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Systematic Review: Impact of Air, Leachate, and Soil Contamination on Health Problems in Landfill Workers and Local Residents

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ABSTRACT

Introduction: The rising global production of municipal solid waste (MSW) poses significant ecological challenges. In developing countries, inadequate landfill management results in the uncontrolled release of hazardous gases and leachate, posing significant risks to human health. This systematic review investigated the association between environmental factors at these landfills and adverse human health outcomes.
Methods: This review was conducted in accordance with the PRISMA guidelines. A comprehensive search was rapidly conducted across ScienceDirect, Scopus, PubMed, and EBSCOhost for articles published between 2020 and 2025. PECO criteria screening was conducted independently by two reviewers, resulting in the selection of 25 articles for critical synthesis.
Results: Hazardous landfill pollutants—including heavy metals, volatile organic compounds (VOCs), and particulate matter—are rapidly escalating severe health issues. Residents and landfill workers face acute respiratory and cardiovascular disorders, heightened cancer risk, reproductive issues, and neurological impairments. Leachate contamination of soil and groundwater compounds these urgent systemic risks.
Conclusion: The ongoing failure to manage landfills effectively, particularly in developing countries, has triggered a pressing environmental and public health crisis. Immediate action to improve waste management and enforce stricter environmental policies is critical for preventing further harm.

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INTRODUCTION

Globally, municipal solid waste (MSW) production is soaring due to several factors, such as lifestyle changes, increased industrialization, modernization, and population growth. Daily MSW production is projected to reach 6.1 million metric tons by 2025. Currently, around 4.3 billion city dwellers worldwide produce an average of 1.42 kg of plastic waste per person per day (1) (2). E-waste generation is predicted to reach 74.7 million metric tons by 2030 (3).

A landfill site is an area specifically designed to treat a variety of MSW such as food waste, plastics, and construction waste (4) (5). Globally, the composition of MSW is dominated by organic waste (44%), followed by paper and cardboard (17%), and plastics (12%) (6) (2). In many developing countries, landfills are often the preferred choice for waste management due to their choice for waste management due to their ease of implementation and efficiency. However, many landfills do not operate to standards, resulting in improper waste sorting. Consequently, there is an uncontrolled release of leachate and toxic gases into the environment (7).

Landfills are a major contributor to greenhouse gas (GHG) emissions, particularly methane (CH_4) and carbon dioxide (CO_2), produced by waste decomposition. In addition, the emission of toxic chemicals from landfills has a serious impact on health, where long-term exposure to arsenic is linked to an increased risk of cancer and heart disease (8) (9) (7). A 2020 research study conducted in Italy focused on the regions most affected by the Hazardous Landfill Site and revealed a significant link between waste risk indicators and an increased probability of hospitalization and death from various cancers, including liver and stomach cancer, in the general population (10). Furthermore, a comprehensive 2024 review contextualizes the major risks posed by landfills through diverse and complex exposure pathways. The review confirms that open dumping landfills – a common practice in developing countries – are the primary cause of water and soil contamination, as they release uncontrolled leachate containing heavy metals and disease – causing microorganisms. The community faces a respiratory threat from open burning and stockpiling operations, which emit gases and fine particulate matter ($PM_{2.5}$). These emissions aggravate chronic diseases and intensify breathing problems among nearby residents (11). In addition, landfills produce various toxic substances, such as carbon monoxide, hydrogen sulfide (H_2S), xylene, and dioxins. Dioxins increase the risk of heart disease-related death, and PAHs are carcinogenic. Hydrogen sulfide (H_2S) gas can also damage the central nervous system if inhaled in high concentrations (12).

Exposure to landfill gases is harmful to human health. Methane (CH_4) inhalation causes nausea to death. Acidic gases, such as NO_2 and SO_2, can trigger respiratory problems and infections. Exposure to heavy metals also increases the risk of lung cancer, asthma, and hypertension (12). Living near landfills is linked to an increased risk of preterm birth and congenital defects in infants (13). The purpose of this study is to identify and compile scientific evidence regarding the relationship between exposure to pollutants and the extent of health consequences impacting both local residents and workers at the landfill site.

METHOD

A comprehensive literature search was performed using ScienceDirect, Scopus, PubMed, and EBSCOhost. The review included studies published from 2020 to 2025. Boolean search strings combined keywords based on the PECO framework, as outlined in Table 1, with Boolean operators. For each database, the search strategy was refined to enhance specificity and relevance. Results were limited to the Title, Abstract, and Keywords fields.

The process for selecting suitable articles strictly followed the PRISMA guidelines. To ensure methodological rigor, two independent reviewers and one arbiter conducted the procedure. Reviewers A and B screened every retrieved article against the predefined PECO criteria, assessing the title or abstract and the full-text separately. Initially, all differences were resolved through discussion and consensus between the two reviewers; any disagreements that persisted were then sent to the third reviewer for a final decision on inclusion or exclusion.

Data extraction was carried out on the 25 final included articles. The goal was to systematically gather key information relevant to the PECO question, including Study Title and Publication Year, Research Objective, Study Design and Sample Characteristics, and Major Findings or Conclusions, all summarized in Table 3.

Based on Table 1, this study uses a combination of keywords and the Boolean operators "AND" and "OR" to comprehensively search the literature. This study aims to ensure relevant coverage of the impact of landfills on health, thereby minimizing the risk of missing important studies.

Table 1. Keywords and Boolean

Database	Boolean Combination	Date of Final Search
ScienceDirect	((“landfill” OR “disposal site”) AND (“adverse effect” OR “health impact”) AND (“$PM_{2.5}$” OR “heavy metals” OR “VOCs”))	30 October 2025
Scopus	TITLE-ABS-KEY ((“landfill” OR “waste disposal” OR “refuse site”) AND (“health risk” OR “adverse health” OR “health impact”) AND (“$PM_{2.5}$” OR “heavy metals” OR “VOCs”))	30 October 2025
PubMed	(("landfill"[MeSH] OR "refuse site"[tiab] OR "dumpsite"[tiab]) AND ("health risk"[tiab] OR "adverse health"[tiab] OR "disease"[MeSH] OR "environmental exposure"[tiab]))	30 October 2025
EBSCOhost	((“landfill*” OR “dump site”) AND (“health risk” OR “adverse health” OR “health impact”) AND (“VOCs” OR “heavy metals” OR “$PM_{2.5}$”))	30 October 2025

Boolean search strings were systematically reconstructed and tailored for each database. This approach optimized both sensitivity and specificity. Boolean operators targeted landfill pollutants, including heavy metals, volatile organic compounds (VOCs), and particulate matter. The search strategy also addressed adverse health outcomes, including respiratory, cardiovascular, cancer, and neurological disorders. These methods improved retrieval accuracy and reduced the inclusion of unrelated environmental or occupational studies. The four databases were searched independently, with the final search conducted on October 30, 2025. October 30, 2025, was set as the final date for replicability of this systematic review.

`Table 2 presents the PECO framework used to develop research questions and study selection criteria. P (Population) refers to residents who live near landfills and landfill workers. E (Exposure) involves various environmental factors and pollutants originating from the landfill. C (Comparison) is a resident who lives far from the landfill. Finally, O (Outcome) focuses on health problems arising from exposure to landfills.

Table 2. PECO Analysis

PECO Elements	Analysis
P (patient, population, problem)	Residents living near landfill and landfill workers
E (exposure)	Environmental factors and pollutants from landfill
C (comparison, control)	Residents who live far from landfill
O (outcome)	Health problems

From the 11,704 records identified across the four databases, 381 duplicates were automatically identified and removed using the reference management software, Mendeley. This process yielded 11,323 unique records for the initial screening stage. Following the screening of titles and abstracta against the PECO criteria, 1,050 reports were identified as potential and retrieved for full-text review.

Strict inclusion criteria were then applied during the full-text review: 1) The document must be a research article; 2) It must have been published between 2020 and 2025; and 3) The full text must be available and peer-reviewed. The primary exclusion criterion was that the article was not in English. After independent screening and eligibility assessment by two reviewers and an arbiter, 25 unique studies were included in the synthesis. Access to all articles, including those from subscription-based journals, was secured trough the extensive institutional subscription provided by Diponegoro University.

Methodological transparency and study quality were ensured using the ROBINS-I (Risk of Bias in Non-randomized Studies – of Interventions) framework, which was identified as the most suitable tool for evaluating bias. This approach enabled assessment across the included non-randomized observational studies: cross-sectional, cohort, and Health Risk Assessment designs. The risk of bias was evaluated across seven domains, including confounding,

classification of interventions, and outcome measurements. Final risk-of-bias judgments for each study informed the synthesis and the interpretation of overall confidence in the findings.

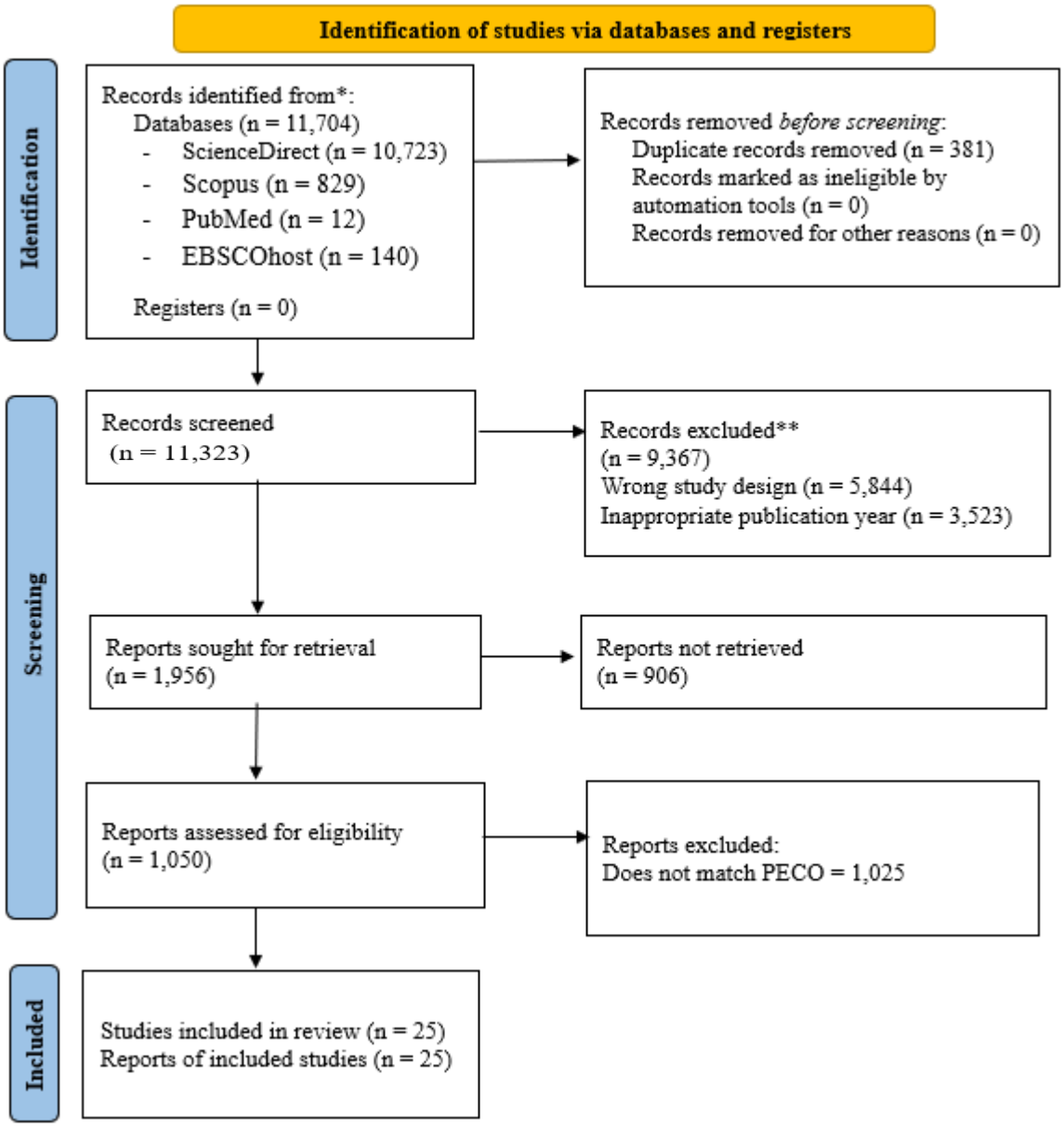

Figure 1. Flow Chart of Article Screening

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Adhering to the PRISMA 2020 framework, the article identification and screening procedures are illustrated in Figure 1, which demonstrated how studies were selected and excluded at each review phase. As shown in Figure 1, this process is detailed by the count of studies at every stage. The final 25 included studies offer varied research designs and geographical settings to explore the association between environmental factors at landfills and human health.

RESULTS

All 25 selected research articles addressed contamination by heavy metals and metalloids, biological pollutants, gases, fine particulate matter, and volatile organic compounds (VOCs). As shown in Table 3, the research locations encompass countries in Africa, Asia, Europe, and South America. The methodologies employed include environmental monitoring, observational, scenario-based, and experimental studies, as well as laboratory analyses

Table 3. Data Extraction

Research Title and, Year	Study Location	Study Design and Sample	Pollutant Metrics	Health Outcome Reported	Key Finding
Health effects associated with proximity to waste collection points in Beitbridge Municipality, Zimbabwe (2020) (14)	Zimbabwe	Method: Cross-sectional. Sample: 700 respondents were selected by *stratified random sampling* around 5 waste collection points.	Not explicitly stated (focuses on health outcomes).	Common contaminant/risk	Proximity ≤50 m to waste collection points increases the likelihood of respondents experiencing poor health by almost 16 times.
Human exposure to trace elements and PCDD/Fs around a hazardous waste landfill in Catalonia (Spain) (2020) (15)	Spain	Method: Cross-sectional. Sample: Soil and air around the HWL and surrounding areas (inside and outside the facility).	PCDD/Fs (Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans) and heavy metals.	Common contaminant/risk	Despite increased pollutant concentration, current public health risks in the surrounding area are below safe limits.
Syphilis and other sexually transmitted infections among waste pickers in Brasilia, Brazil (2020) (16)	Brazil	Method: Cross-sectional. Sample: All waste collectors registered in waste recycling cooperatives (minimum 18 years old and working in 2016-2017).	Biological agents (pathogen causing STIs) and occupational risk factors.	Infectious diseases	A high prevalence of Syphilis was found among waste pickers.
Urban Municipal Solid Waste management: Modelling air pollution scenarios and health impacts in the case of	Ghana	Method: Modelling and Health Impact Assessment (HIA).	$PM_{2.5}$.	Respiratory disorders and irritation	Stopping open burning can reduce the health burden associated with $PM_{2.5}$ by 94%.

Accra, Ghana (2021) (17)		Sample: Not in the form of a direct population, but based on data and models used to simulate future conditions until 2030.			
Trace volatile compounds in the air of domestic waste landfill site: Identification, olfactory effect and cancer risk (2021) (18)	China	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: Air sampling in multiple areas (waste weighing sites, disposal areas, and enclosed areas with HDPE).	VOCs (Benzene, Trichloroethylene, and 1,3-Butadiene) and odorous gases (H_2S and Styrene).	Respiratory disorders and irritation, cancer risk	VOC emissions and odors from landfills pose health risks, such as cancer and respiratory tract irritation.
Occurrence, source apportionment, plant bioaccumulation and human exposure of legacy and emerging per- and polyfluoroalkyl substances in soil and plant leaves near a landfill in China (2021) (19)	China	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: Soil and different types of plants (cabbage, camphor, cephalotaxus, and reed) collected from 32 different locations around the landfill.	PFASs (Per-and Polyfluoroalkyl Substances).	Common contaminant/risk	PFAS contamination poses a health risk due to the ingestion of contaminated vegetables.
Carcinogenic Risk of Pb, Cd, Ni, and Cr and Critical Ecological risk of cd and cu in soil and groundwater around the municipal solid waste open dump in central Thailand (2022) (20)	Thailand	Method: Health Risk Assessment (HRA) and Ecological Risk Assessment (ERA). Sample: Soil and groundwater collected from areas surrounding the landfill site.	Heavy metals (lead, cadmium, nickel, chromium).	Cancer risk	Lifetime carcinogenic risks from nickel and chromium in adults and children exceed established limits, indicating high and ongoing chronic health concerns through oral exposure.

Health symptoms and inflammatory blood biomarkers from exposure of recyclable waste workers to particulate matter and bioaerosols (2022) (21)	Denmark	Method: Cross-sectional. Sample: 64 respondents (exposed group: 40 recycling workers and control group: 24 UTFPR staff and students).	Particulate matter (dust), bioaerosols (bacteria, fungi, and endotoxin).	Respiratory disorders and irritation	Exposure to air pollutants is associated with an increased risk of respiratory symptoms and alterations in inflammatory blood biomarkers.
Health risks and perceptions of residents exposed to multiple sources of air pollutions: A cross-sectional study on landfill and stone mining in Danang city, Vietnam (2022) (22)	Vietnam	Method: Cross-sectional. Sample: 314 respondents who lived near landfills and rock mines (>18 years) from 3 different areas (LS, ST, and far-exposed areas).	H_2S, CH_4, TSP (Total Suspended Particles), and noise levels.	Common contaminant/risk	Residents near pollution sources report a higher perception of health risks and increased incidence of certain health symptoms.
Multiple Exposures to Heavy Metals and Changes in Steroid Hormones Production in 4-Year-Old Children (2023) (23)	China	Method: Prospective cohort. Sample: 42 children aged 4 years (25 boys and 17 girls). Sample media are human milk (breast milk) and serum blood.	Heavy metals (lead, cadmium, and mercury).	Reproductive and developmental problems	Prenatal exposure to mercury (Hg) may influence sex hormones in children by affecting DHEA levels.
Potential environmental pollution study by leachate generation and health risk assessment in the vicinity of bandhwari landfill disposal site, National Capital Region, India (2023) (24)	India	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: Groundwater sources include foretells, pipe wells, and hand pumps around landfill.	Heavy metals and physicochemical parameters.	Common contaminant/risk	Landfills impact groundwater quality, thereby increasing human health risks through exposure to contaminated water.
Effects of dumpsite leachate plumes on surface and groundwater and the possible	Africa	Method: Environmental Monitoring and Health Risk Assessment (HRA).	Heavy metals and physicochemical parameters.	Common contaminant/risk	Open dumpsites significantly contribute to groundwater pollution, releasing heavy

public health risks (2023) (25)		Sample: 10 shallow wells and 1 borehole within a radius of 200 m from the dumpsite.			metals and hazardous chemicals that pose a potential risk to public health.
Geochemistry pollution status and ecotoxicological risk assessment of heavy metal(oid)s in soil influenced by co-landfilling of MSW and sewage sludge, Morocco (2023) (26)	Morocco	Method: Environmental Monitoring. Sample: Soil at 19 points within a 200 m radius of landfill and sewage sludge-affected areas.	Heavy metals and metaloid.	Cancer risk	The carcinogenic risks from heavy metals, especially in children, are well above the accepted threshold.
Exploring hazard quotient, cancer risk, and health risks of toxic metals of the Mehmood Booti and Lakhodair landfill groundwaters, Pakistan (2023) (27)	Pakistan	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: Groundwater and respondents from the community around the landfill (50 people aged >15 years).	Heavy metals.	Cancer risk and systemic organ damage	Heavy metals pose a carcinogenic risk and may cause various diseases, such as respiratory and digestive disorders.
Exposure particulate matter ($PM_{2.5}$) and health risk assessment on informal workers in landfill site, Indonesia (2023) (28)	Indonesia	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: 39 informal workers at landfills (working for at least 1 year and aged >18 years).	$PM_{2.5}$.	Respiratory disorders and irritation	Exposure to $PM_{2.5}$ above threshold levels increased the health risks of landfill workers, leading to respiratory symptoms.
Assessment of health risk and pollution load for heavy and toxic metal contamination from leachate in the vicinity of dumping site in Mid-Brahmaputra	India	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample:	Heavy metals.	Common contaminant/risk	Unstable landfills allow leachate to seep, contaminating soil and groundwater with harmful heavy metals.

Valley, India (2023) (29)		12 soil samples were taken from around the landfill, groundwater was collected from wells in residental areas around the landfill, and leachate was collected from the landfill location.			
A comparative study on metal pollution from surface dust of informal and formal e-waste recycling sectors in national capital region of New Delhi and associated risk assessment (2023) (30)	India	Method: Comparative Environmental Monitoring Study and Health Risk Assessment (HRA). Sample: Surface dust from e-waste management areas in formal and informal sectors.	Heavy metals.	Cancer risk and common contaminant/risk	Informal e-waste management contributes to increased heavy metal pollution, thereby heightening human health risks, particularly children.
Risk assessment and partitioning behavior of PFASs in environmental matrices from an e-waste recycling area (2023) (31)	China	Method: Environmental Monitoring and Health Risk Assessment (HRA). Sample: 12 soil and water samples, 26 atmospheric samples, quetionnaires and physical measurements of children's health.	PFASs (Per- and Polyfluoroalkyl Substances).	Reproductive and developmental problems	PFAS-contaminated environments may interfere with children's growth and development, much like other environmental pollutants.
Pervasiveness and classification of microplastics in Landfill Leachate: Impacts, risks, and treatment efficiency (2024) (32)	Bangladesh	Method: Environmental Monitoring and Ecological Risk Assessment. Sample: 70 samples from 21 sites (30 surface water samples, 30 groundwater	Microplastics.	Common contaminant/risk	Landfill leachate has the potential to compromise surface and groundwater quality by introducing microplastic contamination, which can impact human health.

		samples, and 10 leachate samples from various treatment stages).			
Characterization of potentially toxic elements in leachates from active and closed landfills in Nigeria and their effects on groundwater systems using spatial, indexical, chemometric and health risk techniques (2024) (33)	Nigeria	Method: Comparative Environmental Monitoring Study. Sample: Groundwater and wastewater from active and closed landfills, as well as sediments from related areas, were collected.	Heavy metals.	Systemic organ damage	Heavy metals (As, Cd, Pb) pose a significant health risk, necessitating monitoring to prevent organ dysfunction and chronic diseases.
Trace elements accumulation in vegetables and soils of waste dumping sites in southwestern Bangladesh and implication on human health (2024) (34)	Bangladesh	Method: Health Risk Assessment (HRA) Sample: Trace elements measured in vegetables and soils.	Heavy metals.	Common contaminant/risk	The contamination of landfill sites consequently causes a human health risk through the food chain.
Quantification and characterization of municipal solid waste at aler dumpsite, Lira City, Uganda: Assessing pollution levels and health risks (2024) (35)	Uganda	Method: Health Risk Assessment (HRA). Sample: Waste, liquid by-products, soil, and food crops.	Heavy metals and water/leachate quality parameters.	Systemic organ damage, developmental problems, and cancer risk	The Aler Landfill is causing serious pollution with heavy metals in the local environment, water, and food chain, posing an extremely high health risk to the surrounding community.
Evaluating the seasonal variations of risks associated with potentially toxic elements in underground water sources near a dumpsite in Awka, Nigeria (2024) (36)	Nigeria	Method: Multi-variate chemical analysis and Health Risk Assessment (HRA). Sample: Underground water, primarily collected from boreholes located around the Awka dumpsite.	Heavy metals	Cancer risk	Landfill contamination renders groundwater unfit for consumption, which creates a seasonally heightened health hazard.

Investigating the respiratory and systemic effects of exposure to BTEX among municipal solid waste workers (2025) (37)	Iran	Method: Cross-sectional and Health Risk Assessment (HRA). Sample: 30 waste management workers (exposed group) and 30 green space workers (control group) who have worked for >2 years.	BTEX (Benzene, Toluene, Ethylbenzene, and Xylenes).	Respiratory disorders and irritation, systemic organ damage	BTEX exposure is associated with alterations in blood biomarkers and changes in respiratory parameters.
Assessment of Groundwater Quality, Heavy Metal Contamination, and Human Health Risks in Roundhill Municipal Landfill, Eastern Cape, South Africa (2025)(38)	South Africa	Method: Integrated analytical approach (laboratory analysis, WQI, IWQI, Health Risk Assessment, PCA) Sample: Groundwater were collected from five boreholes located near the landfill and one sample from the landfill leachate point.	Heavy metals, general parameters, microbial contaminants.	Cancer risk, non-carcinogenic risk, infectious disease risk.	Heavy metals and microbial contamination from the Roundhill Landfill leachate contaminate the surrounding groundwater, which, as a result, becomes unsuitable for drinking and poses a high risk of cancer and organ damage, especially to children.

Risk of Bias Assessment

The methodological quality of the 25 included studies was evaluated using the ROBINS-I framework. Risk of bias assessments are summarized in Figure 2 (Risk of Bias Summary Matrix) and Figure 3 (Risk of Bias Summary by Domain). Most studies showed a moderate risk of bias, a common finding in environmental and public health research. The main concerns were bias due to confounding (Domain 1) and bias in outcome measurement (Domain 6). These concerns highlight challenges in controlling extraneous variables in observational studies.

Study	D1: Confounding	D2: Classification of Interventions	D3: Selection of Participants	D4: Deviations from Intended Intervention	D5: Missing data	D6: Measurement of Outcome	D7: Selection of Reported Result
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Figure 2. Risk of Bias Summary Matrix (ROBINS-I, n = 25)

Risk judgement:

- Low Risk
- Moderate Risk
- Serious Risk
- Critical Risk

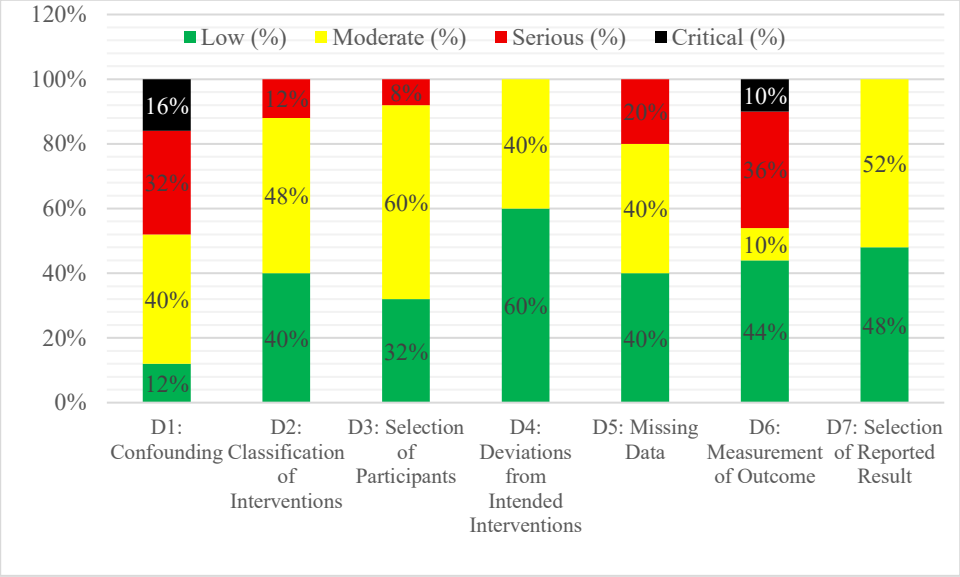

Figure 3. Risk of Bias Summary by Domain (ROBINS-I, n = 25)

The review examined how factors at landfills – air, water, soil, and leachate – affect the health of workers and local residents. The analysis was based on 25 studies with 30 adverse outcomes, found varied, complex, and often overlapping health problems. Health categories were as follows: Common Contaminant or Risk Focus appears in 45% of studies, Respiratory Disorders and Irritation in 25%, and Cancer Risk in 20%. Less frequent but still significant were Systemic Organ Damage (15%), Reproductive and Developmental Problems (10%), and Infectious Diseases (5%). Because many studies reported multiple risks in a single study, the sum of percentages (120%) reflects that individual studies often identified more than one health category, further illustrating the interconnected nature of health consequences associated with landfills. Table 4 visually summarizes associations between landfill pollutants and health outcomes. This overview lays the groundwork for a detailed analysis of exposure pathways.

Table 4. Comparative Heatmap: Association Between Landfill Pollutants and Health Outcomes Reported in The Studies

Health Outcome Category	Heavy Metals	VOCs and BTEX	Particulate Matter ($PM_{2.5}$ or PM_{10})	Leachate/Groundwater Contamination	Biological Agents/Pathogens
Respiratory Disorders and Irritation	■	■	■		
Cancer Risk	■	■		■	
Reproductive and Developmental Problems	■			■	
Systemic Organ Damage	■	■		■	
Infectious Diseases				■	■

Note: Cells marked green indicate an association reported and synthesized from the included studies.

DISCUSSION

Air Pollution and its Health Impact

Landfills mainly harm health through air pollution, primarily from fine particulate matter ($PM_{2.5}$), volatile organic compounds (VOCs), and biogas (28). Synthesized studies further identified VOCs and bioaerosols – airborne biological particles such as bacteria, fungi, or viruses – as the main pollutants (18) (22). These pollutants are responsible for reported cases of respiratory disorders and irritations, which account for 25% of findings.

Building on this, compiled epidemiological data indicate that short-term exposure to these contaminants raises rates of respiratory symptoms and eye or throat irritation in landfill workers and residents (14) (21) (28). Moreover, supporting studies show that particulate matter and bioaerosols trigger systemic inflammation (39), a response that exacerbates existing respiratory diseases and increases illness among susceptible populations.

Furthermore, studies show that BTEX compounds – Benzene, Toluene, Ethylbenzene, and Xylene, a group of volatile organic chemicals commonly emitted from landfills – are linked to measurable respiratory health changes and increased carcinogenic risks (18) (37). These volatile organic chemicals are commonly emitted from landfills. This highlights the long-term cancer risk associated with air pollution. Specifically, BTEX exposure alters blood biomarkers and respiratory parameters (37). These are measurable indicators in the blood and measures of lung function, which indicate potential systemic organ damage.

The relevance of these findings is amplified when considering that landfill air pollution, which includes styrene and other malodorous compounds, has high irritant potency (18). There is a clear mechanistic link between VOCs or $PM_{2.5}$ and systemic inflammation or alterations in biomarkers. This highlights the importance of stringent emission control policies.

Leachate Pollution and its Health Impact

Leachate, a toxic liquid produced during landfill waste decomposition, poses a significant threat to the environment and public health. Studies show that leachate contamination often exceeds World Health Organization (WHO) limits, increasing risks to human health (24) (25) (29). Landfill contamination also renders groundwater unsafe to drink, posing seasonal health hazards to local residents (36).

Furthermore, the systemic health risks documented in this review are strongly associated with exposure to Heavy Metals (PTEs) found in both leachate and contaminated soil. High concentrations of these elements were repeatedly confirmed to be associated with potential poisoning and subsequent organ function disorders (27) (33) (40) (41). Building on this association, studies specifically highlight that heavy metals (such as As, Cd, and Pb) pose a significant health risk, necessitating monitoring to prevent organ dysfunction and chronic diseases (33). Additionally, chronic exposure to these metals (e.g., As, Cd, Pb) is demonstrated to be a significant source of carcinogenic risk (26) (30) (40). This high environmental persistence aligns with external literature emphasizing that heavy metals induce oxidative stress, which is subsequently associated with kidney damage and various chronic diseases (40).

In addition to heavy metals, this contamination pathway also serves as an entry point for emerging contaminants. Our evidence suggests that leachate is a significant source of microplastic contaminants (32) and facilitates the migration of PFASs (19), which pose particular health risks through the consumption of contaminated vegetables. Moreover, contamination by heavy metals and microbial agents from landfill leachate compromises the surrounding groundwater (38), resulting in unsuitability for drinking and posing a high risk of cancer and organ damage, especially to children.

Finally, studies further evidence the chronic and reproductive implications of these toxic elements by linking exposure to growth and developmental issues in children (23) (31). Taken together, this evidence suggests the need for immediate reform in leachate containment and treatment strategies.

Soil Pollution and its Health Impact

The contamination of the soil matrix at the landfill is mainly caused by leachate seepage and the direct disposal of diverse refuse, including industrial and electronic waste. Evidence synthesized in this review indicates that this process leads to the accumulation of potentially toxic elements (PTEs) and other contaminants in soil (29). These contamination are consequently taken up by crops grown in this soil, resulting in the transfer of trace elements

into vegetables and food crops consumed by humans, thereby causing human health risks through the food chain (34) (35).

For vulnerable groups, the primary health impacts from contaminated soil are delivered through dermal contact and ingestion. Evidence highlights that the carcinogenic risk from elements like Arsenic (As) and Cadmium (Cd) is elevated by soil exposure, frequently comprising the largest portion of the total carcinogenic risk (26) (30). Additionally, elevated PTE concentrations in soil are associated with developmental outcomes, including growth disorders in children (23).

Furthermore, contaminated soil acts as a persistent reservoir for emerging pollutants. This review's findings show that PFASs accumulate near landfills, facilitating human exposure through the consumption of contaminated vegetables (19). This significant pathway underscores the need for rigorous regulatory reform regarding waste segregation, particularly for e-waste, to safeguard local food security and childhood development (41) (42).

Other Health Issues

Heavy metal exposure is a serious risk to reproductive health, and people who are more at risk are. Our analysis highlights a strong link between heavy metals and developmental issues, proving that exposure to them can cause childhood growth issues (23) (31) and leads to poor health outcomes in people who are more likely to be affected. This is also shown by findings of developmental issues connected to heavy metal pollution in the local area and food supply (35).

Infectious diseases also pose ongoing threats to the most vulnerable, especially waste pickers. These threats come from direct contact with unsafe waste. Beyond concerns about toxicity, the evidence presented here demonstrates that social factors are significant. There are high rates of Syphilis and other STIs in this group, suggesting their risk is increased by complicated work and living conditions (16). Additionally, there is a higher risk of disease from heavy metals and pathogens in landfill liquid that seeps into groundwater (38).

Extending this examination of landfill-associated risks, analysis of external literature affirms the persistent threat posed by biological pollutants, including viruses, bacteria, and other pathogens, at landfills. These risks are compounded by poor management, as numerous studies document the enhanced potential for the transmission of infectious diseases (43), underscoring a critical public health crisis stemming from inadequate waste disposal practices.

Limitations and Cautions

This systematic review has several limitations that should be considered when interpreting the findings. The 25 included articles use different study designs (cross-sectional, cohort, HRA), locations, and pollutant measurements. These differences prevent drawing standardized, numerical conclusions about specific disease risks. Thus, the associations in this review show correlation, not causation, and do not establish direct causal links. The review identifies potential health effects instead of quantifying risk. Methodological limitations remain, as most included studies were observational. Most studies showed a moderate risk of bias, especially for confounding and outcome measurement (as rated by the ROBINS-I framework). This further limits the establishment of definitive cause-and-effect relationship.

Recommendations for Future Research

Future research should prioritize strengthening causal validity by employing longitudinal studies, rather than relying on common observational methods. Longitudinal designs can help show whether chronic conditions, such as cancer and neurological disorders, result directly from long-term, low-level exposure to landfill contaminants. Given the identified challenges, researchers must employ more rigorous methods to control for known confounders—factors that influence both exposure and outcome. Research must also aim to measure the dose-response relationship, which refers to the effect of varying exposure levels on disease risk. Specific research should track chronic exposure to key pollutants, such as BTEX (benzene, toluene, ethylbenzene, and xylene) and heavy metals, alongside the incidence of chronic diseases. These steps will produce stronger evidence to guide public health policy.

CONCLUSION

The rapid increase in municipal solid waste (MSW) has made landfills a significant source of pollution. This issue is especially acute in developing countries, where poor management enables the escape of toxic gases and leachate into the environment. Landfills emit heavy metals, volatile organic compounds (VOCs), and fine particulate matter ($PM_{2.5}$ and PM_{10}). These pollutants are associated with severe health issues for landfill workers and local residents. Key health outcomes include respiratory and cardiovascular disease, elevated cancer risk, and increased reproductive, neurological, and gastrointestinal disorders. The data underscore the need for comprehensive environmental policy reform and enhanced waste management. Tighter leachate containment and treatment are essential to prevent groundwater and soil contamination by heavy metals and microbes. Additionally, strengthening waste management systems and minimizing open burning are crucial to reducing acute respiratory threats and long-term cancer risks associated with pollutants. Effective management and reduce open burning are critical to lowering emissions and protecting public health.

AUTHOR'S CONTRIBUTION STATEMENT

Under the guidance of an academic supervisor, the author is solely responsible for each stage of this research. The author's contributions cover several key areas: designing research frameworks and methodologies (NZ, MRS, and SLS); independently conducting data collection and analysis (NZ, MRS, and SLS); compiling and revising all these based on the supervisor's input (NZ, MRS, SLS, NJZ, and TJ); and creating all visual materials and preparing the final presentation (NZ and MRS).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors utilized Trinka AI to refine the grammar and language of this manuscript. All AI-suggested changes were subsequently reviewed and edited by the authors, who retain full responsibility for the final context of publication.

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