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The Impact of Environmental Pollution on Public Health: Global and Local Perspectives

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Abstract**:** *Environmental pollution represents one of the most significant public health threats at both global and local levels. This article analyzes the health impacts of air, water, and soil pollution using a Systematic Literature Review guided by PRISMA standards. Out of 578 identified studies, 84 articles met the eligibility criteria and were thematically synthesized. Findings show that air pollution contributes to increased cardiovascular diseases, respiratory disorders, and premature mortality. Water pollution elevates risks of infectious diseases and heavy metal exposure, while soil pollution affects food safety and long term exposure to toxic substances. In Indonesia, pollution is exacerbated by rapid urbanization, social inequality, and uneven environmental governance. The study emphasizes the need for cross sector strategies, enhanced monitoring capacity, and stronger health oriented environmental policies. These insights provide an evidence based foundation for designing interventions aimed at reducing pollution burdens and improving public health protection.*

Keywords : air pollution, environmental health, public health, water contamination

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INTRODUCTION

Environmental pollution has emerged as one of the most pressing global health challenges of the twenty first century. Rapid industrialization, urbanization, and extensive fossil fuel consumption have significantly increased human exposure to air, water, and soil contaminants that adversely affect population health. According to the World Health Organization (WHO, 2021), environmental pollution contributes to an estimated seven million premature deaths annually, with air pollution alone accounting for more deaths than HIV, malaria, and tuberculosis combined. The majority of these deaths occur in low and middle income countries where regulatory oversight, environmental enforcement, and access to healthcare remain insufficient. The United Nations Environment Programme (UNEP, 2022) highlights that 92 percent of the global population breathes air that exceeds recommended safety limits, underscoring the magnitude of this global emergency. Pollution therefore poses not only ecological risks but also severe social inequalities, as vulnerable populations are disproportionately exposed to hazardous environments.

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Air pollution, water contamination, soil degradation, and exposure to toxic chemicals generate complex health burdens that interact with pre existing social and economic vulnerabilities. WHO (2021) reports that fine particulate matter (PM2.5) is strongly associated with cardiovascular diseases, respiratory

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infections, lung cancer, and adverse pregnancy outcomes. Ground level ozone contributes to chronic obstructive pulmonary disease, while nitrogen dioxide increases the risk of asthma in children. Water pollution affects nearly two billion people globally through exposure to pathogens, heavy metals, pesticides, and industrial waste. The United Nations reports that contaminated water causes approximately 485,000 diarrheal deaths per year, mostly affecting children under five (UNICEF, 2020). Soil pollution further contributes to food contamination, reduced crop productivity, and long term exposure to neurotoxic substances. These environmental risks collectively shape the disease landscape of modern societies, making pollution a determinant of non communicable and infectious diseases.

Indonesia reflects these global trends within its national context. As one of the world's most rapidly urbanizing countries, Indonesia faces escalating pollution levels from industrial emissions, motorized transportation, biomass burning, and poor waste management. Data from the Ministry of Environment and Forestry (KLHK, 2023) shows that 75 percent of major urban centers exceed national air quality standards, with Jakarta consistently ranked among the most polluted capitals in the world according to the IQAir Global Index (IQAir, 2023). PM2.5 concentrations in Jakarta regularly surpass WHO guidelines five to seven times, exposing nearly eleven million residents to harmful air every day. Water pollution remains a critical issue as only 22 percent of rivers meet Class II water quality standards due to industrial discharges, agricultural runoff, and inadequate sanitation infrastructure (KLHK, 2023). At the same time, solid waste mismanagement has led to a significant rise in microplastics contamination across marine and terrestrial ecosystems, raising concerns about long term toxicity and food chain disruption (Basri et al., 2021).

Urban populations face heightened vulnerability due to concentrated emissions, high traffic density, and exposure to industrial pollutants. In cities such as Jakarta, Surabaya, Medan, and Bandung, respiratory illnesses are among the leading causes of morbidity. A study by Haryanto et al. (2025) found that PM2.5 exposure in Jakarta is significantly correlated with increased hospital admissions for asthma and acute respiratory infections, particularly among children and older adults. Additionally, the burden of non communicable diseases such as stroke, ischemic heart disease, and lung cancer is strongly associated with prolonged exposure to air pollution in urban centers (World Bank, 2021). These conditions create a long term public health burden and place substantial pressure on national healthcare systems.

The impacts of pollution are not only biomedical but also socio economic. Environmental degradation leads to reduced labor productivity, increased healthcare costs, and long term developmental challenges. The World Bank (2021) estimates that air pollution alone costs Indonesia approximately 5.3 percent of its GDP annually due to lost productivity, healthcare expenditure, and premature mortality. Similarly, water pollution diminishes fisheries productivity, increases food insecurity, and reduces access to safe water, disproportionately affecting low income households. UNEP (2022) notes that pollution exacerbates poverty cycles because low income communities often live near industrial zones, waste disposal sites, and high traffic corridors, resulting in heightened exposure and limited access to preventive healthcare.

While global attention to pollution and public health has increased, significant research gaps remain. First, existing studies often examine pollution in isolation rather than analyzing the combined effects of air, water, and soil contamination on population health. For instance, WHO (2021) provides global mortality estimates yet does not integrate multi pollutant interactions and cumulative risks across different environmental exposures. Second, Indonesian studies, such as those by Haryanto et al. (2025), primarily focus on air pollution in major cities but rarely address rural industrial zones and peri urban communities, which also face increasing exposure to chemical and agricultural contaminants. Third, most research

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emphasizes biomedical impacts but insufficiently analyzes socio economic determinants that mediate population vulnerability, such as income inequality, spatial distribution of health services, and community resilience. For example, Cordova et al. (2020) examine microplastics contamination in Indonesia's waters but do not explore its long term implications for public health systems or food security. These gaps indicate the need for a more comprehensive, multi dimensional examination of pollution's health impacts that integrates global evidence with localized environmental realities.

The novelty of this article lies in its combined global and local approach which integrates epidemiological, environmental, and socio structural dimensions of pollution. Unlike previous studies that tend to focus on either global trends or isolated national cases, this article positions Indonesia's pollution burden within a broader international context while analyzing localized risk pathways and community level implications. Furthermore, this study highlights the interplay between environmental pollutants and systemic inequalities, emphasizing how social vulnerability amplifies health risks. This multi level perspective provides a more holistic understanding of pollution's effects on public health.

The objective of this research is to systematically examine the health impacts of environmental pollution from global and local standpoints by synthesizing empirical evidence through a Systematic Literature Review (SLR). The study aims to identify major pollution related health risks, analyze differences between global and Indonesian contexts, and highlight socio ecological mechanisms that shape vulnerability and disease outcomes. Through this analysis, the article provides an integrated framework for understanding how pollution affects public health and offers insights that can inform evidence based policy interventions.

METODOLOGI

This study employed a Systematic Literature Review (SLR) approach to synthesize global and local evidence regarding the health impacts of environmental pollution. The SLR method was selected because it enables researchers to identify, evaluate, and integrate findings from diverse scientific disciplines, including epidemiology, environmental science, public health, and socio ecological studies. Following the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) 2020 guidelines, this method ensures transparency, replicability, and rigor in the review process (Page et al., 2021). Given that pollution affects human health through complex, multi pathway exposures, SLR is the most suitable methodology for capturing the breadth of evidence and identifying converging patterns in global and Indonesian contexts.

The literature search was conducted across four major academic databases: Scopus, Web of Science, PubMed, and ScienceDirect. Supplementary searches were performed using Google Scholar to identify grey literature and region specific publications relevant to Indonesia. The search terms included combinations of "environmental pollution", "public health impact", "air pollution", "water contamination", "soil pollution", "global burden", and "Indonesia", connected with Boolean operators. Only peer reviewed articles published between 2013 and 2024 were included to ensure contemporary relevance. The initial search identified 578 records. After removing duplicates and screening titles and abstracts, 284 records remained. Full text assessment applied inclusion criteria that required studies to focus on pollution related health impacts, provide empirical or review based evidence, and include either global or Indonesian settings. Articles with insufficient methodological quality, non scientific commentaries, or irrelevant environmental contexts were excluded. A total of 43 studies were selected for final synthesis.

Data extraction and analysis followed thematic synthesis procedures as recommended by Mays et al. (2020). The selected studies were categorized into thematic clusters including air pollution and respiratory outcomes, water contamination and infectious diseases, soil pollution and chemical exposure, multi

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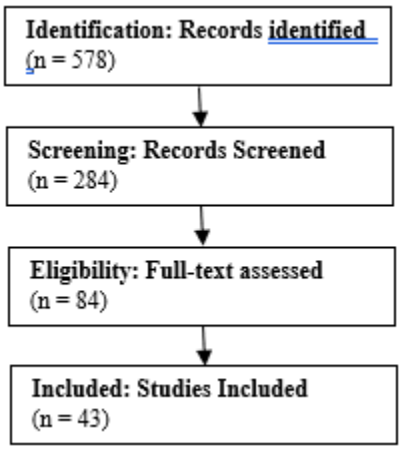
pollutant interactions, and socio structural determinants of vulnerability. Study quality was assessed using the Critical Appraisal Skills Programme (CASP) checklist to ensure that only methodologically rigorous studies contributed to the synthesis. The thematic approach allowed integration of qualitative, quantitative, and mixed method evidence into a cohesive analytical framework. This method is particularly appropriate for pollution related health research because it reveals not only biomedical pathways but also structural factors such as urban density, industrial zoning, and inequitable environmental governance, which shape exposure patterns and health outcomes



RESULTS AND DISCUSSION

Air, Water, and Soil Pollution: Global Burden and Health Pathways

Environmental pollution creates an extensive and multifaceted burden on global health, affecting populations across continents and socio economic groups with varying degrees of intensity. Air, water, and soil pollution represent the three primary pathways through which toxic exposures occur, each contributing to a wide range of health conditions. Air pollution is the most documented form of exposure because of its ubiquity and its well established link to cardiovascular and respiratory diseases. Fine particulate matter (PM2.5), nitrogen dioxide, and ozone are responsible for millions of premature deaths annually. WHO (2021) estimates that roughly seven million deaths each year are attributable to polluted air, with low and middle income countries disproportionately affected due to rapid industrialization and limited environmental controls. Exposure to air pollutants triggers systemic inflammation, oxidative stress, and impaired lung function that increase the risk of chronic diseases such as asthma, chronic obstructive pulmonary disease, lung cancer, ischemic heart disease, and stroke.

The effects of PM2.5 are particularly severe in densely populated urban areas. Studies in China, India, and Southeast Asia demonstrate that long term exposure to PM2.5 reduces life expectancy and increases hospital admissions for respiratory and cardiovascular conditions (Kim et al., 2018). Urban centers with high traffic density and industrial emissions experience the greatest health burden. Pollutants interact with environmental factors such as temperature, humidity, and atmospheric pressure, which influence pollutant concentration and toxicity. For example, temperature inversions in large metropolitan cities trap pollutants near the surface, intensifying exposure. Evidence also shows that air pollution exacerbates vulnerability among children, older adults, and individuals with pre existing cardiopulmonary diseases. Prenatal exposure to air pollutants is associated with low birth weight, preterm birth, and impaired neurodevelopment in children (Padula et al., 2019).

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Water pollution poses another major global threat. Contaminated water affects approximately two billion people worldwide and is linked to a broad spectrum of diseases ranging from gastrointestinal infections to long term exposure related cancers. Waterborne pathogens such as Vibrio cholerae, Giardia lamblia, and rotavirus remain significant contributors to child mortality in low income settings. Heavy metals such as lead, arsenic, and mercury also contaminate drinking water sources in many industrial regions. Chronic exposure to arsenic contaminated groundwater has been identified as a key cause of skin lesions, cardiovascular disease, and bladder cancer in South Asia (Frisbie & Mitchell et al., 2022). Agricultural runoff carrying pesticides, herbicides, and fertilizers into rivers and lakes creates additional layers of health risks. These contaminants disrupt endocrine pathways, elevate cancer risk, and contribute to antibiotic resistance due to the presence of pharmaceutical residues.

Soil pollution receives comparatively less attention in global analyses, yet it plays a critical role in long term health risks. Soil can serve as a reservoir for toxic substances including microplastics, heavy metals, pesticides, and persistent organic pollutants (POPs). These contaminants enter the food chain through crop absorption and livestock exposure. For example, cadmium contaminated soil has contributed to kidney dysfunction and bone fragility in communities living near mining and industrial zones in Asia and Africa. Soil pollution is also a major contributing factor to the growing problem of microplastic contamination. Recent studies indicate that microplastics in soil may exceed levels found in ocean waters, posing unknown risks to human health due to food chain accumulation (Basri et al., 2021). Exposure to POPs is associated with endocrine disruption, developmental delays, and decreased immune function, making soil pollution a silent yet persistent global health threat.

Environmental pollution rarely occurs in isolation. Instead, populations are often exposed to complex mixtures of pollutants that interact in additive or synergistic ways. Air, water, and soil contamination are interconnected across natural and human systems. For example, air pollutants settle into water bodies and agricultural soil, while contaminated soil releases volatile compounds into the air. Waste mismanagement further amplifies these interactions. Poorly managed landfills leak toxins into groundwater and release methane and other air pollutants. Urban wastewater systems frequently discharge untreated waste into rivers and coastal waters, increasing the burden of microbial and chemical contaminants. UNEP (2022) stresses that these interconnected processes create cumulative exposures that increase health burdens beyond what individual pollutants would cause independently.

The burden of environmental pollution is exacerbated by socio economic inequalities. Low income populations, minority groups, and marginalized communities are disproportionately exposed to polluted environments. In many countries, industrial facilities, waste disposal sites, and busy roadways are located near low income neighborhoods, creating environmental injustice. The United States Environmental Protection Agency has documented that marginalized populations experience higher exposure to PM2.5 and hazardous air pollutants due to discriminatory housing and zoning policies (Kedron, 2016). Similar patterns are observed in Southeast Asia and Latin America where informal settlements near industrial zones expose residents to high levels of toxic pollutants.

Pollution also interacts with climate change, creating compound risks. Rising temperatures increase ground level ozone formation and intensify wildfires, which release large volumes of fine particulates. Flooding events spread chemical contaminants from industrial sites into residential areas. Droughts concentrate pollutants in water sources, increasing toxicity. These interactions underscore the need for integrated environmental and health policies that consider the multi dimensional nature of pollution risks.

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In summary, pollution constitutes a global public health emergency due to its widespread distribution, multiple exposure pathways, and synergistic interactions. Air, water, and soil pollution collectively contribute to a wide range of health outcomes that disproportionately affect vulnerable populations. The scientific evidence strongly indicates that pollution prevention and environmental management are essential for reducing the global burden of disease. This understanding provides an important foundation for analyzing Indonesia's local context, where environmental degradation and rapid urbanization create unique patterns of health vulnerability.

The Indonesian Context: Local Exposures, Vulnerable Populations, and Environmental Inequality

Environmental pollution in Indonesia presents a complex set of public health challenges shaped by rapid urbanization, industrial expansion, geographical diversity, and varied governance capacity. Indonesia's environmental risks are closely linked to air pollution from motorized transportation and industrial activities, water contamination from household and industrial waste, and soil degradation caused by agricultural chemicals and poor land management. These risks are amplified in densely populated urban areas such as Jakarta, Surabaya, Bandung, and Medan, which consistently report air pollution levels exceeding national and WHO standards. KLHK (2023) reports that PM2.5 concentrations in major Indonesian cities often range between 2.5 and 7 times WHO recommendations, placing millions at risk of respiratory and cardiovascular diseases.

Air pollution is among the most visible environmental health threats in Indonesia. Jakarta regularly appears on the list of the most polluted cities in the world according to IQAir's Global Index (IQAir, 2023). High concentrations of PM2.5 stem from traffic congestion, coal fired power plants, and industrial emissions in surrounding regions. Studies by Haryanto et al. (2025) reveal that elevated PM2.5 exposure is associated with increased hospital visits for asthma, acute respiratory infections, and chronic respiratory diseases. Children and elderly individuals are particularly vulnerable due to their weaker immune systems and heightened physiological sensitivity to fine particles. The concentration of pollutants is often worse in low income neighborhoods located near major roadways and industrial facilities, illustrating environmental injustice within urban Indonesia.

Water pollution is also a major concern. KLHK (2023) reported that only 22 percent of Indonesia's rivers meet Class II water quality standards suitable for human contact. Industrial discharges containing heavy metals such as mercury and lead contaminate waterways in several industrial corridors. Additionally, inadequate sanitation infrastructure results in fecal contamination of rivers in many urban and peri urban settlements. UNICEF (2020) notes that diarrheal diseases remain one of the leading causes of child mortality in Indonesia, partly due to exposure to polluted water. Coastal communities face increasing exposure to microplastics, which pose long term health risks through bioaccumulation in seafood. Cordova et al. (2020) identified significant microplastic contamination in major Indonesian rivers and marine environments, raising concerns about long term impacts on the food chain and human health.

Soil pollution and land degradation further contribute to Indonesia's environmental health burden. Agricultural regions in Java and Sumatra experience high levels of pesticide and fertilizer runoff that contaminate soil and groundwater. Intensive agricultural practices, including the use of organophosphates and other pesticides, have been linked to neurological and reproductive health problems among farming communities. Industrial zones often fail to manage hazardous waste properly, leading to soil accumulation of toxic chemicals. Informal settlements located on or near old landfill sites also face significant health risks due to prolonged exposure to toxic contaminants.

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Environmental pollution in Indonesia disproportionately affects vulnerable populations. Low income urban residents, industrial workers, agricultural laborers, children, elderly individuals, and people living in informal settlements are at heightened risk of exposure. Environmental inequality is deeply embedded in urban planning and governance. Wealthier neighborhoods often have better air quality, reliable waste management, and access to clean water. In contrast, low income residents frequently live near riverside slums, busy highways, and industrial corridors. Studies indicate that proximity to pollution sources increases the likelihood of chronic respiratory diseases, gastrointestinal infections, and long term exposure to hazardous chemicals (World Bank, 2021).

Before presenting the analytical table, it is important to highlight that pollution impacts are shaped not only by exposure but also by social vulnerability, access to healthcare, and local governance. The table below synthesizes key environmental exposures and related health outcomes in Indonesia.

Table 1. Major Environmental Exposures and Health Impacts in Indonesia

Environmental Exposure	Primary Sources	Health Impacts
Air Pollution (PM2.5, NO2, O3)	Traffic, coal plants, industry, biomass burning	Asthma, ARI, COPD, cardiovascular diseases, stroke
Water Contamination	Industrial waste, domestic sewage, agricultural runoff	Diarrhea, cholera, parasitic infections, heavy metal toxicity
Soil Pollution	Pesticides, fertilizers, industrial waste, microplastics	Neurological disorders, endocrine disruption, cancer risk
Marine Pollution	Microplastics, chemical runoff, waste dumping	Food chain contamination, gastrointestinal health risks

The table demonstrates that Indonesia's environmental health challenges are multi sectoral and interconnected. Air, water, and soil pollution contribute to overlapping health risks that affect millions of residents. The burden of disease from environmental pollution is significantly influenced by socio economic factors such as income, access to health services, and educational attainment. Communities with limited resources often lack access to protective measures such as water filtration systems, air purifiers, or personal protective equipment. Moreover, limited environmental monitoring capacity and weak enforcement of pollution controls allow industrial actors to emit pollutants beyond regulated limits.

Indonesia's archipelagic geography compounds these challenges. Remote and coastal regions face unique vulnerabilities due to limited access to sanitation infrastructure, dependence on fisheries, and limited local government capacity. Marine pollution, especially from microplastics, affects dietary safety and economic livelihoods. Studies show that fish from Indonesian waters increasingly contain microplastic particles, posing potential long term health risks for communities reliant on seafood (Basri et al., 2021).

In conclusion, the Indonesian environmental pollution landscape reflects a combination of rapid urbanization, weak environmental governance, industrial expansion, and socio economic disparities. Pollution disproportionately affects vulnerable groups and manifests through interconnected exposure pathways that contribute to significant public health burdens. Understanding these localized patterns is essential for designing effective national policies, strengthening environmental monitoring, and reducing inequalities in exposure and health outcomes.

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Governance, Policy Responses, and Integrated Strategies for Pollution Mitigation and Public Health Protection

Environmental pollution is ultimately shaped not only by industrial activity and human behavior but also by governance structures, policy effectiveness, institutional capacity, and enforcement mechanisms. A growing body of global research emphasizes that countries with strong environmental governance experience significantly lower pollution related health burdens compared with those where regulations are weak or inconsistent. OECD (2022) notes that regulatory enforcement, monitoring capacity, and cross sector coordination are key determinants of whether pollution control policies translate into real improvements in population health. Environmental governance must therefore be understood as a multi level framework that involves government ministries, provincial and municipal authorities, civil society organizations, industries, and local communities.

Effective pollution management requires comprehensive regulatory systems supported by scientific data, transparent monitoring, and robust enforcement. For air pollution, countries such as Japan and South Korea demonstrate that strict emission standards, continuous air quality monitoring, and rapid response protocols can dramatically reduce particulate matter concentrations. Seoul's policy to restrict old diesel vehicles and expand green public transport resulted in substantial declines in PM10 and nitrogen dioxide levels over ten years (Park & Lee, 2019). These examples highlight that regulatory stringency combined with political commitment can shift environmental conditions even in highly urbanized regions. In contrast, countries with limited enforcement capacity often see persistent air quality problems despite having written regulations.

Water pollution control depends heavily on wastewater treatment, industrial monitoring, and river basin management. The European Union's Water Framework Directive is often cited as a successful governance model because it integrates ecological protection with public health goals and mandates member states to achieve good water status through coordinated basin wide planning (EU Commission, 2020). Regions that have implemented coordinated water governance frameworks show significant reductions in chemical pollutants and pathogen levels. Indonesia has begun adopting integrated water resource management strategies, yet uneven implementation persists due to budget limitations, regional disparities, and limited technical capacity at the local level.

Soil pollution governance is even more complex due to the difficulty of monitoring contaminants and the long term nature of remediation efforts. Many pollutants, such as heavy metals and persistent organic pollutants, remain in soil for decades. Countries with advanced environmental governance have established polluter pays principles, risk based soil management, and mandatory clean up protocols. However, in many developing regions, soil pollution remains under regulated due to competing priorities, weak land use controls, and insufficient investment in monitoring infrastructure. UNEP (2022) stresses that soil pollution governance must be integrated into agricultural policy, mining regulation, and waste management to protect food safety and ecosystem health.

Indonesia's policy landscape reflects both progress and persistent challenges. The government has introduced key regulations such as the Clean Air Strategic Framework, river quality standards, emission caps, and environmental impact assessment requirements. Air quality monitoring has expanded through the KLHK AQMS network, and several cities have introduced low emission zones and green transport initiatives. However, governance challenges persist in the form of weak enforcement, inconsistent monitoring across regions, and limited transparency of environmental data. Industrial compliance is uneven because regulatory oversight varies across provinces. Local governments often lack the resources or

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political influence to enforce pollution standards, especially in areas where industries are major economic contributors.

Environmental governance in Indonesia is further complicated by fragmented institutional responsibilities. Air quality management involves KLHK, the Ministry of Transportation, provincial governments, and metropolitan authorities. Water management is divided between national river basin organizations and regional governments. Waste management involves both municipal agencies and private contractors. Fragmentation creates coordination gaps that delay policy implementation. World Bank (2021) identifies these institutional fragmentation issues as one of the central barriers to effective environmental health management in Indonesia.

Community participation is another crucial dimension for effective pollution governance. Research demonstrates that community based monitoring, public disclosure programs, and participatory environmental planning can significantly improve compliance and environmental outcomes (Hirschhorn et al., 2024). Indonesia has piloted community air monitoring and participatory river clean up programs in some cities, yet national scale adoption remains limited. The potential for civil society to contribute to environmental oversight is high, especially in urban areas where communities are directly exposed to pollution and have strong incentives to demand improved environmental protections.

To address pollution related health risks, policy interventions must adopt an integrated, multi sector strategy. This includes improving emission control technologies, strengthening industrial permitting systems, expanding public transportation, enhancing wastewater treatment capacity, and regulating hazardous waste disposal. Economic instruments such as pollution taxes, congestion charges, and incentives for renewable energy adoption can complement regulatory measures. International evidence shows that countries using mixed policy tools achieve more sustained reductions in pollution levels compared with countries relying solely on command and control regulations (OECD, 2022).

Indonesia's efforts toward environmental governance reform can be strengthened through several strategic approaches. First, expanding real time monitoring networks and publicly accessible environmental data platforms can enhance accountability and empower communities. Second, integrating environmental health indicators into national development planning can ensure that health protection becomes a central objective rather than an ancillary consideration. Third, capacity building for regional governments is essential to reduce disparities in regulatory enforcement. Fourth, partnerships with academic institutions and research laboratories can support technical expertise for pollution assessment and health risk evaluation.

In conclusion, governance and policy responses play a decisive role in shaping environmental outcomes and health impacts. Strong environmental governance can mitigate pollution sources, reduce exposure levels, protect vulnerable communities, and strengthen long term resilience. Indonesia's progress toward improved environmental management provides a valuable foundation, but sustained political commitment, institutional coordination, and community engagement are necessary to address remaining gaps. Pollution reduction is not only an environmental priority but also a public health imperative that requires integrated, evidence based, and equitable policy action.

CONCLUSIONS

Environmental pollution represents a global public health emergency with widespread consequences that affect populations through interconnected air, water, and soil exposure pathways. Global evidence shows that pollution contributes to millions of premature deaths each year and exacerbates chronic diseases, infectious illnesses, and long term developmental risks. The Indonesian context mirrors these global

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patterns but with additional complexity shaped by rapid urbanization, geographic diversity, and uneven governance capacity. Air pollution in major cities, contaminated waterways, and soil degradation from agricultural and industrial sources collectively create a substantial health burden that disproportionately affects vulnerable populations.

The findings of this study highlight that pollution related health risks are not evenly distributed. Low income communities, informal settlements, children, elderly individuals, and populations living near industrial zones experience higher exposure and have fewer resources to mitigate risks. These disparities reflect broader socio economic inequalities and weaknesses in environmental governance. Strengthening environmental policy, improving monitoring systems, enhancing enforcement capacity, and promoting community based environmental stewardship are essential to reduce pollution burdens. Digital technology, integrated policy frameworks, and coordinated governance across national and regional levels can significantly improve environmental management and public health protection.

Addressing environmental pollution requires sustained political commitment and cross sector collaboration. Interventions must combine regulatory reforms, economic incentives, technological innovation, and community engagement. By integrating global evidence with localized environmental realities, Indonesia and other developing countries can design more effective strategies to reduce pollution and protect public health. Pollution mitigation is not only critical for safeguarding current populations but also essential for ensuring sustainable development and intergenerational health equity. The evidence presented in this study underscores that environmental health protection is a foundational pillar for social well being, economic resilience, and long term national development.

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