breaths is vital, as every breath holds hope.**

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