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Research article

Respiratory Health Risks from H_2S Exposure at Indonesian Landfills: A Review of Key Individual and Exposure Related Risk Factors

Lina Nur Qolifah*, Suhartono, Nurjazuli

Universitas Diponegoro, Semarang, Indonesia
*Corresponden Author: Lina Nur Qolifah (qolifahlina@gmail.com)

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ABSTRACT

Background: Landfills emit various hazardous gases through the decomposition of waste, one of which is hydrogen sulfide (H_2S), a gas that is particularly harmful to the human respiratory system. Individuals living or working near landfills are at higher risk of developing respiratory disorders due to prolonged exposure to polluted air. This review aimed to identify the risk factors of H_2S exposure from landfills that contribute to respiratory problems.
Methods: A literature review methodology was used by collecting studies from Google Scholar. Sixteen articles were selected based on predefined inclusion criteria after identification and screening.
Results: The results of the review indicate that respiratory disorders are influenced by various factors, such as H2S concentration, H2S intake, H2S RQ value, exposure patterns (duration, frequency, and intensity), and individual characteristics (age, gender, nutritional status, use of personal protective equipment).
Conclusion: The concentration of H2S is relatively low compared to other gases produced from TPA, and individual risk factors have an impact on lung function disorders.

I. Introduction

Air pollution is one of the most significant environmental risk factors affecting public health. Each year, poor air quality contributes to approximately 7 million premature deaths worldwide. One of the contributing sources of air pollution is the increasing volume of waste, which continues to rise annually. According to the World Bank, global waste production reaches approximately 2.01 billion tons per year, with 33% of it being unmanaged, leading to environmental contamination. Global waste production is projected to increase by 70% by 2050, reaching an estimated 3.40 billion tons per year (Kaza et al., 2018).

Waste composition is a critical aspect of environmental science and public health, with a significant portion of waste being composed of organic materials. This organic waste, when not managed properly, leads to serious environmental issues, particularly when it is subjected to poor waste management practices such as open dumping. Open dumping is a method where waste is indiscriminately discarded in open areas without any form of treatment or processing. This approach not only contributes to the accumulation of waste but also facilitates the anaerobic decomposition of organic materials. During this process, a range of hazardous gases is produced, including methane (CH_4), hydrogen sulfide (H_2S), carbon dioxide (CO_2), nitrogen (N_2), hydrogen (H_2), oxygen (O_2), ammonia (NH_3), and others. Each of these gases has distinct properties and implications for both environmental quality and human health.

The production of methane, for example, is particularly concerning due to its potency as a greenhouse gas, being approximately 25 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year period (IPCC, 2014). In contrast, hydrogen sulfide (H_2S), a gas often associated with

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the characteristic smell of rotten eggs, poses immediate health risks, particularly to individuals living in proximity to landfills. This group, often comprised of low-income communities, is subjected to continuous exposure to air contaminated with these hazardous emissions from waste processing. The implications of such exposure are dire, as numerous studies have indicated a correlation between proximity to landfill sites and increased incidence of respiratory disorders, cardiovascular diseases, and even neurological conditions (Akbar, 2016; Sekar Harjanti et al., 2016; Annisa et al., 2017).

Hydrogen sulfide (H_2S) is particularly noteworthy due to its unique characteristics and the severe health risks it poses. It is a colourless gas that is highly flammable and classified as an asphyxiant, meaning it can displace oxygen in the air, leading to suffocation. The threshold for detection of H_2S is alarmingly low, with individuals able to detect its presence at concentrations as low as 0.0005 parts per million (ppm). At lower concentrations, exposure can cause irritation of the eyes, nose, and throat, and for those with pre-existing conditions such as asthma, it can exacerbate respiratory distress. The severity of H_2S exposure escalates with concentration; at higher levels, it can lead to unconsciousness and even death (Mataloni et al., 2016; ATSDR, 2016).

The inevitability of H_2S presence in environments where waste is improperly managed underscores the urgent need for effective waste management strategies. The continuous generation of waste through human activities necessitates a shift towards more sustainable practices. Comprehensive and integrated waste management strategies that encompass the entire waste lifecycle—from generation and collection to treatment and disposal—are essential. Such strategies not only mitigate the emission of hazardous gases like H_2S but also improve overall public health outcomes. For instance, implementing composting initiatives can significantly reduce the volume of organic waste sent to landfills, thereby decreasing methane and H_2S emissions. Moreover, educating communities about proper waste segregation and recycling can empower them to take an active role in waste management, ultimately leading to healthier living environments.

In light of these considerations, the purpose of this study is to assess the extent to which H_2S emissions from landfill sites contribute to respiratory disorders. By analysing data from various landfill sites and correlating it with health outcomes in surrounding communities, this research aims to provide robust scientific evidence that can inform health-centred recommendations and intervention programmes. The findings from such a study could be instrumental in shaping policy decisions and public health initiatives aimed at reducing the health risks associated with landfill proximity.

The composition of waste, particularly the dominance of organic materials, poses significant challenges when coupled with poor waste management practices like open dumping. The resultant emissions of hazardous gases, particularly hydrogen sulfide, have profound implications for both environmental quality and public health. As communities continue to grapple with the consequences of inadequate waste management, it becomes increasingly clear that implementing comprehensive strategies is not just beneficial but necessary. By prioritising integrated waste management and community education, we can mitigate the adverse health effects associated with landfill emissions and pave the way for healthier, more sustainable living environments. The need for urgent action in this area cannot be overstated, as the health of vulnerable populations hangs in the balance.

II. METHODS

This study employed a literature review methodology. Data were collected from various research studies conducted in Indonesia that examined the effects of hydrogen sulfide (H_2S) exposure from landfills and other associated risk factors on respiratory health. Article searches were carried out using the Google Scholar database. he keywords used in the search were derived using the PEOS framework, which includes: 1) Population: individuals living in proximity to landfill sites 2) Exposure: exposure to H_2S emissions from landfills and other contributing risk factors 3) Outcome: respiratory disorders 4) Study design: observational analytic studies. Based on this framework, the research question formulated was "Is there an association between H_2S exposure and individual risk factors with respiratory health problems among communities residing near landfill sites?" The search terms used included: "H_2S exposure AND health disorders AND communities living near landfill sites."

The inclusion criteria for article selection were as follows: full-text articles published between 2014 and 2024, studies specifically addressing H_2S exposure from landfill sources, and articles that discussed health impacts. Articles were excluded if they lacked clear sources, or if they were systematic reviews, meta-analyses, or literature reviews. The articles collected were screened for relevance based on their

titles, abstracts, and full texts to ensure alignment with the research topic. The selection process is illustrated in the PRISMA flow diagram below.

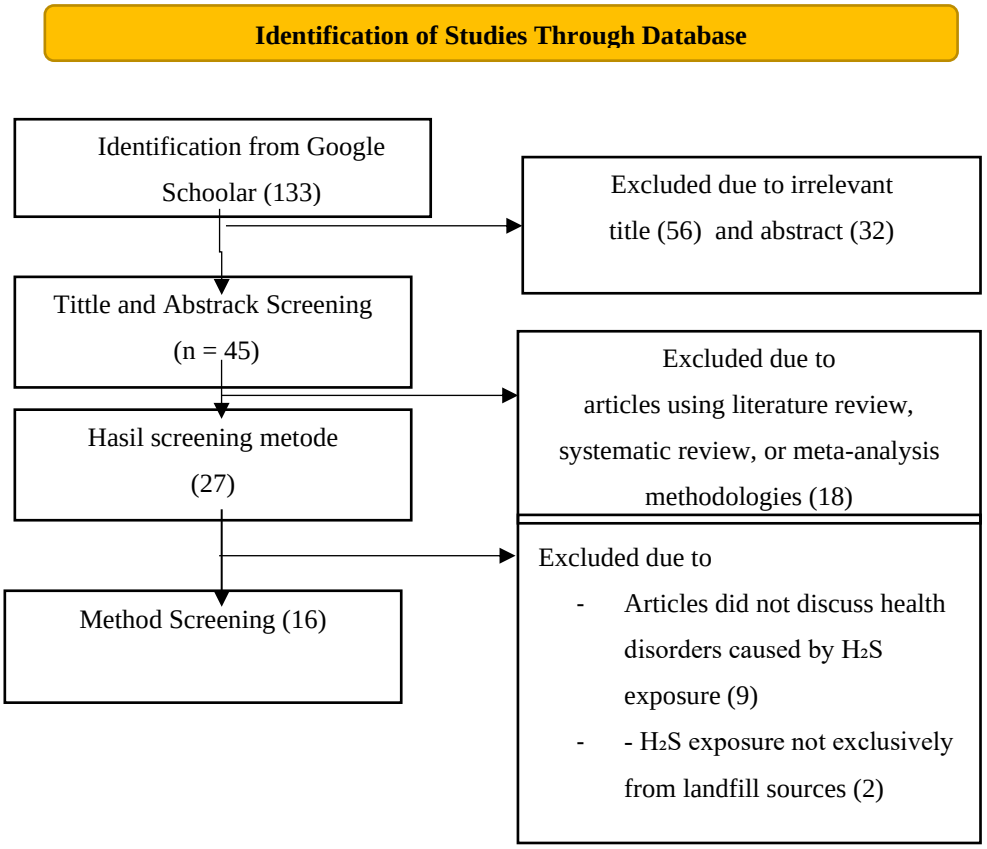

Figure 1. Flowchart of Database Selection

III. RESULTS

A total of 16 articles met the predefined inclusion and exclusion criteria. These studies collectively explored the relationship between hydrogen sulfide (H_2S) exposure from landfills in Indonesia and the occurrence of respiratory disorders. The key findings and study characteristics have been summarized in the following table.

Table 1. Data Extraction

No	Authors and Year	Title	Method and Study Subjects	Findings
1.	(Zulkarnain *et al.*, 2018)	The Risk Quotient of Sulfide Hydrogen toward Lung Vital Capacity of People Living Around Landfill Area	Cross-sectional, 78 individuals living near the landfill	H_2S concentration: 0.300–0.675 µg/Nm³. Poor nutritional status (p value = 0.022) and RQ above the median (p value = 0.016) were associated with impaired lung vital capacity. No correlation was found with age, gender, smoking, or distance from residence.
2.	(Hartini and Kumalasari, 2015)	Faktor-Faktor Risiko Paparan Amonia dan Hidrogen Sulfida Terhadap Keluhan Gangguan Kesehatan pada Pemulung di TPA Jatibarang Kota Semarang	Cross-sectional, 30 female scavangers	H_2S concentration in zones I and II: 0.001 ppm. Respiratory complaints were most common. Working duration and age were significantly associated with health complaints (p-value= 0.026). No correlation with rest habits or distance from residence.
3.	(Simbolon *et al.*, 2019)	Pengaruh Pajanan Gas Hidrogen Sulfida (H_2S) terhadap Keluhan Saluran Pernapasan pada Pemulung di Tempat Pembuangan Akhir (TPA) Ganet Kota Tanjung Pinang Tahun 2018	Cross-sectional, 27 scavangers	H_2S levels at sorting and loading points: 0.06 and 0.07 ppm (above standard); rest area: 0.01 ppm (below standard). Gender (p-value= 0.019) and intake (p-value = 0.039) influenced respiratory complaints. No correlation with age, body weight, exposure time/duration.
4.	(Hidayanti *et al.*, 2024)	Analisis Risiko Paparan Gas H2S terhadap Pemulung di TPA Air Dingin Kota Padang	Cross-sectional EHRA approach	H_2S concentrations at unloading, rest, and sorting points were below the standard. Real-time RQ: 0.93 (no health risk); lifetime RQ: 1.98 (indicating health risk).
5.	(Ayathollah *et al.*, 2021)	Analisis Kadar Hidrogen Sulfida dan Keluhan Pernapasan pada Pemulung di TPA Puuwatu Kota Kendari	Cross-sectional EHRA approach, 50 scavangers	H_2S concentrations at three points: 0.001, 0.0011, 0.009 ppm (below standard). Real-time RQ: 1.5355 indicating health risk.

No	Authors and Year	Title	Method and Study Subjects	Findings
6.	(Fuadiyah Haq *et al.*, 2021)	Hubungan Konsentrasi Gas Amonia (NH_3) dan Hidrogen Sulfida (H_2S) dengan Gangguan Pernafasan (Studi pada masyarakat sekitar TPA Pakusari Kabupaten Jember)	Cross-sectional, 84 residents living <500 m from landfill	H_2S concentrations: 0.9, 1.3, 1.1 µg/Nm³ (below standard). Respiratory complaints were significantly associated with disease history (p = 0.036); no association with gender, age, smoking.
7.	(Ardiyanti Rufaedah *et al.*, 2019)	Paparan Hidrogen Sulfida terhadap Risiko Kesehatan Masyarakat di Sekitar TPA Cibereum Kota Banjar	Cross-sectional, 86 residents living <250 m from landfill	H_2S levels: 0.0034 and 0.0046 ppm (below standard). RQ real-time: 0.42; 10 years: 0.94 (no risk); 20 years: 1.47 and lifetime: 1.99 (indicating health risk).
8.	(Rifa *et al.*, 2016)	Analisis Risiko Kesehatan Lingkungan Pajanan Gas Hidrogen Sulfida (H_2S) pada Pemulung Akibat Timbulan Sampah di TPA Jatibarang Kota Semarang	Cross-sectional EHRA approach, 65 scavangers	H_2S levels at zone 1, zone 2, rest area: 0.005; 0.005; 0.006 ppm (below standard). Real-time RQ: 0.67 (no risk); RQ 5–20 years and lifetime >1 (health risk).
9.	(Fahmi *et al.*, 2023)	Paparan Gas Hiderogen Sulfida dan Aktivitas Pemulung terhadap Risiko Kesehatan Lingkungan di TPA Tahun 2022	Cross-sectional EHRA approach, 33 scavangers	H_2S concentrations: 0.0311, 0.331, 0.0260 µg/Nm³. Real-time RQ: 2.72; lifetime RQ: 5.46 (health risk).
10.	(Hidayatullah *et al.*, (n.d.))	Risiko Paparan Gas H_2S dan NH_3 pada Masyarakat di TPA Piyungan	Cross-sectional EHRA approach, 59 residents living <600 m from landfill	H_2S concentration: 0.00805 ppm (below standard). RQ: 1.2163 (health risk).
11.	(Faisya *et al.*, 2019)	Analisis Risiko Kesehatan Lingkungan Paparan Hidrogen Sulfida (H_2S) dan Amonia (NH_3) pada Masyarakat di Wilayah TPA Sukawinatan Kota Palembang Tahun 2018	Cross-sectional EHRA approach , 50 residents living 300–600 m from landfill	Cross-sectional (EHRM), 50 residents living 300–600 m from landfill
12.	(Wahyu Aqil Alwan Satria Wibawa and Muhammad Farid Dimjati	Environmental Health Risk Analysis of Hydrogen Sulfide (H_2S) Exposure to Jabon Sidoarjo Landfill Scavangers	Cross-sectional EHRA approach, 46 scavangers	H_2S at Point 1: 0.00242 ppm (above standard); Point 2: 0.00081 ppm (below). RQ real-time, 10 years, lifetime: 0.13; 0.25; 0.37 (no risk).

No	Authors and Year	Title	Method and Study Subjects	Findings
	Lusno, 2023)			
13.	(Firdaus, 2018)	Analisis Risiko Pajanan NH_3 dan H_2S terhadap Gangguan Pernapasan pada Penduduk Sekitar Tempat Pembuangan Akhir Sampah Bukit Pinang Samarinda	Cross-sectional, 34 residents	H_2S levels in settlement 1 (morning, afternoon, evening): 0.0010; 0.0030; 0.0001 ppm; settlement 2: 0.0020; 0.0020; 0.0150 ppm. Significant association between H_2S concentration, exposure duration, and RQ with respiratory issues.
14.	(Faidatul Utami *et al.*, 2023)	Pengaruh Lama Paparan Gas Hidrogen Sulfida (H_2S), Pengetahuan dan Penggunaan Alat Pelindung Diri (APD), Terhadap Gangguan Pernapasan pada Pemulung di TPA Supit Urang Kota Malang	Cross-sectional, 60 scavangers	Significant relationship between exposure duration (p-value= 0.035), PPE use behavior (p-value= 0.001) and respiratory complaints.
15.	(Akbar, 2016)	Pengaruh Paparan CH_4 dan H_2S terdapat Keluhan Gangguan Pernapasan Pemulung di TPA Mrican Kabupaten Ponorogo	Cross sectional, 32 scavangers	H_2S levels: active zone: 0.024 ppm; passive: 0.022 ppm (above standard). Rest and control zones: 0.019 and 0.013 ppm (below standard). Significant association with gender (p-value = 0.004), work duration (p-value = 0.024). No association with age, exposure time, nutrition, smoking, or PPE use.
16.	(Dwicahyo *et al.*, 2020)	Risk Analysis of H_2S Gas Exposure at Benowo Landfill Surabaya	Cross sectional, 37 residents near landfill	H_2S concentration: 0.001 µg/Nm³; RQ: 2.95 (indicating health risk).

IV. DISCUSSION

Most studies found that H_2S concentrations at landfill sites were relatively low and generally below the established threshold of 0.02 ppm. Only a few studies, such as those conducted by Simbolon & Hasan (2019), Firdaus (2018), and Andhika & Tofan (2016) reported H_2S levels exceeding the regulatory limit. The lower H_2S concentrations in most sites are attributed to the dominance of ammonia (NH_3) and carbon monoxide (CO) gases in landfill emissions, which account for 90–98% of the total composition. The remaining 2–10% comprises nitrogen, sulfides, oxygen, hydrogen, and other trace gases. The variation in gas concentration is influenced by several factors, including waste management models, technology employed, oxygen levels, humidity, temperature, gas pumping pipeline systems, and thermal barrier design in landfill structures (Bavutti *et al.*, 2014; Koliopoulos, 2019).

Although low in concentration, H_2S can still pose a significant health risk. For example, Firdaus (2018) found a statistically significant association between H_2S concentration and respiratory health issues. H_2S is considered one of the most toxic gases, second only to hydrogen cyanide (HCN), and is approximately five times more toxic than carbon monoxide (CO) (Registry, 2016; Firdaus, 2018). International studies, such as those from Northern China and St. Petersburg, Russia, have identified H_2S as a critical pollutant

that poses greater health risks compared to other landfill gases, despite its low concentration (Yu *et al.*, 2018; Mironenko *et al.*, 2020).

In China, H_2S levels were found to be less than 10 µg/m³, lower than other pollutants yet had the most pronounced impact on lung function, including reductions in FEV1%, MMF, MVV, FEF25, FEF50, and FEF75 indices. In addition, H_2S exposure was associated with reduced lysozyme levels, indicating suppressed immune function in children attending schools near landfill sites (Yu *et al.*, 2018). In Russia, despite H_2S ranking only fourth out of 30 pollutants in concentration, it had the highest risk quotient (RQ), suggesting its critical impact on public health (Mironenko *et al.*, 2020).

Exposure patterns, including work duration, exposure time, and frequency were found to be strongly linked to respiratory disorders in high-risk populations. Waste pickers, for instance, are exposed to pollutants for extended periods as they work without fixed hours and often wait near waste unloading zones. Likewise, residents living near landfills may be exposed 24 hours a day if they conduct most activities around their homes. Longer exposure durations significantly increase contaminant intake via inhalation, which elevates the risk of adverse health effects (Sunarsih *et al.*, 2019).

Age was another significant factor. In the study conducted at Jatibarang Landfill, a positive correlation was found between increasing age and respiratory complaints (Hartini and Kumalasari, 2015). Pulmonary function naturally declines with age, beginning around 20–25 years old, with a 40% reduction observed by age 80 (Hollams *et al.*, 2014; Roman *et al.*, 2016). This decline limits ventilation capacity, restricting physical activity and increasing susceptibility to respiratory illnesses, particularly in polluted environments (Fujianti *et al.*, 2015).

Sex also influenced vulnerability. Studies at Bukit Pinang and Mrican landfills found a significant association between male sex and respiratory issues (Akbar, 2016; Firdaus, 2018). Males have a 20–25% larger lung capacity than females and therefore inhale more air and pollutants per breath. The greater oxygen demand and larger alveolar surface area in males further increase pollutant intake (Chio *et al.*, 2019).

Nutritional status also emerged as a significant modifier. Obesity, on the other hand, restricts airway function and contributes to decreased FEV1 and FVC levels. Individuals with poor nutritional status were more susceptible to respiratory impairment. Malnutrition compromises immune function and weakens respiratory muscles, while good nutritional status supports better lung capacity and immune defense (Zulkarnain *et al.*, 2018).

The use of personal protective equipment (PPE) was found to reduce, but not eliminate risk. Many waste pickers rely on cloth masks or improvised coverings, which offer little protection against fine pollutants. In contrast, standardized medical-grade masks are more effective at blocking inhalation of airborne contaminants (Sholihati and Astorina Yunita, 2017), Discrepancies in study findings regarding PPE efficacy may stem from variations in mask quality and compliance.

Importantly, most studies reported RQ values greater than 1, both in real-time and lifetime exposure assessments, indicating significant long-term health risks. The RQ is directly proportional to intake, which is influenced by gas concentration, exposure duration and frequency, and individual body weight (Direktorat Jendral PP dan PL, 2012) The most frequently reported health outcomes were respiratory symptoms such as coughing, wheezing, shortness of breath, and reduced pulmonary function based on spirometry. Although H_2S concentrations were generally low, prolonged exposure among at-risk groupsparticularly informal workers like waste pickers and nearby residents still presented measurable health risks. The RQ is a predictive measure, meaning actual health outcomes may vary depending on lifestyle factors, such as diet, smoking habits, exercise, and overall immune resilience, all of which play a key role in mitigating or exacerbating pollutant effects.

V. CONCLUSION

The findings from this literature review indicate that the concentration of hydrogen sulfide (H_2S) around landfill sites is generally low when compared to other gases emitted from waste decomposition. However, even at low concentrations, H_2S can still cause adverse respiratory effects in humans when exposure occurs over a prolonged period. The most frequently reported health outcomes include respiratory symptoms such as coughing, wheezing, shortness of breath, and decreased lung function, as measured through spirometric evaluation.

Several factors contribute to the risk of respiratory disorders due to H_2S exposure, including H_2S concentration, H_2S intake levels, Risk Quotient (RQ) values, exposure patterns (duration, frequency, and intensity), ndividual characteristics (age, sex, nutritional status, and use of personal protective

equipment). These conditions may be further exacerbated by higher concentrations of H_2S, increased exposure duration and frequency, and unhealthy lifestyle habitssuch as poor nutrition, smoking, and lack of physical activity.

This review specifically focuses on H_2S exposure and respiratory effects among high-risk populations, particularly waste pickers and residents living near landfill sites. However, the potential health risks may be even greater considering that landfills release multiple hazardous gases simultaneously. Individuals in close proximity are thus exposed to a complex mixture of pollutants for extended periods.

Given these findings, it is crucial to implement comprehensive risk management strategies to mitigate the health hazards associated with landfill emissions. This includes upstream interventions such as reducing organic waste generation and promoting waste-to-resource practices (e.g., composting or value-added products). Such measures can play a pivotal role in improving community health outcomes and protecting vulnerable populations.

VI. CONFLICTS OF INTEREST

The authors declare that this study is free from any conflicts of interest.

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