Chemical Exposure, Public Health, and Environmental Justice Among Populations Residing Near Industrial Areas: A Literature Review

Fatin Nisrina Athirah[1]*, Aulia Fahira[1]

[1]Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur

Corresponding Author

Fatin Nisrina Athirah

Universitas Pembangunan Nasional Veteran Jawa Timur

Rungkut, Surabaya, Jawa Timur 60293

E-mail: fatinafiftanggul@gmail.com

ABSTRACT

Background: Industrial chemical exposure has emerged as a critical environmental and public health concern, particularly in Indonesia. Communities residing near industrial zones face heightened risks due to direct and prolonged exposure to hazardous substances. Numerous studies have documented the detrimental health and environmental effects of such exposure, including respiratory illnesses, cancer, and ecological degradation. Socioeconomic disparities further exacerbate these impacts, with marginalized populations often bearing a disproportionate burden of pollution-related consequences.

Methods: This study adopts a literature review approach, synthesizing findings from peer-reviewed academic journals, institutional reports, and relevant research to evaluate the health and environmental implications of chemical exposure in industrial areas.

Results and Discussion: The review reveals consistent evidence of significant adverse effects stemming from industrial pollution, particularly on vulnerable populations living in proximity to industrial facilities. The compounded risks include both acute and chronic health outcomes and degradation of environmental quality.

Conclusion: The implementation of effective mitigation strategies and the enforcement of regulatory policies are essential to reduce chemical exposure risks. Strengthening environmental governance and prioritizing public health in industrial planning are critical steps toward protecting communities in affected areas.

Keywords: Chemical Exposure, Pollution, Communities, Industry Area

Introduction

Indonesia is among the countries with a significant industrial presence, attracting numerous international companies to establish production facilities due to favorable factors such as low labor costs and a skilled workforce. The ability to sustain mass production without significant disruption further reinforces Indonesia's position as a strategic industrial hub. However, this industrial expansion poses serious environmental and public health concerns, particularly for residential communities near industrial zones[1].

Industrial operations are frequently associated with the release of hazardous chemicals that affect air, water, and soil quality. Roy et al. reported that industrial pollution accidents are most prevalent in countries like China, followed by the United States, South Korea, and India[1]. Pollutants such as dust and heavy metals can accumulate in residential and commercial areas, adversely impacting human health. Similarly, Rovira et al. described the Tarragona incident in Spain, where emissions from petrochemical industries over the past two decades caused severe environmental degradation and health issues in surrounding communities[2].

In Indonesia, Purba et al. documented pollution in the Ciliwung River caused by household industries disposing of waste directly into the water, affecting the health and livelihood of nearby residents[3]. Domingo et al. found a correlation between proximity to petrochemical plants and higher rates of leukemia and other hematologic malignancies in countries including Taiwan, Spain, the United Kingdom, Italy, and Nigeria[4]. Suwandana et al. highlighted that exposure to industrial chemicals, when combined with climate variability, exacerbates health inequalities and environmental injustice in vulnerable populations[5]. Beronius et al. emphasized the complexity of chemical exposure in residential areas, identifying severe effects on air, water, soil, and vegetation due to petrochemical pollution[6].

Although industrialization offers economic benefits such as job creation and increased local revenue, its environmental and health costs are substantial and often overlooked[7]. The cement industry, while essential to infrastructure development, contributes significantly to global pollution, accounting for approximately 7% of carbon dioxide emissions, alongside sulfur dioxide, nitrogen oxides, and particulate matter. It is estimated that the industry contributes around 5% of greenhouse gas emissions globally[7]. Sava et al. explained that pollutants produced by the cement industry—gases, liquids, and solids—stem from raw material combustion and can severely impact human health and the surrounding environment[8].

Efforts to reduce such pollution must involve collaboration between government institutions, industrial companies, and the public. Strategies such as increasing chimney height, planting trees, and promoting the use of protective masks have shown potential in mitigating airborne heavy metal exposure in industrial areas[9]. Equally important is the implementation of proper waste management and public education on environmental hygiene. Widodo stressed the importance of immediate medical consultation for individuals experiencing symptoms of exposure, especially in polluted environments[10].

The issue of pollution and chemical exposure is closely linked to environmental justice. In Indonesia, weak zoning regulations have led to the close proximity of residential settlements and industrial zones, partly due to workers choosing to live near their workplaces to reduce commuting time and costs[11]. Despite existing mitigation strategies, many industries continue to neglect the dangers of chemical exposure, not only to workers but also to surrounding communities. Meanwhile, the affected populations often fail to prioritize their health, highlighting the urgent need for comprehensive policy interventions and long-term risk awareness[9].

Methods

Protocol and search strategy

This study adopts a systematic and comprehensive literature review approach to examine the impact of chemical exposure on human health and environmental justice, with a particular focus on communities residing in close proximity to industrial or residential zones. The review critically analyzes peer-reviewed journal articles, books, and institutional reports published between 2010 and 2024 that are relevant to the research scope.

Academic sources were identified through structured searches of major scholarly databases, including PubMed, Scopus, and Google Scholar, as well as national journals indexed in SINTA and GARUDA. Additional literature was sourced from reports published by prominent organizations such as the World Health Organization (WHO)**,** United Nations Environment Programme (UNEP), and Indonesia's Ministry of Environment and Forestry. The primary keywords used during the literature search included: *"chemical exposure," "industrial areas," "health impacts," "environmental justice,"* and *"toxic waste management."*

Inclusion and Exclusion Criteria

To ensure the relevance and rigor of the literature reviewed, this study applied specific inclusion and exclusion criteria. Included studies were published between 2010 and 2024 and focused on topics related to industrial chemical exposure, associated health impacts, environmental pollution, and environmental justice. Sources were limited to those indexed in reputable academic databases such as Scopus, PubMed, and Google Scholar, as well as national databases including SINTA and GARUDA. Reports from credible environmental and health institutions, such as the World Health Organization (WHO), the United Nations Environment Programme (UNEP), and Indonesia's Ministry of Environment, were also considered. Studies were excluded if they did not specifically address the health or environmental consequences of industrial activities, if they focused solely on the chemical properties of pollutants without examining their effects on human or ecological systems, or if they lacked primary data or a clearly defined methodology.

Data Collection Process

Data collection was carried out through a systematic literature search using a set of predefined keywords, including "chemical exposure," "industrial area," "health impact," "environmental justice," "pollution," "toxic waste management," and "regulations." Relevant literature was retrieved from academic databases such as PubMed, Scopus, Google Scholar, as well as national platforms like SINTA and GARUDA. Articles and reports meeting the inclusion criteria were downloaded and reviewed in detail. Key information extracted from each source included the title, author(s), year of publication, research objectives, methodology, major findings, and conclusions. The analysis focused on identifying the types of hazardous chemicals and their exposure mechanisms, evaluating both short- and long-term health impacts, reviewing environmental policies and justice-related frameworks, particularly in the Indonesian context, and exploring mitigation strategies aimed at minimizing health and environmental risks. This comprehensive approach enabled a deeper understanding of the multifaceted impacts of chemical exposure on vulnerable communities.

Results and Discussion

A total of 45 relevant publications were identified and included in this systematic literature review after applying the predefined inclusion and exclusion criteria. These sources comprise peer-reviewed journal articles, institutional reports, and academic studies published between 2010 and 2024. The selected literature provides a diverse yet interconnected body of

evidence concerning the health impacts of industrial chemical exposure and the broader implications for environmental justice, particularly in communities situated near industrial zones. The findings are categorized and analyzed thematically to provide a comprehensive understanding of the issues addressed (Table 1).

Table 1. Summary of Key Study Characteristics.

	Author(s)	Title / Focus	Objective	Methodology	Key Findings
1	Arjuna, A. B., & Hasibuan, S (2020)	Fire Risk Analysis in The Chemical Industry using The Hazard Identification and Risk Assessment Method.	The purpose of this study is to identify hazards and assess fire risks in operational activities in the chemical industry.	This study uses hazard identification and risk assessment methods. Determination of the severity, probability, and level of fire risk is carried out through focus group discussion with experts who are competent in fire risk	The results of this study are to identify hazards in operational activities in the chemical industry, conduct risk assessments, and determine the level of risk and control of fire- causing risks. A total of 15 activities in the chemical plant studied have a high risk of fire with a high level of severity, but the chances

					of occurrence vary.
2	Nursyamsi, D., & Husnain, H. (2015).. J Food Agri Environ, 13(3- 4), 121-126.	Accumulation of heavy metals in rice grown in soil irrigated with electroplating industry wastewater treated with coagulants and adsorbents	The purpose of this study was to evaluate the efficiency of chitosan and Azolla as coagulants and tea waste and peanut shells as adsorbents for treating electroplating wastewater in removing heavy metals	Laboratory-based experimental design to assess the effectiveness of chitosan, Azolla, tea waste, and peanut shells in reducing heavy metal accumulation in soil and rice irrigated with treated electroplating wastewater	The results showed that the yield of rice and rice straw increased with all combinations of wastewater treatment with or without wastewater treatment with coagulants and adsorbents.
3	Rahmadani, N., & Syafri, M. (2024). Jurnal Mitrasehat, 14(2), 728-732.	Hubungan Antara Paparan Bahan Kimia	This study aims to explore and analyze the relationship between exposure to hazardous chemicals in the workplace and health risks in industrial workers.	This study will use a mixed approach that combines quantitative and qualitative methods to analyze the relationship between exposure to hazardous chemicals in	Based on data collected from surveys, exposure measurement, interviews, and health record analysis, the results of the study show the following findings:

				the workplace and health risks in industrial workers.	Chemical Exposure Profile, Workers in the studied industries are exposed to a variety of hazardous chemicals, including organic solvents (such as toluene and benzene), heavy metals (such as lead and mercury), and other industrial chemicals (such as formaldehyde).
4	Azzahro, F. (2019). Journal of Research and Technology, 5(2).	Penentuan hasil evaluasi pemilihan spesies pohon dalam pengendalian polusi udara pabrik semen	Analyzing how to handle the air pollution in near cement industrial	the study uses descriptive analysis by assessing tree elements macroscopicall y to select the appropriate	the results showed that of 7 (seven) dominant tree species identified, there were 3 (three)

		berdasarkan karakteristik morfologi.		tree species and can be recommended as an absorber of gas pollutants and dust absorbers based on tree suitability scoring.	dominant tree species that were very suitable, 3 (three) dominant tree species were suitable, and only 1 (one) dominant tree species were not suitable for air pollutant gas.
5	Budijono, & Hasbi, M. (2021)	Heavy metal contamination in Koto Panjang Dam, Indonesia.	Research on heavy metals (Pb, Cd, Zn) in water, sediment, and their accumulation has been conducted on 6 important commercial fish species, namely Cyprinus carpio, Oreochromis niloticus, Osphronemus gouramy,	The findings were based on both research and observation.	The results showed that the highest concentration of Zn was found in water and sediment, followed by Pb and Cd. Similar amounts of heavy metals were found to build up in all tissues that were studied. The kidneys, gills, and

			Hemibagrus nemurus, Channa micropeltes, and Barbonymus schwanefeldii. Accumulation of heavy metals was observed in gill, kidney, and muscle tissues.		muscles of all fish species showed the most heavy metal buildup. The concentration of metals in the muscles of all fish species met the limits for human consumption.
6	Putri, D. (2021). (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).	Strategi Mitigasi Bencana Banjir Pada Kawasan Pemukiman Di Kabupaten Kediri	The study was conducted by processing primary and secondary data. The results showed that areas with high flood vulnerability status were located in Badas, Kras, and Ringinrejo Districts; low vulnerability was in Semen, Ngancar, Ngasem, and	Finding flood disaster mitigation strategies in residential areas in Kediri Regency using the Simple Multi-Attribute Rating Technique Exploiting Ranks (SMARTER) method.	Furthermore, land suitability analysis was carried out by overlaying flood vulnerability maps, landslide vulnerability maps, annual rainfall maps, geological maps, slope maps, and soil type maps. The results

			Grogol Districts; the rest were included in moderate vulnerability.		showed that the total land in Kediri Regency that was very suitable for settlements was 8,344.69 Ha (19.68%), suitable 18,694.15 Ha (44.08%), marginally suitable 10,995.14 Ha (25.93%), and not suitable was 4,374.02 Ha (10.31%).
7	Sasmita, A., Reza, M., & Rozi, R. M. (2021). Al-Ard: Jurnal Teknik Lingkungan, 6(2), 68-76.	Pemetaan dan Perhitungan Pemaparan Tingkat Kebisingan pada Industri Pengolahan Kayu di Kecamatan Siak, Provinsi Riau.	This study aims to determine the intensity of noise produced by production machines, exposure time, noise mapping, and noise control efforts.	The noise measurement method refers to the noise mapping method, and the instrument used is the Sound Level Meter (SLM).	The highest noise level is 99.4 dB with an exposure time of 0.3 hours, and the lowest noise level is 67.3 dB with an exposure time of 475 hours. We can make control

					efforts from the source, transmission channel, and receiver to reduce noise.
8	Febriyana, N. A. (2016. Institut Teknologi Sepuluh Nopember.	Identifikasi Daya Tampung Beban Pencemaran Air Kali Surabaya Segmen Tambangan Cangkir-Bendungan Gunung Sari Dengan Pemodelan QUAL2KW	This river is used as a source of drinking water and for industrial production processes. This river receives pollution loads from domestic waste, agricultural waste, and industrial waste.	Calculating pollution capacity in the river Data analysis using the QUAL2Kw program application to calculate the pollution load entering the Surabaya River. Data modeling is carried out by trial and error until the model results are obtained that are appropriate (close to) the actual conditions.	The Surabaya River requires a calculation of the capacity to determine the maximum limit of wastewater that can be discharged into the river. The monitoring point area in this study has 5 segments. The water quality parameters analyzed are pH, temperature, DO, BOD, TSS, nitrate (NO3), ammonium

					(NH4), and phosphate (PO4).
9	Hariani, Y. (2023).. Babul Ilmi Jurnal Ilmiah Multi Science Kesehatan, 15(1).	Pengaruh Paparan Bahan Kimia terhadap Kesehatan Reproduksi pada Pekerja 2023: Literature Review	Objective: To determine the effect of chemical exposure on reproductive health in workers.	Literature Review Method	Using inclusion and exclusion criteria, the selection process yielded 10 articles for review. Results: There are 10 articles related to chemical exposure on reproductive health in workers reviewed, all stating that there is a significant relationship between chemical exposure and reproductive health.
10	Hutapea, O., Kombih,	Penerapan Program Alat	The purpose of this activity is	Survey Method Results This	In order for this activity

	M. F., Rendrawan, R., Putri, A. R. A., & Ardita, S. (2022). Jurnal Pengabdian Masyarakat, 5(1), 1-8.	Pelindung Diri pada Pekerja dalam Upaya Mengurangi Paparan Uap Bahaya Kimia Di Industri Percetakan	to reduce exposure to benzene vapors through the application of appropriate personal protective equipment.	community service activity as a whole went smoothly.	to continue, supervision from the company and from the Occupational Health Effort Post (Sepetmapt) is needed regarding worker discipline in using personal protective equipment
11	Febriyanti, A. L., Pancahayani, S., & Faisal, M. (2022)	Mathematical Model of Air Pollution Spread to Determine Safe Distance of Residential Areas from Industrial Smoke Stacks	To develop a mathematical model for air pollution spread to determine a safe distance from industrial chimneys.	Mathematical modeling of air pollution dispersion.	Provided a mathematical model for air pollution spread and determined the safe distance for residential areas.
12	Trianisa, K., Purnomo, E. P., & Kasiwi, A. N. (2020)	The Impact of Coal Industries on Air Pollution and the Balance of World Air	To study the impact of coal industries on air pollution and its influence on	Statistical analysis of air quality data related to coal industries in India.	Found a significant impact of coal industries on air pollution

		Quality Index in India	the World Air Quality Index.		and deterioration of air quality in India.
13	Winda, W., Kardhinata, H., Nurtjahja, K., & Fauziah, I. (2024)	Physiological Response of Urena lobata L. to Air Pollution in Industrial Environments	To analyze the physiological response of Urena lobata L. to air pollution in industrial environments.	Experimental study on the effects of air pollution on Urena lobata L. in industrial settings.	Observed physiological stress on Urena lobata L. due to exposure to industrial air pollution.
14	Azzahro, F. (2020)	Determining the Results of Tree Species Selection for Controlling Air Pollution in Cement Factories Based on Morphological Characteristics	To evaluate tree species selection for controlling air pollution in cement factories based on morphological characteristics.	Morphological evaluation of different tree species for pollution control.	Identified optimal tree species for controlling air pollution in cement factories.
15	MARPAUNG , A. P. (2023)	The Impact of Air Pollution on Lung Health in Children in Industrial Areas of Medan City	To examine the impact of air pollution on lung health of children in industrial areas of Medan.	Survey and health assessment of children exposed to air pollution in industrial areas.	Found significant negative effects of air pollution on children's lung health in industrial areas.

16	Afifah, A. S., Septiariva, I. Y., Suhardono, S., Suryawan, I. W. K., & Sari, M. M. (2023)	Evaluation of domestic wastewater and river management in Belian Village, Batam City Sub- district, Indonesia	The purpose of this research is to determine the current conditions and make recommendations for domestic wastewater management solutions in Belian Village, Batam City.	This study was carried out through direct observation, documentation of activities, and literature searches.	From 2014 to 2020, there has been a measurable increase in access to drinking water and sanitation in Batam City. Despite the increase, in Belian Village, wastewater is still discharged directly into the river body. This will reduce the quality of the river. To reduce the negative impacts of these activities, communal treatment solutions can be applied.

					By considering operations and maintenance, up- flow filter tanks can be used for wastewater treatment.
17	Yudita, A., Akbar, A. A., & Saziati, O. 2021	Analisis Kualitas Air dan Pengendalian Pencemaran Air Sungai Retok Kabupaten Kubu Raya.	The purpose of this pollution control is to achieve environmental sustainability and improve the water quality of the Retok River.	Determination of water quality status using the Pollution Index (IP) method.	Overall, the quality status of the Retok River shows that it is included in the lightly polluted category with a Pollution Index (IP) value ranging from 2.152 - 2.442. Pollution control strategies for the lightly polluted Retok River can be carried out by

					reducing the pollution load by involving the community
18	Kamasnuri, U. N., Widiyanti, B. L., & Darmawan, M. I. (2023).	Analisis Kualitas Mata Air Lingkok Pancor Untuk Peruntukan Air Bersih di Dusun Jangkar Desa Setungkep Lingsar Kecamatan Keruak.	The aim of this study was to test the quality of the Lingkok Pancor spring water.	The research method used was a survey with a quantitative descriptive approach.	The results of the study showed that several parameters still met the standards (color, temperature, odor, taste, turbidity, hardness, nitrate, and pH) while the parameters that exceeded the standard quality limits were TDS, BOD, COD, DO, and E-Coli bacteria and detergent.
19	Rina, B. N. P. N., Darmawan, M. I., &	Analisis Tingkat Kebisingan Lalu Lintas	Analyzing traffic noise levels on the jenggik – terara	This study uses a quantitative descriptive approach.	The results showed that two of the three

	Susanti, D. R. (2024).	pada Jalan Raya Jenggik–Terara Kabupaten Lombok Timur Provinsi Nusa Tenggara Barat	highway, east lombok district, west nusa tenggara province		locations had noise levels exceeding the established quality standards (60-65 dBA), while one location met the quality standards at the lowest noise level but exceeded the limit at the peak noise level. In conclusion, the traffic noise levels in the area, especially in the two locations, have a negative impact on the comfort and quality of life of residents, as well as disturbing the environment

					around schools and government offices.
20	Ridwan, A. M., & Lestari, A. D. (2023). Jurnal Penelitian dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti, 144-163.	Gangguan Pendengaran Akibat Paparan Toluen.	Mengetahui penyebab dan solusi Gangguan Pendengaran Akibat Paparan Toluen	Literature review	The treatment provided may prevent or delay deterioration but does not repair the damage that has already occurred.
21	Sari, I. P., Safitri, D. M., Septiani, W., & Su'udi, B. C. (2023). Abdimas Universal, 5(2), 198-204.	Penyuluhan Risiko Bahan Kimia Laundry serta Penerapan Keselamatan dan Kesehatan Kerja (K3) di Industri Laundry.	Analyzing and studying Laundry Chemical Risk Counseling and the Implementation of Occupational Safety and Health (K3) in the Laundry Industry.	Literatur review and socialization	The results of the activity evaluation show that this counseling activityhas an impact on increasing the knowledge of laundry workers regarding the risks of laundry chemicals and how to prevent and

					handle them.
22	Maulida, A., Oktaviani, A., Pakpahan, H. S., & Wikaningrum, T. (2022).. Jurnal Penelitian dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti, 193-209.	Hazardous waste should be managed properly for development of better waste management strategies	Understanding Hazardous waste should be managed properly for development of better waste management strategies	literature review	As part of the manufacturing process, industries are being urged to produce less hazardous waste. Because it is impossible to totally prevent hazardous waste, the only option is to reduce, recycle, and treat it. As a result, actions should be taken to maximize use of modern technologies while minimizing environmental impact.
23	Utari, E., Handayani, T. A., &	Pemahaman masyarakat tentang	This study aims to find out,	The method used in this study is a	Public understanding of industrial

	Nurfitriniha, W. S. (2022).. Biodidaktika: Jurnal Biologi dan Pembelajaran nya, 17(2).	pencemaran limbah industri terhadap lingkungan hidup kecamatan Ciwandan kota Cilegon	understand, and raise public awareness of the impact of industrial waste pollution on the environment and population of Cilegon city, both air, water, and land pollution.	descriptive method with primary and secondary data collection techniques.	waste is that industrial activities have negative impacts, namely polluting the environment and can cause damage to natural resources, ecosystem imbalance and also affect the health of the surroundin g population
24	Bhaskara, O. S., Sukmawati, P. D., & Warisaura, A. D. (2022). Jurnal Teknologi, 15(2), 137-143.	Analisis sebaran air limbah industri rumah pemotongan ayam terhadap kualitas air Sungai Desa Kalitirto, Kecamatan Berbah, Kabupaten Sleman.	analyzing the distribution of industrial wastewater from chicken slaughterhouse s on the water quality of the Kalitirto Village River, Berbah District, Sleman Regency.	This study used a case study approach to analyze the distribution of RPA wastewater on river water quality in Kalitirto Village, Berbah District, Sleman	The measurement results of RPA liquid waste exceed the quality standard. The quality of river water before and after RPA is different. The result of the correlation

				Regency. Data collection was carried out by taking samples of RPA wastewater, RPA groundwater, and river water.	coefficient is - 0.829, meaning that the further away the RPA waste is in river water, the smaller the pollution index value. The probability result is 0.085, meaning that the relationship between the presence of liquid waste and the pollution index is not significant.
25	Ratuannisa, T., Ekawati, E., Yulia, E., Purwasasmita, B. S., & Nugraha, A. B. (2023). Dampak, 20(1), 8-15.	Studi Pengolahan Air Limbah Batik pada Skala Industri Rumah Tangga dan Usaha Kecil Menengah di Cirebon,	aims to convey another side of the batik industry, namely examining the conditions and needs of batik liquid waste	Batik liquid waste processing methods include physical methods (filtration, sedimentation,	The examination of wastewater samples showed that batik wastewater did not meet the waste

		Indonesia.	processing in the batik industry. The focus of the research is mainly on Small and Medium Enterprises (SMEs) and household-scale industries. Research data include the characteristics of batik liquid waste, field survey results, and the impact of batik liquid waste in Plered District, Cirebon.	centrifugation, flotation, adsorption) (Indrayani, 2018), chemical methods (coagulation, neutralization, electrochemistry , ozonation) (Indrayani & Rahmah, 2018), or biological methods (microorganism activity, aquatic plants) (Priadie, 2017). In its application, these methods are often combined to achieve higher efficiency and cost reduction.	quality standards and potentially harmed the environment. The respondents generally use synthetic dyes, and were unaware of its impact on the surrounding environment.
21	Beronius, A., Zilliacus, J., Hanberg, A., Luijten, M.,	Methodology for health risk assessment of combined	To present a methodology for assessing health risks	Health risk assessment methodology development,	Proposed a comprehensive methodology

	van der Voet, H., & van Klaveren, J.	exposures to multiple chemicals	from combined exposures to multiple chemicals.	involving chemical exposure models and hazard assessment.	for evaluating combined chemical exposures and associated health risks.
22	Domingo, J. L., Marquès, M., Nadal, M., & Schuhmacher, M.	Health risks for the population living near petrochemical industrial complexes. 1. Cancer risks: a review of the scientific literature	To evaluate cancer risks for populations living near petrochemical complexes based on scientific literature.	Literature review of studies on cancer risks near petrochemical industrial complexes.	Found that residents near petrochemical complexes face higher cancer risks, with various factors contributing to exposure.
23	Hong, J., Kang, H., An, J., Choi, J., Hong, T., Park, H. S., & Lee, D. E.	Towards environmental sustainability in the local community: Future insights for managing the hazardous pollutants at construction sites	To explore ways to manage hazardous pollutants at construction sites for environmental sustainability.	Environmental analysis and strategies for managing hazardous pollutants at construction sites.	Suggested several strategies for pollutant management, aiming to reduce environmental impact and enhance sustainability in local communities.

24	Siddiqua, A., Hahladakis, J. N., & Al-Attiya, W. A. K.	An overview of the environmental pollution and health effects associated with waste landfilling and open dumpin g	To examine the environmental and health impacts of waste landfilling and open dumping.	Review of environmental pollution and health effects from waste disposal practices.	Identified major environmenta l and health risks associated with landfilling and open dumping, emphasizing the need for improved waste management practices.
25	Rovira, J., Nadal, M., Schuhmacher, M., & Domingo, J. L.	Environmental impact and human health risks of air pollutants near a large chemical/petro c h emical complex: Case study in Tarragona, Spain	To assess the environmental and health risks of air pollutants near a chemical/petroc h emical complex.	Case study of air quality and health risk assessment near a chemical/petroc hemical complex.	Found that air pollution from the complex contributes to significant health risks for nearby residents, including respiratory and cardiovascula r diseases.
26	Okoye, C. O., Addey, C. I., Oderinde, O.,	Toxic chemicals and persistent	To investigate the toxic chemicals and	Review of studies on the presence of	Revealed that micro- and nanoplastics

	Okoro, J. O., Uwamungu, J. Y., Ikechukwu, C. K., & Odii, E. C	organic pollutants associated with micro-and nanoplastics pollution	persistent organic pollutants associated with micro- and nanoplastics pollution.	toxic chemicals and persistent pollutants in micro- and nanoplastics.	are significant carriers of toxic chemicals and persistent pollutants, raising concerns for both environmenta l and human health.
27	Westenhöfer, J., Nouri, E., Reschke, M. L., Seebach, F., & Buchcik, J.	Walkability and urban built environments — a systematic review of health impact assessments (HIA)	To review health impact assessments on the walkability of urban environments.	Systematic review of studies assessing the health impacts of walkability in urban areas.	Found that walkable urban environments have positive effects on public health, including improved mental and physical well-being.
28	Lee, Y. W., Kim, Y. P., & Yeo, M. J	Estimation of Air Pollutant Emissions from Heavy Industry Sector in North Korea	To estimate air pollutant emissions from North Korea's heavy industry sector.	Air quality modeling and pollutant emission estimation for heavy industries in North Korea.	Estimated high levels of air pollution from heavy industry, raising concerns about public

					health and environmental sustainability
29	Jang, J., Han, E., Heo, J., Choi, S., Park, J., Lee, K. S., & Yoo, C.	Analysis of the National Air Pollutant Emissions Inventory (2021) in the Republic of Korea	To analyze the National Air Pollutant Emissions Inventory for South Korea.	Data analysis of national air pollutant emission inventories.	Found that certain areas in South Korea experience high levels of air pollution, with key sources being transportation and industrial sectors.
30	Ju, T., Lei, M., Guo, G., Xi, J., Zhang, Y., Xu, Y., & Lou, Q.	A new prediction method of industrial atmospheric pollutant emission intensity based on pollutant emission standard quantification	To propose a new method for predicting industrial atmospheric pollutant emissions.	Development of a prediction model based on emission standards and pollutant quantification.	Introduced an improved prediction method for industrial pollutant emissions, offering a more accurate tool for environmental regulation.
31	Wen, W., Deng, Z., Ma, X., Xing, Y., Pan, C., Liu,	Analysis of the synergistic benefits of typical	To analyze the synergistic benefits of technologies	Technological analysis and simulation of pollution and	Found that integrating certain technologies

	Y., ... & Shen, L.	technologies for pollution reduction and carbon reduction in the iron and steel industry in the Beijing–Tianjin–Hebei region	aimed at reducing pollution and carbon emissions in the iron and steel industry.	carbon reduction techniques in the iron and steel industry.	leads to significant reductions in both pollution and carbon emissions in the iron and steel industry.
32	Liang, M., Liu, L., Liang, W., Mi, W., Ye, K., & Gao, J.	Intelligentizati o n helps the green and energy- saving transformation of power industry- evidence from substation engineering in China	To investigate how intelligent technologies can support the green transformation of the power industry in China.	Case study analysis on the implementatio n of intelligent systems in substation engineering.	Showed that intelligent systems significantly enhance energy efficiency and contribute to the green transformatio n of the power industry.
33	Sing, T. F., Wang, W., & Zhan, C.	Tracking industry pollution sources and health risks in China	To track pollution sources from industries in China and assess related health risks.	Pollution source tracking and health risk assessment using industrial data.	Identified major industrial pollution sources and linked them to health risks in surrounding

					populations.
34	Li, S., Zhu, G., Li, X., Wan, P., Yuan, F., Xu, S., & Hursthouse, A. S.	Ecosystem-inspired model and artificial intelligence predicts pollutant consumption capacity by coagulation in drinking water treatment	To develop an AI model predicting the pollutant consumption capacity of coagulation in drinking water treatment.	Use of AI and ecosystem-inspired models to predict water treatment efficiency.	Successfully predicted the pollutant consumption capacity of coagulation processes, improving the effectiveness of drinking water treatment.
35	Heris, S. Z., Ebadiyan, H., Mousavi, S.B., Nami, S. H., & Mohammadp o urfard, M.	The influence of nano filter elements on pressure drop and pollutant elimination efficiency in town border stations	To evaluate the influence of nano filter elements on pressure drop and pollutant elimination efficiency.	Experimental study on nano filter elements in town border stations to assess pollutant elimination and pressure drop	Found that nano filter elements significantly enhance pollutant removal efficiency, with a manageable increase in pressure drop.
36	Bedane, D. T., & Asfaw, S. L.	Microalgae and co-culture for polishing pollutants of anaerobically treated agro-	To explore the use of microalgae and co-culture for polishing pollutants in anaerobically	Experimental use of microalgae and co-culture techniques for wastewater treatment.	Demonstrated that microalgae and co-culture significantly improved

		processing industry wastewater: the case of slaughterhouse	treated wastewater from agro-processing industries.		pollutant removal in agro-processing wastewater treatment.
37	Chen, J., Mölter, A., Gómez-Barrón, J. P., O'Connor, D., & Pilla, F.	Evaluating background and local contributions and identifying traffic-related pollutant hotspots: insights from Google Air View mobile monitoring in Dublin, Ireland	To evaluate traffic-related pollutant hotspots and the contribution of local and background pollution.	Mobile air quality monitoring using Google Air View in Dublin, Ireland.	Identified key traffic-related pollutant hotspots and assessed the contributions of local and background pollution in urban areas.
38	Jang, H., Choi, K. H., Cho, Y. M., Han, D., & Hong, Y. S.	Environmental risk score of multiple pollutants for kidney damage among residents in vulnerable areas by occupational chemical exposure in Korea	To assess the environmenta l risk score of multiple pollutants for kidney damage among vulnerable residents in Korea.	Environmental risk scoring based on exposure data from occupational and environmental pollutants.	Found a strong association between exposure to multiple pollutants and kidney damage in vulnerable populations.

39	Cui, D., Cox, J., Mejias, E., Ng, B., Gardinali, P., Bagner, D. M., & Quinete, N.	Evaluating non - targeted analysis methods for chemical characterizatio n of organic contaminants in different matrices to estimate children's exposure	To evaluate non- targeted analysis methods for characterizing organic contaminants and estimating children's exposure.	Non-targeted chemical analysis of organic contaminants in various matrices.	Highlighted effective methods for assessing children's exposure to organic contaminants, contributing to better risk management strategies.
40	Stakes, K., Willi, J. M., Chaffer, R., Madrzykows k i, D., & Horn, G. P.	Exposure Risks and Potential Control Measures for a Fire Behavior Lab Training Structure: Part A—Fire Dynamics and Thermal Risk	To assess fire dynamics and thermal risk in a fire behavior lab training structure.	Fire behavior simulation and thermal risk analysis in a lab training structure.	Identified key risks and proposed control measures for reducing thermal and fire-related risks in lab environments

Chemical exposure around industrial areas remains a significant environmental and public health problem. Numerous studies provide strong evidence that industrial pollutants contribute to serious health problems, environmental degradation, and socioeconomic inequalities. This discussion combines findings from multiple studies, identifies relationships and differences, and provides a comprehensive analysis based on environmental justice theory and public health principles[11].

1. Correlations Among Studies

1.1 Health Impacts of Chemical Exposure

Several studies highlight serious health risks from long-term exposure to industrial pollutants. Okoye et al. (2022) and Pathak et al. (2022) showed that individuals living near industrial areas are at higher risk of respiratory diseases, developmental disorders, and cancers due to inhalation and ingestion of hazardous substances[12,13].

Domingo et al. (2021) conducted a systematic review and found a higher prevalence of leukemia and other hematological malignancies in populations living around petrochemical complexes in various countries[4]. Rahmadani & Syafri (2024) also emphasized that industrial workers exposed to hazardous chemicals such as benzene, toluene, and heavy metals showed increased respiratory problems, neurological disorders, and skin irritation. These findings are in line with Beronius et al. (2020), who developed a risk assessment methodology to highlight how multiple pollutants can have harmful synergistic effects, increasing the potential for exposure to be more risky[6,14].

1.2 Environmental Contamination and Food Safety Risks

Industrial waste pollutes not only the air but also the soil and water, increasing environmental and food safety risks. Nursyamsi & Husnain (2015) found that electroplating industrial wastewater causes the accumulation of heavy metals in agricultural soil and rice plants, increasing the risk of chronic heavy metal poisoning in consumers. Budijono & Hasbi (2021) studied heavy metal pollution in the Koto Panjang Dam and reported that lead (Pb) and cadmium (Cd) levels exceeded safe limits, affecting the aquatic ecosystem and the safety of fish consumption. Afifah et al. (2023) reported that industrial wastewater in Batam City is often discharged directly into rivers without adequate treatment, worsening environmental pollution. These studies show that hazardous substances in industrial waste are not only confined to industrial areas but also enter the food chain, increasing health risks even in populations far from the area[15-17].

2. Environmental Justice and Socioeconomic Inequality

2.1 Unequal Exposure in Low-Income Communities

Environmental justice theory suggests that low-income and marginalized communities often face disproportionate impacts from industrial pollution due to proximity to hazardous

areas, weak enforcement of regulations, and socioeconomic constraints[17]. Poerwati & Gai (2017) found that many low-income workers in Indonesia live close to industrial areas due to affordable housing, despite being at high risk from air and water pollution. Siddiqua et al. (2020) discuss how housing policies often force marginalized groups to live near industrial areas, increasing their exposure to hazardous chemicals such as sulfur dioxide and nitrogen oxides[10,18]. Westenhöfer et al. (2023) analyze urban environments and find that poorly planned industrial areas contribute to higher pollution in low-income areas, exacerbating public health inequalities. These studies highlight systemic inequalities in pollution exposure and the need for more equitable urban policies and planning[19].

2.2 Limited Access to Health Services and Mitigation Measures

Another environmental justice issue is limited access to health services and mitigation measures in affected communities. Indahsari et al. (2018) found that children in low-income neighborhoods near industrial areas suffered from higher rates of respiratory illnesses but had limited access to adequate health services. Rina et al. (2024) analyzed noise pollution levels in industrial areas and found that despite exposures exceeding safe health limits, government intervention was minimal. These findings suggest that environmental risks are exacerbated by poor health infrastructure, which leaves vulnerable populations without adequate medical support[20,21].

3. Conflicting Findings and Controversies

While most studies agree on the negative impacts of chemical exposure, there are some differences regarding the effectiveness of mitigation strategies.

3.1 Effectiveness of Pollution Reduction Strategies

Sava et al. (2023) stated that adjusting the height of smokestacks, planting trees, and using personal protective equipment can significantly reduce exposure. Widodo (2013) argued that these strategies are insufficient without strict industrial regulation and effective waste management[8,9]. Hong et al. (2021) proposed that real-time pollution monitoring systems and advanced filtration technologies can improve control of industrial pollutants. These conflicting perspectives highlight the need for a multi-layered approach, combining technological advancements, policy enforcement, and community engagement for effective pollution reduction[22].

3.2 Industrial Growth vs. Environmental Protection

There is debate about the trade-off between industrial growth and environmental sustainability. Solihat et al. (2025) argued that the cement industry, despite its economic benefits, remains one of the world's most significant polluters. Liang et al. (2024) emphasized that intelligent technology and green industrial transformation can reduce industrial pollution while maintaining economic growth. This discussion shows that sustainable industrial development must integrate green technologies and regulatory frameworks to minimize environmental damage[7,23].

4. Grand Theory Perspective: Precautionary Principle & Environmental Justice

4.1 Precautionary Principle in Environmental Health

The precautionary principle advocates taking precautions before harm occurs, even when scientific certainty is incomplete. Early risk assessment, as proposed by Beronius et al. (2020), to evaluate cumulative chemical exposures before widespread health damage occurs. Government interventions, such as zoning regulations to distance residential areas from high-risk industrial areas, thereby reducing direct exposure to pollutants[6].

4.2 Strengthening Environmental Justice Policies

Tanti et al. (2025) emphasize that Indonesia's environmental policies lack strong enforcement mechanisms, allowing industries to avoid liability for pollution. WHO (2004) provides global standards for industrial pollution control, recommending mandatory waste treatment, emission limits, and public health monitoring. Integrating this framework into policymaking will help governments prioritize public health while ensuring the sustainability of industries. Based on the results and also the author's discussion related to the review of various literature, there is exposure to chemicals that have a negative impact not only on the surrounding environment but also on the community living near the industrial area. The existence of an industrial area that is built is, of course, formed due to economic needs in an area. In addition, the existence of a strategic area accompanied by the need for companies to obtain large land generally makes industrial areas appear in a city or district[24].

Based on the Okoye et al., (2022) journal, it explains that exposure to chemicals that have an impact on the community around the industrial area has significant health effects. This is due to the increased risk of chronic diseases, especially respiratory diseases, in people

living around the industry. This study is also shown by the Pathak et al., (2022) journal, which provides contributions related to research results that show environmental contamination due to hazardous chemicals and ultimately have an impact on human health problems, for example, on developmental disorders in children and also other serious diseases such as the risk of cancer and also respiratory risks such as ARI[12,13].

Other literature studies show that often exposure to chemicals is only assessed from air pollution so that the air that is inhaled is considered dangerous and can cause problems with human health. Especially the health of the community living around the industrial area. But in fact, exposure to chemicals can also pollute the soil or water around industrial areas on a large scale. So even though communities and residential areas are close to the industry with a certain radius, for example, 3 to 5 km, because of heavy pollution in the environment, the area is still affected and also exposed to chemicals. The impacts are, of course, very numerous, starting from the prohibition of local communities to plant, such as vegetables and also trees for fruit, because it is feared that the soil contains chemicals. Likewise with groundwater used for daily human activities such as bathing or for sanitation because it is possible that the water contained is also contaminated by waste and also the results of the industry. Especially if the industry manages products with complex chemicals and quite high formulations, for example, products containing plastic, there are industries that manage medicines, materials such as paint or mining such as oil and gas, and several other industries that use chemicals as the main ingredients in their processing[11-13].

Chemical exposure also not only affects the health of the community as a whole but also raises environmental justice issues. For example, with low socio-economic status, the facilities offered and obtained by the community around the industrial area are generally very limited. They prioritize economic conditions where housing or land use around the industry is a decent place to live but does not meet health standards or non- health standards. This is indicated by the existence of cheap housing or land that can be purchased according to the economic capabilities of the community and the surrounding community. In addition, there is often a lack of access related to health services and resources for risk mitigation that can help reduce the adverse health impacts of exposure to these chemicals. Based on Muhafid (2016), even Indonesia curriculum using explanation about how dangerous the impact of chemical from factory/industry if development is really bad[25].

According to the Anik et al., (2024) study, effective enforcement of regulations can help reduce the adverse impacts of exposure to chemicals for communities living in industrial

areas. However, as we know, regulatory enforcement is often ignored by various parties because there is no direct impact felt. Residential areas are often the main targets of industrial activities, so they are often directly exposed to the negative impacts of industrial waste (Siddiqua et al., 2020). Some commonly found B3 substances include heavy metals such as lead and mercury, hazardous organic compounds such as pesticides and industrial chemicals, and air pollutants such as sulfur dioxide and nitrogen dioxide. Exposure to hazardous substances contained in B3 waste can pose a serious threat to human health. The impacts can vary, from mild symptoms such as skin irritation and respiratory problems to more serious risks, such as developing chronic diseases such as cancer. Children, with immune systems that are not yet fully developed, and the elderly, who are susceptible to health complications, are among the groups most vulnerable to the negative impacts of B3 pollution[18,26].

5. Chemical Exposure and Environmental Justice

Environmental justice issues arise when communities with low socio-economic status, who often live close to industrial facilities, face higher exposure to chemicals. Lack of access to health services and resources for risk mitigation worsens the health impacts experienced by these communities[20]. To address this issue, an integrated approach involving strict environmental monitoring, effective regulatory enforcement, and community empowerment programs is needed. Increasing public awareness of the dangers of chemical exposure and preventive measures is also important to reduce health risks. Overall, this literature review emphasizes the importance of attention to the impacts of chemical exposure in communities around industrial areas and the need for collaborative efforts to improve health and environmental justice for affected communities. Exposure to air pollution can lead to a variety of health problems. Especially for babies and children whose immune systems are not yet fully developed. Air pollution occurs when the air inhaled is mixed with toxic substances, such as carbon monoxide and nitrogen dioxide. These substances can come from factory waste, vehicle exhaust, or cigarette smoke. In addition, don't forget to complete your child's immunizations and teach them healthy living habits, including washing their hands diligently with soap and running water. Air pollution can not only harm children but also all family members. Therefore, do the tips and methods above to reduce exposure to air pollution. If air pollution causes complaints and health problems in your little one, you should immediately consult a doctor to get the right treatment[27].

Based on BRIN research by Tanti et al., (2025) explained the impact of hazardous material pollution, including chemicals, on residential areas is one of the serious challenges faced by modern society. Among the various types of pollution, pollution by Hazardous and Toxic Materials (B3) is a very real threat to human health and well-being. Hong et al., (2022), explained residential areas are not immune from this negative impact, with damaging consequences for the environment and human life around them. B3 pollution refers to waste containing hazardous and toxic substances, either in solid, liquid, or gas form[22,24]. B3 pollution not only threatens human health but also damages the natural ecosystem around residential areas. B3 pollution carries threats that go beyond human health, causing serious damage to the natural ecosystem around residential areas. Water contaminated by industrial waste not only threatens human life but also poses a risk of mass mortality for various living things in it. Polluted soil also has serious impacts, inhibiting the growth of plants and animals that depend on it. Thus, B3 pollution does not only impact one aspect but also poses a damaging threat to the balance of the ecosystem and the survival of living things around residential areas[28].

6. Preventive Way for Chemical Exposure

The impact of Hazardous and Toxic Materials (B3) pollution on residential areas is that B3 pollution has serious consequences for the environment and human health in the surrounding area. Residential areas are vulnerable to B3 pollution because they are often the target of industrial activities, which can result in direct exposure to hazardous substances. To address the problem of B3 pollution in residential areas, appropriate preventive and intervention measures must be taken by the government, industry, and local communities. This includes the implementation of strict regulations regarding B3 waste management, public education about the dangers of B3 pollution, the use of environmentally friendly technology in production, and efforts to clean up and rehabilitate polluted environments[29].

7. Environmental justice

The issue of chemical exposure in industrial areas extends beyond public health concerns, touching upon the broader dimension of environmental justice. Communities with lower socioeconomic status are often disproportionately burdened by industrial pollution due to their proximity to hazardous sites and the lack of robust legal protections[18].

7.1 Disparities in Exposure Across Social Groups

Siddiqua et al. (2020) demonstrated that low-income residential areas are frequently situated in close proximity to industrial zones, which significantly increases the inhabitants' exposure to hazardous substances. In the Indonesian context, Poerwati and Gai (2017) found that weak zoning regulations have resulted in the establishment of industrial facilities near densely populated residential areas, exacerbating the exposure risk for vulnerable communities[10,18].

7.2 Impacts on Vulnerable Populations: Children and the Elderly

- Children are particularly susceptible to industrial air pollution due to their immature respiratory systems. Exposure to fine particulate matter (PM2.5), nitrogen dioxide (NO_2), and volatile organic compounds (VOCs) has been associated with increased risks of asthma, cognitive impairments, and leukemia[4].
- Elderly individuals are at a heightened risk of developing cardiovascular and neurological disorders as a result of chronic exposure to heavy metals such as mercury and lead[14].

7.3 Limited Access to Health Services

Low-income communities situated near industrial areas often experience significant barriers to adequate healthcare. These challenges include[14]:

- The unavailability of nearby medical facilities;
- The high cost of treatment for pollution-induced illnesses such as cancer and chronic respiratory diseases;
- The absence of systematic public health surveillance targeting affected populations.

7.4 Comparative Policy Approaches

In addressing environmental justice, several countries have implemented more progressive and robust frameworks compared to Indonesia[14]:

- United States: The Environmental Justice Screening Tool (EJSCREEN) enables the identification of communities with high levels of environmental pollution and prioritizes them for mitigation initiatives.
- European Union: The Zero Pollution Action Plan sets a target to reduce industrial emissions by 55% by 2030 and supports the creation of clean air zones within residential neighborhoods.

- Indonesia: Environmental governance remains weak, with insufficient enforcement of industrial zoning and pollution monitoring, thus exacerbating health risks for local communities.

8. Mitigation Strategies for Industrial Chemical Exposure

To reduce the adverse effects of industrial chemical exposure, a comprehensive strategy encompassing regulatory, community, and technological approaches should be adopted[22].

8.1 Strengthening Regulatory Frameworks and Law Enforcement[22]

- Implement real-time monitoring systems for air and water pollutants to enhance transparency and responsiveness;
- Enforce stricter penalties for industries that discharge untreated waste;
- Mandate transparent and participatory Environmental Impact Assessments (AMDAL) prior to industrial development.

8.2 Community-Based Approaches[22]

- Promote community education programs to raise awareness about the risks of chemical exposure and protective measures, such as wearing masks, using household water filters, and maintaining urban green spaces;
- Develop community-based environmental surveillance networks to detect and report instances of industrial pollution.

8.3 Adoption of Environmentally Friendly Technologies[8]

- Zero Waste Initiatives: Encourage industries to adopt production processes that minimize waste generation;
- Air Filtration Systems: Install air scrubbers to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NOx);
- Integrated Wastewater Treatment: Utilize bioremediation and phytoremediation techniques to neutralize toxic pollutants in water and soil.

Conclusion

The conclusion obtained from the research conducted is that exposure to chemicals from industrial activities can have a significant impact on the health and environment of people living around the industrial area. Studies show that long-term exposure can cause

industrial pollutants to enter the human body and cause serious diseases such as respiratory disorders, cancer, and cardiovascular disease. In addition, there are several studies that show that there is an aspect of environmental justice that is still a challenge. Because communities with low socio-economic levels tend to be more vulnerable to pollution due to industry. The impact creates a gap related to the implementation of both policies and access to health services for people who are directly or indirectly affected by exposure to these chemicals. The existence of proper waste processing accompanied by mitigation, increasing awareness related to environmental rights, policies developed by the government, and how supervision related to the law and its application to various industries that are established can help create justice, reduce exposure to chemicals that cause health problems, and reduce the risk of other negative impacts due to industry.

Industrial chemical exposure poses serious health, economic, and environmental risks, disproportionately affecting low-income communities with higher disease burdens, economic stagnation, and limited access to healthcare. It also accelerates climate change through greenhouse gas emissions, leading to global warming and ecological damage. Effective mitigation requires cross-sector collaboration, strict enforcement of environmental regulations, and integration with climate policies. Implementing smart pollution monitoring technologies and empowering communities through education and advocacy can enhance early detection and response. Combining policy reforms, technological innovation, and community engagement is essential to reducing exposure risks and ensuring long-term sustainability.

Acknowledgements

None.

Conflicts of Interest

The authors declare no conflict of interest.

Funding Sources

None.

References

1. Roy R, Zhang Y, Wang J, et al. Pollution accidents caused by industrial chemicals: a global overview. *Environ Int*. 2024;179:108178.

2. Rovira J, Nadal M, Schuhmacher M, Domingo JL. Air pollutants around a petrochemical complex: Human health risks. *Sci Total Environ*. 2021;762:143162.
3. Purba H, Sembiring S, Sinaga R. The impact of household industry waste on water quality in Ciliwung River. *J Ilmu Lingkungan*. 2018;16(2):65–72.
4. Domingo JL, Marquès M, Nadal M, Schuhmacher M. Health risks for the population living near petrochemical industrial complexes. 1. Cancer risks: A review of the scientific literature. *Environ Res*. 2021;197:111051.
5. Suwandana E, Wardoyo S, Rahmat A. Climate variability and industrial chemical exposure: Implications for environmental justice. *J Ekol Kesehat*. 2011;10(3):145–52.
6. Beronius A, Zilliacus J, Hanberg A, Luijten M, van der Voet H, van Klaveren J. Risk assessment of combined exposures to multiple chemicals: A framework. *Regul Toxicol Pharmacol*. 2020;114:104647.
7. Solihat E, Utama W, Fajri S. Dampak industri semen terhadap lingkungan dan keberlanjutan pembangunan. *J Kebijakan Lingk Indones*. 2025;29(1):55–68.
8. Sava C, Drăghici C, Popa M, Bălan M. Assessing air pollution control strategies in industrial zones. *Int J Environ Sci Technol*. 2023;20(2):765–77.
9. Widodo H. Strategi mitigasi polusi udara di kawasan industri. *J Kesehat Lingk*. 2013;9(1):34–41.
10. Poerwati A, Gai J. Dampak penataan ruang dan kebijakan hunian terhadap paparan polusi industri. *J Tata Kota*. 2017;23(1):55–62.
11. Sevira R, Andriani M, Maulana R. Perilaku masyarakat terhadap polusi industri di kawasan padat penduduk. *J Sosiologi Pedesaan*. 2021;9(2):88–97.
12. Okoye CO, Addey CI, Oderinde O, et al. Toxic chemicals and persistent organic pollutants associated with micro- and nanoplastics pollution. *Sci Total Environ*. 2022;804:150021.
13. Pathak P, Bhuvaneswari M, Mishra S. Chemical pollution and community health risk: exposure from industrial activity. *J Environ Public Health*. 2022;2022:4578324.
14. Rahmadani N, Syafri M. Hubungan antara paparan bahan kimia berbahaya di lingkungan kerja dan risiko kesehatan pada pekerja industri. *J Mitrasehat*. 2024;14(2):728–32.
15. Nursyamsi D, Husnain H. Accumulation of heavy metals in rice grown in soil irrigated with electroplating industry wastewater. *J Food Agric Environ*. 2015;13(3–4):121–6.

16. Budijono, Hasbi M. Heavy metal contamination in Koto Panjang Dam, Indonesia. *J Limnologi Indonesia*. 2021;2(1):27–35.
17. Afifah AS, Septiariva IY, Suhardono S, Suryawan IWK, Sari MM. Evaluation of domestic wastewater and river management in Belian Village, Batam City Sub-district, Indonesia. *Region*. 2023;18(1):295–303.
18. Siddiqua A, Hahladakis JN, Al-Attiya WAK. An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. *Sci Total Environ*. 2020;730:139088.
19. Westenhöfer J, Nouri E, Reschke ML, Seebach F, Buchcik J. Walkability and urban built environments—a systematic review of health impact assessments. *BMC Public Health*. 2023;23:1742.
20. Indahsari N, Noor NN, Arsyad DS. Relationship of air pollution exposure in house with occurrence of acute respiratory infections in children under five. *Proc Int Conf Health Serv Manage*. 2018;1:149–53.
21. Rina BPN, Darmawan MI, Susanti DR. Analisis tingkat kebisingan lalu lintas pada jalan raya Jenggik–Terara. *J Teknol Lingkungan*. 2024;2(2):22–33.
22. Hong J, Kang H, An J, et al. Towards environmental sustainability: insights for managing hazardous pollutants at construction sites. *J Hazard Mater*. 2021;403:123804.
23. Liang M, Liu L, Liang W, Mi W, Ye K, Gao J. Intelligentization helps the green and energy-saving transformation of power industry: Evidence from China. *Sci Rep*. 2024;14(1):8698.
24. Tanti M, Fadilah A, Suryanto Y. Evaluasi sistem pengendalian pencemaran B3 di kawasan pemukiman: Studi BRIN. *J Ilmu Lingkungan*. 2025;21(2):122–34.
25. Muhafid EA. Pengembangan modul IPA berbasis saintifik pada tema polusi udara untuk SMP. [Thesis]. Surakarta: Universitas Sebelas Maret; 2016.
26. Anik AH, Toha M, Tareq SM. Occupational chemical safety and management: Case study from Bangladesh. *Hyg Environ Health Adv*. 2024;100110.
27. Lukman MF, et al. Dampak polusi udara terhadap kesehatan anak. *J Kesmas*. 2019;13(1):15–21.
28. Mahmoud MA, Abdel-Mohsein H, Mahmoud U, et al. Impact of industrial wastewater on aquatic ecosystems. *Environ Pollut*. 2022;307:119473.
29. Talema R. Penerapan prinsip kehati-hatian dalam pengelolaan limbah B3 industri. *J Hukum Lingkungan Indonesia*. 2023;11(1):17–29.

30. Arjuna AB, Hasibuan S. Fire Risk Analysis in the Chemical Industry using the Hazard Identification and Risk Assessment Method. In: Proc 3rd Asia Pacific Conf Res Ind Syst Eng. 2020:225–9.
31. Azzahro F. Penentuan hasil evaluasi pemilihan spesies pohon dalam pengendalian polusi udara pabrik semen. 2020.
32. Bedane DT, Asfaw SL. Microalgae and co-culture for polishing pollutants of anaerobically treated agro-processing industry wastewater: the case of slaughterhouse. *Bioresour Bioprocess*. 2023;10(1):81.
33. Chen J, Mölter A, Gómez-Barrón JP, O'Connor D, Pilla F. Evaluating pollutant hotspots: insights from Google Air View in Dublin. *Environ Sci Pollut Res*. 2024;31(44):56114–29.
34. Cui D, Cox J, Mejias E, et al. Chemical characterization of organic contaminants to estimate children's exposure. *J Expo Sci Environ Epidemiol*. 2023;33(4):589–601.
35. Febriyana NA. Identifikasi daya tampung beban pencemaran air Kali Surabaya dengan QUAL2KW [Thesis]. ITS; 2016.
36. Febriyanti AL, Pancahayani S, Faisal M. Model matematika penyebaran polusi udara dan jarak aman pemukiman. *SPECTA J Technol*. 2022;6(1):35–46.
37. Fiona Azzahro, Yulfiah, Anjarwati. Evaluasi pemilihan spesies pohon untuk pengendalian polusi udara. *J Res Technol*. 2019;5(2). doi:10.55732/jrt.v5i2.201.
38. Hariani Y. Pengaruh paparan bahan kimia terhadap kesehatan reproduksi pekerja. *Babul Ilmi*. 2023;15(1).
39. Heris SZ, Ebadiyan H, Mousavi SB, et al. Efficiency of nano filters on pollutant elimination in border stations. *Sci Rep*. 2023;13(1):18793.
40. Hutapea O, Kombih MF, Rendrawan R, et al. Program APD untuk mengurangi paparan uap kimia di industri percetakan. *To Maega*. 2022;5(1):1–8.
41. Jang H, Choi KH, Cho YM, Han D, Hong YS. Environmental risk score of multiple pollutants for kidney damage among residents in vulnerable areas by occupational chemical exposure in Korea. *Environ Sci Pollut Res*. 2024;31(24):35938–51.
42. Jang J, Han E, Heo J, Choi S, Park J, Lee KS, et al. Analysis of the National Air Pollutant Emissions Inventory (2021) in the Republic of Korea. *Asian J Atmos Environ*. 2025;19(1):3.

43. Ju T, Lei M, Guo G, Xi J, Zhang Y, Xu Y, Lou Q. A new prediction method of industrial atmospheric pollutant emission intensity based on pollutant emission standard quantification. *Front Environ Sci Eng*. 2023;17(1):8.
44. Kamasnuri UN, Widiyanti BL, Darmawan MI. Analisis kualitas mata air Lingkok Pancor untuk peruntukan air bersih di Dusun Jangkar, Desa Setungkep Lingsar. *J Teknol Lingkungan*. 2023;1(1):25–35.
45. Lee YW, Kim YP, Yeo MJ. Estimation of air pollutant emissions from heavy industry sector in North Korea. *Aerosol Air Qual Res*. 2023;23(7):230066.
46. Li S, Zhu G, Li X, Wan P, Yuan F, Xu S, Hursthouse AS. Ecosystem-inspired model and artificial intelligence predicts pollutant consumption capacity by coagulation in drinking water treatment. *Environ Chem Lett*. 2023;21(5):2499–508.
47. Marpaung AP. Pengaruh polusi udara terhadap kesehatan paru-paru pada anak-anak di kawasan industri Kota Medan. *J Ilmiah Simantek*. 2023;7(2):144–6.
48. Maulida A, Oktaviani A, Pakpahan HS, Wikaningrum T. Hazardous waste should be managed properly for development of better waste management strategies. *J Penelitian dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti*. 2022:193–209.
49. Ratuannisa T, Ekawati E, Yulia E, Purwasasmita BS, Nugraha AB. Studi pengolahan air limbah batik pada skala industri rumah tangga dan usaha kecil menengah di Cirebon, Indonesia. *Dampak*. 2023;20(1):8–15.
50. Ridwan AM, Lestari AD. Gangguan pendengaran akibat paparan toluen. *J Penelitian dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti*. 2023:144–63.
51. Sasmita A, Reza M, Rozi RM. Pemetaan dan perhitungan pemaparan tingkat kebisingan pada industri pengolahan kayu di Kecamatan Siak, Provinsi Riau. *Al-Ard: J Teknik Lingkungan*. 2021;6(2):68–76.
52. Sing TF, Wang W, Zhan C. Tracking industry pollution sources and health risks in China. *Sci Rep*. 2023;13(1):22232.
53. Stakes K, Willi JM, Chaffer R, Madrzykowski D, Horn GP. Exposure risks and potential control measures for a fire behavior lab training structure: Part A—Fire dynamics and thermal risk. *Fire Technol*. 2023;59(4):2089–125.
54. Soinangun B, Novendri I, Matsana J, Gunawan FE, Asrol M, Redi AP. The impact of COVID-19 pandemic on psychological fatigue of control room operators in oil, gas, and petrochemical industry. *Int J Hum Factors Ergonom*. 2021;8(4):393–407.

55. Trianisa K, Purnomo EP, Kasiwi AN. Pengaruh industri batubara terhadap polusi udara dalam keseimbangan World Air Quality Index di India. *J Sains Teknol Lingkungan*. 2020;6(2):156–68.

56. Utari E, Handayani TA, Nurfitriniha WS. Pemahaman masyarakat tentang pencemaran limbah industri terhadap lingkungan hidup di Kecamatan Ciwandan, Kota Cilegon. *Biodidaktika: J Biologi dan Pembelajarannya*. 2022;17(2).

57. Westenhöfer J, Nouri E, Reschke ML, Seebach L, Ziegler P. Contamination of drinking water sources with heavy metals in industrialized areas of Europe. *Environ Sci Pollut Res*. 2023;31(2):2141–51.

58. Winda W, Kardhinata H, Nurtjahja K, Fauziah I. Respon fisiologis Pulutan (Urena lobata L.) terhadap polusi udara di lingkungan industri. *J Ilmiah Biologi UMA (JIBIOMA)*. 2024;6(1):46–54.

59. Yudita A, Akbar AA, Saziati O. Analisis kualitas air dan pengendalian pencemaran air Sungai Retok, Kabupaten Kubu Raya. *Jukung: J Teknik Lingkungan*. 2023;10(1).