Doi: 10.61435/jbes.2025.19964

Journal of Bioresources and Environmental Sciences, 4(3), 156-171

Review Article

Environmental impact of refuse-derived fuel: A Qualitative review of public health risks, energy efficiency, and emission oversight in Indonesia

I Wayan Koko Suryawan*

Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jalan Sinabung II, Terusan Simprug, Jakarta 12220, Indonesia

*Correspondence: i.suryawan@universitaspertamina.ac.id

Received: March 23rd, 2025

Accepted: August 19th, 2025

Published: December 8th, 2025

Copyright: © 2025 by the authors. This work is under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Abstract. Refuse-Derived Fuel (RDF) has been increasingly promoted in Indonesia as an alternative waste-to-energy solution, particularly for industrial applications such as cement production. This study presents a qualitative narrative review that explores the multidimensional environmental impacts of RDF implementation, with a specific focus on the Indonesian context. Four key themes were examined: air pollution, public health risks, low energy efficiency, and the lack of emission monitoring and environmental oversight. Findings indicate that RDF combustion contributes to hazardous emissions, including dioxins, heavy metals, and fine particulates, especially where waste segregation is inadequate. Public health issues such as respiratory infections and long-term toxic exposure are exacerbated by weak regulatory systems and the absence of Continuous Emission Monitoring Systems (CEMS). Additionally, Indonesia's high organic waste content undermines RDF's energy efficiency and sustainability. The review concludes that RDF, in its current form, poses significant environmental and governance challenges and must be reevaluated through the lens of public health protection, regulatory reform, and circular economy principles.

Keywords: Refuse-Derived Fuel (RDF); Environmental Impact; Waste-to-Energy; Public Health; Air Pollution; Emission Monitoring

1. Introduction

As urbanization and population growth accelerate in many developing countries, solid waste management has become a critical environmental and public health challenge (Awino & Apitz, 2024; Conlon, 2020). Indonesia, with a population exceeding 270 million and a rapidly expanding urban footprint, faces mounting pressure to manage its growing volumes of municipal solid waste (MSW) (Fayshal, 2024). The country generates over 175,000 tons of waste per day, the majority of which is organic and wet in nature, leading to significant environmental burdens when inadequately treated or disposed of in landfills (Brotosusilo et al., 2020). The search for sustainable and scalable waste management solutions has led to increased interest in waste-to-energy (WtE) technologies, among which Refuse-Derived Fuel (RDF) has emerged as a prominent strategy (AlQattan et al., 2018; Shehata et al., 2022). RDF refers to the processed fraction of municipal solid waste that has been dried, sorted, and converted into a combustible material, often used as an alternative fuel source in energy-intensive industries such as cement manufacturing (Reza et al., 2013). Advocates of RDF argue that it offers a dual benefit: reducing the volume of waste sent to landfills and supplementing fossil fuel consumption in the industrial sector (Suryawan & Lee, 2024). In Indonesia, national and local governments have supported RDF development as part of broader efforts to improve waste infrastructure and achieve renewable energy targets outlined in the National Energy Policy (KEN) and related climate strategies (Hermansyah et al., 2024). Despite these ambitions, the application of RDF technology in Indonesia has generated significant debate. Several RDF pilot projects, including those in Cilacap, and Bekasi, have received attention for their scale and innovation (Ayuvitari & Wijayanti, 2022; Prariesta et al., 2023). However, stakeholders, including environmental NGOs, public health experts, and community groups have raised concerns about the environmental safety, energy efficiency, and social equity of

RDF systems (Galavote et al., 2024; Randhawa et al., 2020; Tripathy et al., 2025). These concerns are rooted in the contextual realities of Indonesia's waste composition, institutional capacity, and regulatory environment.

While this study focuses on the Indonesian context, the findings have broader relevance to other developing countries with similar waste compositions, governance structures, and levels of RDF technology adoption. For instance, Thailand has demonstrated that the success of RDF production depends on effective local administrative organization and integration with semi-aerobic landfill systems (Payomthip & Wangyao, 2024). In India, RDF utilization in industrial applications, particularly in cement production, highlights both opportunities and operational challenges under varying regulatory and infrastructural capacities (U. Sharma et al., 2025). Comparative experiences from Poland during the COVID-19 pandemic also show that technology entrepreneurship in waste-to-energy enterprises can enhance operational resilience, though it requires strong institutional support (Kordel & Wolniak, 2021). In Indonesia itself, community empowerment models have been introduced to strengthen RDF waste management programs at the local level (Afnan et al., 2025). Earlier studies comparing RDF preparation in Japan and Germany further underscore that differences in microbial consortia and feedstock quality can significantly influence RDF performance and environmental outcomes (Sakka et al., 2006). These examples suggest that the technical, environmental, and governance insights from Indonesia's RDF experience can inform policy and operational strategies in other nations facing similar socio-environmental challenges.

One of the foremost challenges of RDF implementation in Indonesia is the high moisture content of municipal waste, which typically ranges between 60% and 70% (Prihartanto et al., 2023; Qonitan et al., 2021). This is largely due to the predominance of organic materials, such as food waste and garden residues, in the waste stream. RDF, by contrast, is a technology better suited to dry, combustible materials, and thus requires energy-intensive pre-treatment processes to achieve suitable calorific values. In many RDF facilities, fossil fuels are ironically used to dry waste, undermining RDF's status as a sustainable energy source and potentially increasing carbon emissions (Dubsok et al., 2024; Sutthasil et al., 2023). Furthermore, the lack of effective waste segregation at source remains a structural issue in Indonesia's waste management system (Kurniawan et al., 2023; Singer et al., 2019). When plastics, electronic waste, and hazardous materials are mixed with general waste and later incinerated as RDF, the result is the release of harmful pollutants, including dioxins, furans, and heavy metals (U. Sharma et al., 2025). These pollutants are known to have severe health effects and long-term ecological consequences. Without proper sorting and pre-treatment, RDF combustion risks generating more environmental harm than benefit. Another critical issue is the absence of real-time emission monitoring in many RDF facilities. Continuous Emission Monitoring Systems (CEMS), standard in WtE facilities in high-income countries (Baker et al., 2012), are largely missing in Indonesia's RDF infrastructure. This regulatory shortfall leads to gaps in pollution detection and enforcement, making it difficult for authorities to assess environmental compliance and for communities to hold operators accountable. In many reported cases, residents living near RDF plants have complained of foul odors, increased incidence of respiratory diseases, and a lack of transparency in project implementation (Mubarok, 2025). These public health concerns are compounded by limited community involvement in RDF project planning and oversight. Vulnerable and low-income populations often live near waste processing facilities but are excluded from environmental decision-making processes (Dhillon, 2017; Gutberlet & and Uddin, 2017). This exclusion exacerbates environmental injustice and erodes public trust in waste-to-energy solutions.

From a regulatory perspective, Indonesia still lacks a unified, enforceable standard for RDF emissions, waste feedstock composition, and energy recovery benchmarks (Cook et al., 2022). While Presidential Regulation No. 35/2018 includes RDF within the list of nationally strategic WtE projects, detailed environmental performance indicators are either unclear or inconsistently applied across jurisdictions. Moreover, Environmental Impact Assessments (EIAs) are frequently underutilized or conducted without meaningful public participation, further limiting the transparency and accountability of RDF projects. These issues point to a clear research and policy gap in the evaluation of RDF technologies in Indonesia. This study aims to address this gap by conducting a qualitative narrative review of RDF implementation in Indonesia, focusing on four core themes: air pollution, public health risks, energy efficiency limitations, and emission monitoring failures.

2. Method

2.1. Research Design

This study adopts a qualitative research design to explore the environmental and public health implications of Refuse-Derived Fuel (RDF) implementation in Indonesia. The decision to use a qualitative approach is grounded in the complexity and context-specific nature of RDF as a waste-to-energy strategy. Unlike quantitative methods that emphasize statistical generalization, qualitative inquiry is particularly suited to examining socio-environmental phenomena where institutional, behavioral, and ecological dimensions are deeply interwoven. The aim of this research is not to produce numerical measurements of RDF impacts but rather to understand the underlying mechanisms, policy challenges, and experiential dimensions of RDF as interpreted through existing knowledge, expert assessments, and

@The Author(s). 2025. Published by CBIORE

empirical documentation. To implement this qualitative approach, the study employed a narrative mini-review methodology. A narrative review allows for the purposeful selection and synthesis of diverse information sources, enabling researchers to identify trends, tensions, and gaps in knowledge across multiple domains.

The core strength of the narrative mini review lies in its ability to integrate academic literature with contextual grey literature, offering a more comprehensive view of RDF's environmental performance and its social consequences. This is essential in countries like Indonesia, where formal academic studies on RDF are limited but where practical experiences, policy documents, and NGO reports provide valuable empirical insights. Moreover, this method supports an interdisciplinary analysis that includes environmental engineering, public health, environmental governance, and community advocacy perspectives.

2.2. Research Process

Figure 1 shows the methodological framework of this study, which uses a qualitative narrative mini-review. The approach ensures rigor while remaining flexible to address the complex environmental and public health issues related to Refuse-Derived Fuel (RDF) in Indonesia. The process began by defining the research objectives and scope, aimed at exploring the socio-environmental impacts of RDF through a context-sensitive lens. Guiding research questions were then developed to shape the thematic focus and literature selection. Literature collection included both peer-reviewed publications and grey literature, such as policy documents, NGO reports, and technical assessments. Sources were screened and prioritized based on relevance to four themes: air pollution, public health risks, low energy efficiency, and lack of emission monitoring. These themes emerged from both literature and contextual knowledge of Indonesia's waste management challenges. Thematic categorization helped organize the data for meaningful interpretation.Next, a narrative synthesis and contextual analysis were carried out, comparing RDF practices in Indonesia with those in other Southeast Asian countries and considering factors such as waste composition, technology capacity, regulations, and social vulnerability. Critical reflection was then applied, focusing on how RDF-related knowledge, governance, and decisions are shaped socially and politically, with attention to gaps between policy and community realities, especially for low-income groups.

2.3. Research Design

Data for the narrative review were collected from a combination of peer-reviewed academic sources, policy documents, and grey literature. The literature search was conducted using major academic databases including Scopus, Web of Science, and Google Scholar. Key search terms included "Refuse-Derived Fuel," "RDF Indonesia," "waste-to-energy and air pollution," "health risks of RDF," "environmental monitoring RDF," and "sustainability of RDF in developing countries." Additionally, government publications from the Indonesian Ministry of Environment and Forestry, Jakarta City Government, and Badan Pengkajian dan Penerapan Teknologi (BPPT) were reviewed. NGO reports, particularly those from Walhi, Nexus3 Foundation, and IPEN, were also considered as these organizations have conducted field-based investigations on RDF's environmental and public health effects. Sources published between 2010 and 2024 were prioritized to ensure that the review captures recent policy developments and technological applications. The materials were first screened based on relevance to the four key thematic categories: (1) air pollution, (2) public health risks, (3) low energy efficiency, and (4) lack of emission monitoring and environmental oversight. These categories were identified through preliminary reading and refined during the data extraction process.

Once the sources were collected, the data were organized thematically. A narrative synthesis approach was used to identify patterns, contradictions, and knowledge gaps within and across the four themes. This synthesis included comparative reflections on RDF practices in Indonesia, particularly those with similar socio-environmental and governance challenges. The analysis also accounted for contextual factors such as waste composition, technological readiness, public awareness, and policy alignment. Throughout the review process, the study maintained a constructivist epistemological stance, recognizing that environmental knowledge is shaped by social, political, and cultural contexts. No primary data involving human participants were collected, and thus no ethical clearance was required. The review aims to inform more equitable and sustainable waste-to-energy practices by emphasizing not only technical efficiency but also environmental justice and community health considerations.

2.4. Inclusion Criteria

The inclusion criteria for this narrative mini-review were designed to ensure that the selected literature was both relevant and of sufficient quality to address the research objectives. Sources were considered if they examined at least one of the four thematic areas identified in this study: air pollution from RDF combustion, public health risks associated with RDF facilities, low energy efficiency and calorific performance, and the lack of emission monitoring and environmental oversight. While the primary focus was on Indonesia, studies from other countries were also included where they offered comparative insights or transferable lessons for contexts with similar waste compositions, governance

@The Author(s). 2025. Published by CBIORE

structures, and RDF technologies. Both peer-reviewed academic articles and credible grey literature, such as government policy documents, NGO reports, technical assessments, and reputable media investigations, were included to provide a comprehensive and multidisciplinary evidence base. The literature search prioritized works published between 2010 and 2024 to capture recent technological, policy, and governance developments in RDF implementation, with earlier sources incorporated only when they offered essential historical or contextual perspectives. Only publications in English or Bahasa Indonesia were used to ensure accurate interpretation of technical and policy details. Additionally, studies were included only if they provided empirical data, policy analysis, or detailed technical information relevant to RDF, while opinion-based pieces or sources lacking substantive evidence were excluded.

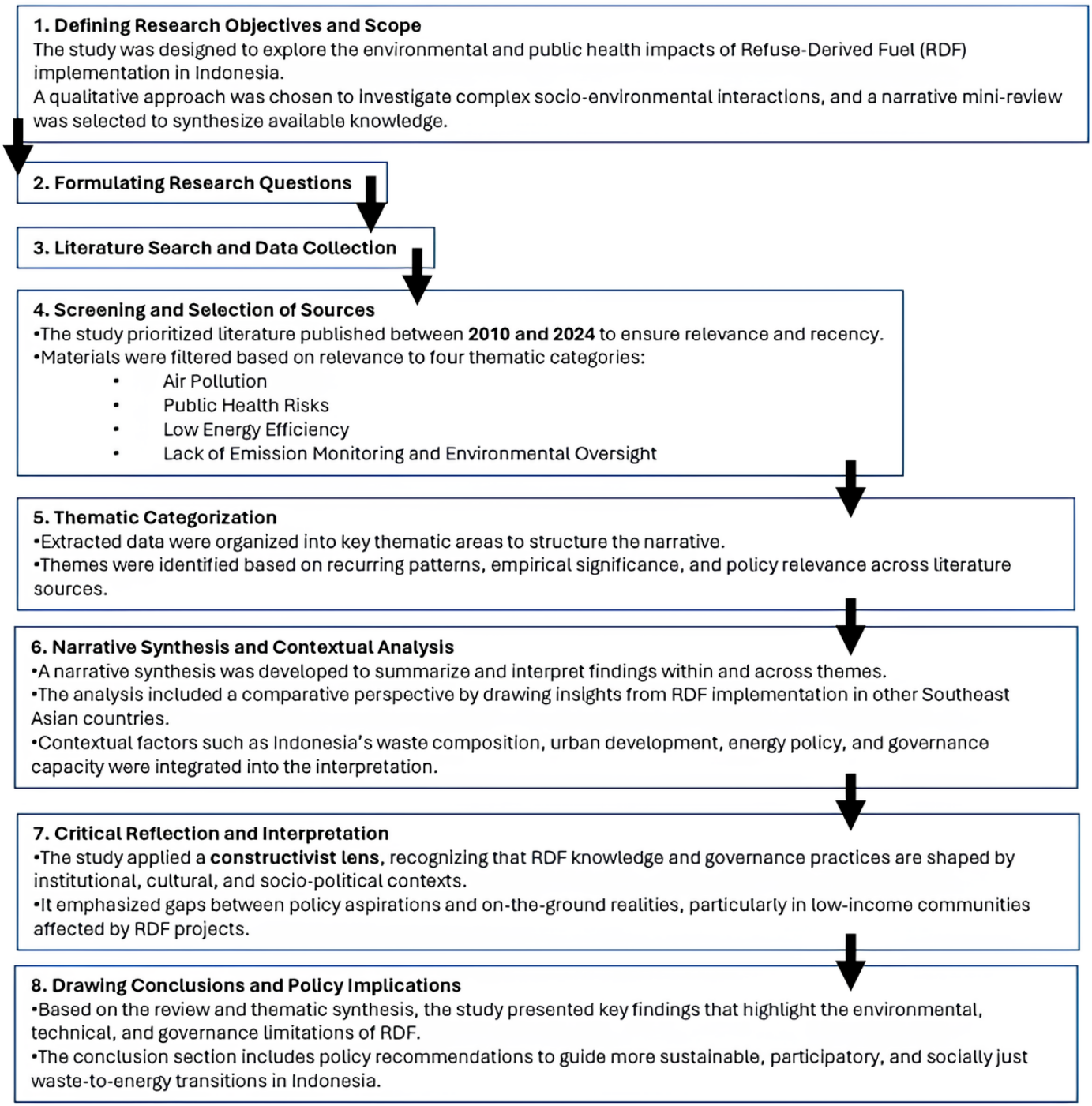

Figure 1. Methodological framework

@The Author(s). 2025. Published by CBIORE

3. Result and Discussion

3.1. Environmental impacts associated with Refuse-Derived Fuel (RDF)

Figure 2 presents a comprehensive mind map of the environmental impacts associated with Refuse-Derived Fuel (RDF) implementation, particularly in the Indonesian context. The diagram is organized into four primary categories: Air Pollution, Public Health Risks, Low Energy Efficiency, and Lack of Emission Monitoring and Environmental Oversight. Each of these branches outlines a set of sub-issues that collectively demonstrate the multidimensional consequences of RDF as a waste-to-energy strategy. The air pollution branch begins with the emission of toxic substances produced during RDF combustion. These include dioxins, furans, heavy metals, and fine particulate matter (PM2.5/PM10), which are recognized for their long-term persistence in the environment and their potential to cause severe health problems such as cancer and neurological disorders (Denisow-Pietrzyk, 2021; Kandpal, 2024). This category also emphasizes the role of inadequate waste segregation, which leads to the incineration of materials such as plastics, electronics, and biomedical waste (Agboola et al., 2025; N. Singh et al., 2022). This improper sorting results in the release of more dangerous toxins into the air, compounding the pollution problem.

The second major category, public health risks, outlines the direct and indirect impacts of RDF emissions on communities living near such facilities. Respiratory illnesses, particularly Acute Respiratory Infections (ISPA), are commonly reported in areas close to RDF plants due to prolonged exposure to air pollutants (Messie Pondie et al., 2024; Robin et al., 2023). The diagram also highlights odor and psychological stress caused by persistent and unpleasant smells, which contribute to reduced quality of life and increased mental health burdens. Furthermore, long-term health effects are illustrated, including increased risks of cancer, hormonal disruption, and compromised immune systems. The figure notes that these risks are often exacerbated by a lack of health surveillance and monitoring in affected communities. The third category, low energy efficiency, addresses the technical limitations of RDF in the Indonesian setting. One key factor is the high moisture content of waste, where 60–70% of municipal waste consists of wet organic matter (Xie et al., 2023; Zhu et al., 2021). This composition significantly impairs combustion efficiency and necessitates energy-intensive pre-drying processes. The negative energy balance sub-branch points out that the energy required to process RDF may exceed the energy recovered, especially when fossil fuels are used for drying, thereby nullifying RDF's claim as a sustainable alternative to conventional energy. The diagram also introduces alternative, more sustainable options such as composting or anaerobic digestion (biogas) (Murphy & Power, 2006; Zulkepli et al., 2017), which are generally more energy-efficient, environmentally friendly, and adaptable to the organic-rich waste streams typical in Indonesia.The final branch, lack of emission monitoring and environmental oversight, identifies institutional and regulatory failures that permit unchecked environmental degradation. The absence of Continuous Emission Monitoring Systems (CEMS) in most RDF plants leads to undetected pollution spikes, limiting timely regulatory responses. This is linked to the broader issue of lack of transparency, as emission data is rarely shared with the public or independently audited, thereby denying communities the information needed to evaluate environmental risks. The regulatory gaps section reveals the inadequacies in national and local policy regarding emission standards and enforcement of source-level waste segregation.

3.2. Air pollution

Refuse-Derived Fuel (RDF) is commonly promoted as an alternative fuel source, particularly for high-energy industries such as cement production. While it is often positioned as a sustainable solution to reduce landfill waste and fossil fuel dependency, its combustion process raises significant environmental and public health concerns, particularly in the form of air pollution. The incineration of RDF produces a complex mix of hazardous air pollutants, which vary depending on the composition of the waste and the combustion technology applied. Among the most concerning by-products are dioxins and furans, which are highly toxic even in minute concentrations. These compounds are known to persist in the environment, accumulate in the food chain, and cause severe health effects, including cancer, reproductive disorders, and immune system suppression ((Ben Seghir et al., 2023; Ojha & Tiwary, 2021; Sombiri et al., 2024; Vandana et al., 2022). In addition to these persistent organic pollutants, RDF combustion also emits heavy metals such as lead (Pb), mercury (Hg), and cadmium (Cd), which are non-biodegradable and capable of contaminating soil and water resource (Crujeira et al., 2005; Ningsih et al., 2019). These metals do not degrade and can contaminate soil and water, posing long-term health risks including neurological damage and kidney dysfunction (Mitra et al., 2022). Furthermore, particulate matter, particularly PM2.5 and PM10, is a component of RDF emissions (Jiang et al., 2024). These fine airborne particles can penetrate deep into the lungs and bloodstream, increasing the risk of respiratory illnesses, cardiovascular events, and premature death (Traboulsi et al., 2017).

A key contributor to the severity of emissions is the inadequate segregation of waste prior to RDF processing. In many developing countries, including Indonesia, municipal solid waste often lacks proper sorting mechanisms. A case

@The Author(s). 2025. Published by CBIORE

study from Bantar Gebang, one of Indonesia's largest landfill and RDF processing site (Ardiatma et al., 2023). Additionally, researchers have found that the start-up phases of waste-to-energy incinerators are especially prone to high emissions of dioxins and other pollutants, further exacerbating the environmental risks (H.-H. Yang et al., 2022). The contamination of food sources near RDF facilities raises serious concerns about the long-term safety and sustainability of this technology, particularly when implemented in densely populated or poorly regulated areas. These findings highlight the urgent need for improved waste segregation, the application of strict emissions control technologies, and the implementation of real-time monitoring systems in RDF operations. Without these measures, RDF risks shifting environmental burdens from land to air, effectively becoming not a clean energy solution, but a hidden contributor to environmental degradation and threats to public health.

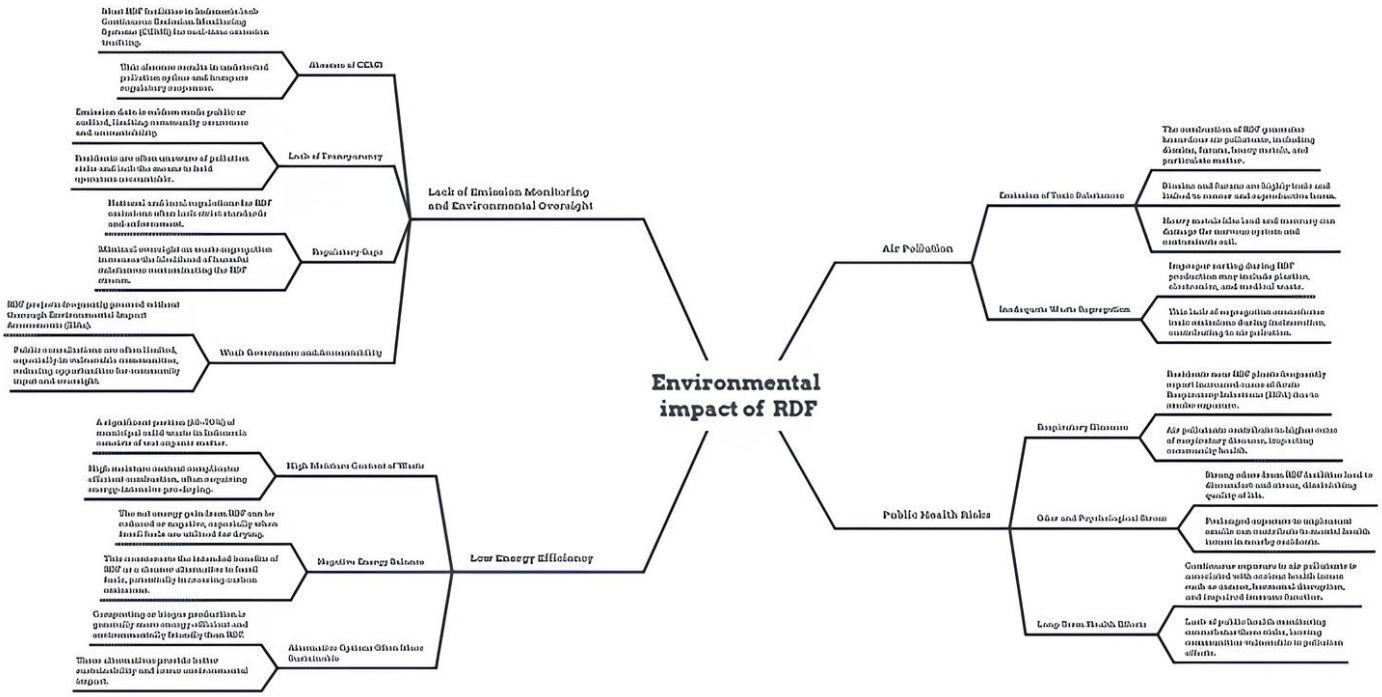

Figure 2. Comprehensive mind map of environmental impacts associated with RDF

3.3. Public Health Concerns

The operation of Refuse-Derived Fuel (RDF) facilities is often associated with significant public health concerns, particularly for communities located near incineration sites. One of the most immediate and visible effects is the increase in respiratory illnesses, most notably Acute Respiratory Infections (ISPA) (Abubakar et al., 2022). Exposure to smoke, fine particulate matter (PM2.5 and PM10), and toxic gases emitted during RDF combustion contribute directly to inflammation of the airways, bronchitis, asthma, and other acute respiratory symptoms. Vulnerable groups such as children, the elderly, and individuals with pre-existing health conditions are at particularly high risk (Maung et al., 2022; Møgelmose et al., 2023; Reynard et al., 2024). Beyond physical illness, RDF facilities also affect residents' well-being through odor pollution (G. Kumar et al., 2024; Qaseem, 2024). The strong, unpleasant odors produced by decomposing waste and RDF combustion contribute to psychological stress, disrupt daily activities, and degrade the overall quality of life. These odors are not only a nuisance but also carry harmful volatile organic compounds (VOCs) that can lead to headaches, dizziness, and mood disturbances (Bhandari et al., 2024; Kharlamova et al., 2023). Chronic exposure to such stressors may further contribute to mental health decline, social tension, and reduced community resilience.

Over the long term, continuous exposure to RDF-related air pollutants poses a more serious and complex threat to public health. Substances such as dioxins, furans, and heavy metals are persistent in the environment and bioaccumulate in human tissue. Epidemiological studies have linked these pollutants to cancer, particularly of the liver and lungs, as well as to hormonal disruption, impaired immune function, and reproductive health issues, including birth defects in children born to exposed mothers (Praud et al., 2023; Wan et al., 2022). These health effects are not limited to direct inhalation but can also occur through indirect exposure via contaminated food, water, and soil, especially in communities near RDF and landfill sites. A further challenge lies in the lack of public health monitoring systems in

areas surrounding RDF facilities. In many cases, affected communities are not regularly assessed for exposure or health outcomes, and there is an absence of comprehensive mitigation strategies. Without reliable data and active surveillance programs, health risks remain poorly understood and largely unaddressed by policymakers. This lack of accountability deepens environmental injustice, particularly in marginalized or low-income neighborhoods where RDF plants are often situated. To protect public health, there is an urgent need for the implementation of real-time environmental monitoring, health impact assessments, and accessible healthcare services in RDF-adjacent communities. Policy interventions must prioritize both preventative health measures and community involvement in environmental decision-making processes to mitigate the long-term health burdens imposed by RDF technologies.

3.4. Low Energy Efficiency

One of the critical challenges facing Refuse-Derived Fuel (RDF) technology, particularly in the Indonesian context, is its low energy efficiency, primarily driven by the high moisture content of municipal solid waste. In Indonesia, studies have consistently shown that approximately 40–70% of household waste is composed of wet organic matter, including food scraps, plant material, and other biodegradable substances (Suhartini et al., 2022). This type of waste has a high-water content, which significantly reduces its calorific value and renders it unsuitable for direct combustion without undergoing energy-intensive drying processes (Suryawan, Septiariva, et al., 2024). The necessity of pre-drying the waste before it can be converted into RDF introduces substantial energy demand. The energy required to remove moisture from organic waste is often greater than the energy that can be recovered from burning RDF itself. As a result, RDF operations may experience a negative energy balance, where the input energy exceeds the output. In many cases, fossil fuels such as diesel or coal are used to fuel the drying process, which contradicts the very goal of RDF as an alternative to fossil fuel dependency. This not only compromises energy efficiency but also increases greenhouse gas (GHG) emissions, ultimately adding to the carbon footprint of RDF facilities.

Moreover, this inefficiency raises questions about RDF's position within broader sustainable waste management strategies. When the waste stream is predominantly organic, alternative treatments such as composting or anaerobic digestion (biogas production) offer more environmentally and economically viable options (Ashokkumar et al., 2022; Jin et al., 2021; P. Sharma et al., 2024). These technologies require far less energy input, can produce nutrient-rich compost or renewable methane gas and have been proven to reduce methane emissions from landfills when integrated effectively (Mignogna et al., 2023; Somya et al., 2024). In addition, composting supports the development of circular agriculture by returning nutrients to the soil, while biogas systems can be scaled to match community-level energy needs. The misplaced assumption that RDF is universally applicable to all waste types and regions overlooks the fundamental mismatch between waste characteristics and incineration-based technologies. In the context of Indonesia and other Southeast Asian countries with similar waste compositions, prioritizing high-energy, combustion-based technologies without addressing basic input quality risks not only technical inefficiency but also economic waste and environmental degradation. Policy and investment decisions must therefore consider local waste profiles, climate conditions, and the availability of infrastructure for pre-treatment before promoting RDF as a large-scale solution.

3.5. Lack of Emission Monitoring and Environmental Oversight

A major environmental governance concern related to Refuse-Derived Fuel (RDF) technology is the widespread lack of emission monitoring systems and weak regulatory oversight, particularly in low- and middle-income countries such as Indonesia. While RDF is often promoted as an alternative energy solution that can reduce landfill dependence and fossil fuel consumption, the absence of robust monitoring infrastructure, especially Continuous Emission Monitoring Systems (CEMS), poses a significant barrier to ensuring its environmental safety. In most RDF facilities across Indonesia, real-time air quality monitoring is either non-existent or sporadic. Without CEMS, emission spikes particularly of toxic compounds such as dioxins, furans, and heavy metals remain undetected, and environmental regulators are left without accurate data to evaluate and enforce compliance. The implications of this CEMS are compounded by strengthens accountability and enforcement mechanisms, contributing to better environmental performance (Srivastava et al., 2024). Emission data, even when collected intermittently, is rarely disclosed to the public or subjected to independent third-party audits. This undermines public trust and community empowerment, as residents living near RDF plants are unable to assess the risks posed to their health and environment. Furthermore, without publicly available data, it becomes nearly impossible for environmental watchdogs, academic researchers, or civil society organizations to hold RDF operators accountable for their environmental performance. Compounding these technical deficiencies are regulatory gaps in both national and local policy frameworks. In Indonesia, standards specific to RDF emissions remain underdeveloped and inconsistently enforced. Unlike traditional thermal power plants, RDF operations often fall into a regulatory grey area, especially when categorized under municipal waste services rather than energy production. Additionally, regulations concerning waste segregation at the source are weakly implemented (Shiam Babu et al., 2025),

@The Author(s). 2025. Published by CBIORE

resulting in a higher likelihood of hazardous materials such as plastics, batteries, and e-waste being included in RDF feedstock. This contributes directly to the production of highly toxic emissions during combustion, further intensifying environmental and health risks (Chanana et al., 2023).

Another critical dimension of oversight failure in RDF development is the lack of effective governance and accountability, particularly during the early planning and approval stages of projects. Waste management initiatives should adopt an adaptive governance approach that prioritizes community participation and ensures local acceptance (Suhardono et al., 2024; Suryawan et al., 2025; Suryawan & Lee, 2025; B.-C. Yang et al., 2025). However, many RDF projects in Indonesia neglect this essential principle. This neglect violates the core tenets of environmental justice, especially when RDF facilities are located near low-income or marginalized communities. These populations often bear the brunt of environmental exposure while being excluded from meaningful decision-making processes. In many documented cases, public consultations are either superficial or entirely absent, reducing community trust and increasing resistance toward RDF implementation.

3.6. Critical Reflection and Interpretation

The critical reflection and interpretation stage serves as the analytical backbone of this study, enabling a deeper contextual understanding of the complex dynamics surrounding Refuse-Derived Fuel (RDF) implementation in Indonesia. This phase adopts a constructivist epistemological stance, which recognizes that knowledge about environmental technologies, governance structures, and public health outcomes is socially constructed shaped by cultural norms, institutional constraints, political agendas, and asymmetrical power relations. This reflection was guided by two core objectives: first, to evaluate whether empirical evidence supports or contradicts prevailing policy narratives that frame RDF as a sustainable waste-to-energy solution; and second, to assess the broader implications of RDF deployment for communities, ecological systems, and governance mechanisms. Beyond considerations of technological efficacy and economic feasibility, this stage critically interrogates questions of distributional justice who gains, who bears the risks, and who is excluded from decision-making processes. One of the central insights emerging from this reflection is the clear disconnect between policy ambition and implementation realities. Although RDF is promoted by various levels of government as an innovative solution for urban waste reduction and renewable energy generation, its execution is frequently hindered by poor planning, inadequate infrastructure, and weak enforcement of environmental safeguards. This is particularly concerning given the unequal distribution of environmental burdens.

These findings point to the urgent need for an adaptive management approach to RDF governance. Adaptive management emphasizes institutional flexibility, iterative learning, stakeholder agency, and system resilience (Suhardono et al., 2025; Suryawan, Suhardono, et al., 2024; Suryawan & Lee, 2023, 2025; B.-C. Yang et al., 2025), all of which are necessary to address the multidimensional challenges of RDF implementation. First, the system must build on existing assets, including local knowledge, community structures, and informal waste systems, which are often overlooked in centralized planning. Second, RDF strategies must incorporate flexibility, allowing for ongoing adjustments in response to changing conditions, new evidence, or community feedback. Third, organizational coherence is vital—this involves strengthening inter-agency coordination and ensuring that roles and responsibilities are clearly defined across levels of government and civil society. Fourth, learning must be institutionalized not only through formal monitoring and evaluation but also through inclusive processes that enable communities and frontline workers to share experiences, voice concerns, and co-produce knowledge. This also includes the need for real-time monitoring systems such as Continuous Emission Monitoring Systems (CEMS) and publicly accessible emissions data to improve transparency and accountability. Lastly, agency particularly community agency must be central. Affected populations should not merely be consulted after decisions are made; they should be embedded in the governance structure as active participants in planning, oversight, and adaptation processes. This reflection also identifies more appropriate and context-sensitive alternatives to RDF. These include community-based waste segregation programs, decentralized composting systems, and biogas production—all of which are better suited to Indonesia's waste profile and socio-economic conditions. These alternatives not only improve resource recovery and reduce environmental harm but also empower local communities, enhance inclusiveness, and support the transition toward a more circular economy.

3.7 Successful Alternatives, Pilot Programs, and Policy Recommendations

The limitations of RDF in Indonesia, particularly those related to low energy efficiency, environmental health risks, and weak governance, underscore the need to explore and scale up alternative waste management strategies that have demonstrated both technical feasibility and social acceptance. Several notable cases within Southeast Asia and beyond provide valuable models for adaptation. In Bali, community-managed decentralized composting programs have successfully transformed segregated organic waste into nutrient-rich compost, which is then supplied to local farmers, closing the nutrient loop and reducing landfill-bound waste. These programs, supported by local government

@The Author(s). 2025. Published by CBIORE

and NGOs, have also shown measurable reductions in methane emissions, thereby contributing to climate mitigation targets. In Thailand, integrating RDF production with semi-aerobic landfill systems has improved waste stabilization while recovering combustible fractions for industrial fuel, thereby balancing energy recovery with reduced environmental impact (Payomthip & Wangyao, 2024). Anaerobic digestion has also proven effective in contexts with high organic waste content, such as in Vietnam and the Philippines, where small to medium-scale biogas facilities have been established to supply renewable energy for local use. These projects have not only reduced dependence on fossil fuels but also supported rural livelihoods by creating jobs in plant operation and maintenance. Beyond Southeast Asia, Japan and Germany have long demonstrated that high-quality RDF production is possible when stringent waste segregation systems and feedstock quality controls are in place (Sakka et al., 2006). Such systems ensure that RDF meets energy performance benchmarks while minimizing toxic emissions, offering lessons on the integration of technical standards with regulatory enforcement.

Building on these insights, Table 1 summarizes the thematic areas that capture the multi-dimensional challenges of RDF implementation in Indonesia. These include the release of hazardous pollutants during combustion, the health burdens borne by nearby communities, the technical inefficiencies caused by high-moisture waste streams, and the institutional gaps in environmental monitoring and enforcement. By pairing each finding with targeted policy recommendations, the table serves as a practical tool for both national and local decision-makers, as well as RDF facility operators, in designing interventions that are technically feasible, socially equitable, and environmentally responsible. The recommendations emphasize preventive measures, stronger regulatory enforcement, technological upgrades, and active community engagement, ensuring that any future RDF development aligns with broader sustainability goals and prioritizes public health protection.

Table 1. Summary of key findings and policy implications for RDF implementation in Indonesia

Thematic Area	Key Findings	Policy Implications
Air Pollution	RDF combustion produces hazardous emissions, including dioxins, furans, heavy metals, and fine particulate matter, especially when waste segregation is inadequate. These pollutants persist in the environment and can enter the food chain.	Enforce strict waste segregation at the source; mandate the use of advanced emission control technologies; implement and enforce emission standards specific to RDF facilities.
Public Health Risks	Communities near RDF facilities face increased risks of respiratory illnesses, long-term exposure to toxic substances, and odor-related psychological stress. Lack of continuous health monitoring exacerbates these risks.	Establish continuous environmental and health monitoring programs; ensure accessible healthcare interventions for affected communities; involve residents in environmental decision-making and oversight.
Low Energy Efficiency	High moisture content in municipal waste reduces RDF calorific value, leading to negative energy balance when pre-drying relies on fossil fuels. Alternative treatments such as composting and anaerobic digestion may be more efficient for organic-rich waste streams.	Promote waste treatment technologies aligned with local waste composition; incentivize composting and anaerobic digestion; require calorific value testing before RDF production.
Emission Monitoring	Most RDF facilities lack Continuous Emission Monitoring Systems (CEMS) and transparent reporting, creating gaps in regulatory enforcement and public accountability.	Mandate CEMS installation and continuous operation; publish real-time emission data on public platforms; conduct third-party audits to verify compliance.

Building on these examples, targeted policy actions are essential to address the systemic weaknesses in Indonesia's current RDF governance framework. At the policy level, the mandatory installation and continuous operation of Continuous Emission Monitoring Systems (CEMS) in all RDF facilities should be enforced as a non-negotiable regulatory requirement. These systems must be paired with transparent, publicly accessible emission reporting platforms to allow independent verification and community oversight. Regulations should also mandate and support

@The Author(s). 2025. Published by CBIORE

comprehensive waste segregation at the source, leveraging a combination of public education campaigns, economic incentives for compliance, and penalties for non-segregation. For RDF facility operators, investment in advanced pre-treatment technologies such as mechanical-biological treatment (MBT) systems, moisture reduction through solar drying, and removal of hazardous materials—can significantly improve calorific value and reduce the risk of hazardous emissions. Operators should commit to publishing annual environmental performance reports, which detail emission levels, waste composition, and energy recovery efficiency. Such transparency can foster greater trust among local communities and environmental stakeholders, reducing opposition to facility siting and operations.

Finally, national and local governments should actively promote the development and scaling of alternative waste management pathways that better align with Indonesia's waste profile and climate commitments. This includes expanding composting and anaerobic digestion infrastructure, supporting public–private partnerships for small-scale renewable energy projects, and incentivizing circular economy initiatives that prioritize waste prevention, reuse, and material recovery. By integrating these alternative technologies with robust governance mechanisms, Indonesia can transition from a narrowly focused RDF strategy toward a more diversified, resilient, and socially equitable waste-to-energy framework that not only reduces environmental and public health risks but also advances sustainable development goals.

4. Conclusion

This study critically highlights the environmental and public health risks associated with the implementation of Refuse-Derived Fuel (RDF) as a waste-to-energy solution in Indonesia. While RDF offers potential benefits in reducing landfill dependence and supplementing fossil fuel use, its practical application reveals significant shortcomings. The analysis shows that RDF combustion contributes to air pollution through the release of toxic emissions such as dioxins, heavy metals, and persistent organic pollutants, especially in contexts where waste segregation is insufficient. Communities near RDF facilities are exposed to serious public health threats, including respiratory illnesses and long-term diseases, compounded by the lack of emission transparency and real-time monitoring. Furthermore, the low energy efficiency of RDF in Indonesia, primarily due to the high moisture content of waste, undermines its viability as a sustainable energy source. Alternative treatments such as composting or anaerobic digestion offer more environmentally sound solutions for managing organic waste. The study also finds a critical gap in regulatory frameworks, environmental oversight, and public participation, which allows RDF operations to proceed without adequate safeguards. Therefore, RDF should not be seen as a one-size-fits-all solution to the country's waste crisis. Its adoption must be carefully evaluated through site-specific assessments, improved regulatory enforcement, and integration with circular economy principles. A just and effective waste management strategy must prioritize environmental health, community involvement, and long-term sustainability over short-term technological fixes.

Looking ahead, future research should focus on conducting quantitative exposure assessments to better understand the magnitude and distribution of health risks associated with RDF facilities. Studies should also explore participatory governance models that integrate community voices into decision-making and monitoring processes, ensuring that waste-to-energy projects align with local priorities and environmental justice principles. In addition, valuation studies and community evaluations are needed to assess the socio-economic trade-offs, willingness to participate, and perceived fairness of RDF-related interventions. Such research will provide a stronger evidence base for designing waste management policies and technologies that are both environmentally sustainable and socially equitable

Acknowledgement

The author gratefully acknowledges the institutional support provided by the Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina. No other individuals contributed to the conception, design, analysis, or writing of this manuscript; all work was solely undertaken by the author.

@The Author(s). 2025. Published by CBIORE

References

Abubakar, I. R., Maniruzzaman, K. M., Dano, U. L., AlShihri, F. S., AlShammari, M. S., Ahmed, S. M. S., Al-Gehlani, W. A., & Alrawaf, T. I. (2022). Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. In *International Journal of Environmental Research and Public Health* (Vol. 19, Issue 19). https://doi.org/10.3390/ijerph191912717

Afnan, D., Wijaya, M., Kartono, D. T., & Wibowo, A. (2025). Community empowerment model in the refuse-derived fuel waste management program in Indonesia. *Cleaner Waste Systems*, *12*, 100364. https://doi.org/10.1016/j.clwas.2025.100364

Agboola, S. O., Inetabor, G. M., Bello, O. O., & Bello, O. S. (2025). *Waste Pollution and Management: Current Challenges and Future Perspectives BT - Smart Waste and Wastewater Management by Biotechnological Approaches* (A. M. Yatoo & M. Sillanpää (eds.); pp. 3–20). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-8673-2_1

AlQattan, N., Acheampong, M., Jaward, F. M., Ertem, F. C., Vijayakumar, N., & Bello, T. (2018). Reviewing the potential of Waste-to-Energy (WTE) technologies for Sustainable Development Goal (SDG) numbers seven and eleven. *Renewable Energy Focus*, *27*, 97–110. https://doi.org/https://doi.org/10.1016/j.ref.2018.09.005

Ardiatma, D., Lestari, P., & Chaerul, M. (2023). Complexity of Waste Handling Technology at Final Disposal Site of Bantargebang, Bekasi City. *IOP Conference Series: Earth and Environmental Science*, *1257*(1), 12006.

Ashokkumar, V., Flora, G., Venkatkarthick, R., SenthilKannan, K., Kuppam, C., Mary Stephy, G., Kamyab, H., Chen, W.-H., Thomas, J., & Ngamcharussrivichai, C. (2022). Advanced technologies on the sustainable approaches for conversion of organic waste to valuable bioproducts: Emerging circular bioeconomy perspective. *Fuel*, *324*, 124313. https://doi.org/https://doi.org/10.1016/j.fuel.2022.124313

Awino, F. B., & Apitz, S. E. (2024). Solid waste management in the context of the waste hierarchy and circular economy frameworks: An international critical review. *Integrated Environmental Assessment and Management*, *20*(1), 9–35. https://doi.org/https://doi.org/10.1002/ieam.4774

Ayuvitari, R. S., & Wijayanti, P. (2022). Potensi Reduksi Emisi GRK dan Kelayakan Finansial dari Teknologi Hidrotermal untuk Pengolahan Sampah di Kabupaten Tangerang. *Jurnal Ilmu Lingkungan*, *20*(1), 1–12. https://doi.org/10.14710/jil.20.1.1-12

Baker, R., Peters, R., & Chikhliwala, E. (2012). A Truly Integrated Continuous Emission Monitoring System (CEMS) Optimized for the Waste-to-Energy (WTE) Applications. *North American Waste-to-Energy Conference*, *44830*, 235–236. https://doi.org/10.1115/NAWTEC20-7032

Ben Seghir, B., Kouadri, I., Messaoudi, M., Rebiai, A., Zeghoud, S., Hemmami, H., & Ben Amor, I. (2023). *Food Chain Contamination and Impact of Xenobiotics on Human Health BT - Xenobiotics in Urban Ecosystems: Sources, Distribution and Health Impacts* (R. Singh, P. Singh, S. Tripathi, K. K. Chandra, & R. Bhadouria (eds.); pp. 109–129). Springer International Publishing. https://doi.org/10.1007/978-3-031-35775-6_6

Bhandari, S., de Ferreyro Monticelli, D., Xie, K., Ramkairsingh, A., Maher, R., Eykelbosh, A., Henderson, S. B., Zimmerman, N., & Giang, A. (2024). Odor, air quality, and well-being: understanding the urban smellscape using crowdsourced science. *Environmental Research: Health*, *2*(3), 35012. https://doi.org/10.1088/2752-5309/ad5ded

Brotosusilo, A., Nabila, S. H., Negoro, H. A., & Utari, D. (2020). The level of individual participation of community in implementing effective solid waste management policies. *Global Journal of Environmental Science and Management*, *6*(3), 341–354. https://doi.org/10.22034/gjesm.2020.03.05

Chanana, I., Sharma, A., Kumar, P., Kumar, L., Kulshreshtha, S., Kumar, S., & Patel, S. K. (2023). Combustion and Stubble Burning: A Major Concern for the Environment and Human Health. In *Fire* (Vol. 6, Issue 2). https://doi.org/10.3390/fire6020079

Conlon, K. (2020). Waste Management in the Global South: An Inquiry on the Patterns of Plastic and Waste Material Flows in Colombo, Sri Lanka [Portland State University PP - United States -- Oregon]. In *ProQuest Dissertations*

and Theses. https://go.openathens.net/redirector/ndhu.edu.tw?url=https://www.proquest.com/dissertations-theses/waste-management-global-south-inquiry-on-patterns/docview/2476547040/se-2?accountid=10534

Cook, E., Velis, C. A., & Cottom, J. W. (2022). Scaling up resource recovery of plastics in the emergent circular economy to prevent plastic pollution: Assessment of risks to health and safety in the Global South. *Waste Management & Research*, *40*(12), 1680–1707. https://doi.org/10.1177/0734242X221105415

Crujeira, T., Lopes, H., Abelha, P., Sargaço, C., Gonçalves, R., Freire, M., Cabrita, I., & Gulyurtlu, I. (2005). Study of toxic metals during combustion of RDF in a fluidized bed pilot. *Environmental Engineering Science*, *22*(2), 241–250. https://doi.org/10.1089/ees.2005.22.241

Denisow-Pietrzyk, M. (2021). Human skin reflects air pollution–a review of the mechanisms and clinical manifestations of environment-derived skin pathologies. *Polish Journal of Environmental Studies*, *30*(4), 3433–3444. https://doi.org/10.15244/pjoes/130525

Dhillon, C. M. (2017). Using citizen science in environmental justice: participation and decision-making in a Southern California waste facility siting conflict. *Local Environment*, *22*(12), 1479–1496. https://doi.org/10.1080/13549839.2017.1360263

Dubsok, A., Niyommaneerat, W., Suphasomboon, T., Sugsaisakon, S., & Kittipongvises, S. (2024). Environmental and Climate Impacts Associated with Refuse Derived Fuel (RDF) Production: A Case Study in Thailand. *E3S Web Conf.*, *566*. https://doi.org/10.1051/e3sconf/202456604006

Fayshal, M. A. (2024). Current practices of plastic waste management, environmental impacts, and potential alternatives for reducing pollution and improving management. *Heliyon*, *10*(23), 1-13. https://doi.org/10.1016/j.heliyon.2024.e40838

Galavote, Tânia, Chaves, Gisele de Lorena Diniz, Yamane, Luciana Harue, & Siman, Renato Ribeiro. (2024). Municipal solid waste management instruments that influence the use of the refuse as fuel in developing countries: A critical review. *Waste Management & Research*, *43*(2), 160–180. https://doi.org/10.1177/0734242X241231402

Gutberlet, J., & and Uddin, S. M. N. (2017). Household waste and health risks affecting waste pickers and the environment in low- and middle-income countries. *International Journal of Occupational and Environmental Health*, *23*(4), 299–310. https://doi.org/10.1080/10773525.2018.1484996

Hermansyah, A. M., Muhammad, M., & Yunus, A. (2024). Analysis of the Potential Development of Waste Power Generation (PLTSa) Program in the Long Term. *Proceedings of the World Conference on Governance and Social Sciences (WCGSS 2023)*, 371. https://doi.org/10.2991/978-2-38476-236-1_38

Jiang, Y., Zhuo, L., Wu, X., Zhang, Z., & Guo, X. (2024). Influence of rice husk dosage on PM emissions during the co-firing of coal with refuse derived fuel. *Fuel*, *376*, 132690. https://doi.org/https://doi.org/10.1016/j.fuel.2024.132690

Jin, C., Sun, S., Yang, D., Sheng, W., Ma, Y., He, W., & Li, G. (2021). Anaerobic digestion: An alternative resource treatment option for food waste in China. *Science of the Total Environment*, *779*, 146397. https://doi.org/10.1016/j.scitotenv.2021.146397

Kandpal, P. C. (2024). *Air Pollution in Delhi: Causes and Consequences BT - Combating Air Pollution: Comparisons between Delhi and Mexico City* (P. C. Kandpal (ed.); pp. 61–75). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-68027-4_3

Kharlamova, M. D., Adamovich, M., Romanovskaya, K. S., Spirin, M. A., Mustaeva, L. R., & Adamovich, N. (2023). Decomposition of individual components of bio organic waste: volatile organic compounds and the impact on health and psycho emotional state. *Вестник Российского Университета Дружбы Народов. Серия: Экология и Безопасность Жизнедеятельности*, *31*(3), 391–406. https://doi.org/10.22363/2313-2310-2023-31-3-390-406

Kordel, P., & Wolniak, R. (2021). Technology Entrepreneurship and the Performance of Enterprises in the Conditions of Covid-19 Pandemic: The Fuzzy Set Analysis of Waste to Energy Enterprises in Poland. In *Energies* (Vol. 14, Issue 13). https://doi.org/10.3390/en14133891

@The Author(s). 2025. Published by CBIORE

Kumar, G., Vyas, S., Sharma, S. N., & Dehalwar, K. (2024). Challenges of Environmental Health in Waste Management for Peri-urban Areas. In *Solid Waste Management: Advances and Trends to Tackle the SDGs* (pp. 149–168). Springer.

Kurniawan, T. A., Meidiana, C., Dzarfan Othman, M. H., Goh, H. H., & Chew, K. W. (2023). Strengthening waste recycling industry in Malang (Indonesia): Lessons from waste management in the era of Industry 4.0. *Journal of Cleaner Production*, *382*, 135296. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.135296

Maung, T. Z., Bishop, J. E., Holt, E., Turner, A. M., & Pfrang, C. (2022). Indoor Air Pollution and the Health of Vulnerable Groups: A Systematic Review Focused on Particulate Matter (PM), Volatile Organic Compounds (VOCs) and Their Effects on Children and People with Pre-Existing Lung Disease. In *International Journal of Environmental Research and Public Health* (Vol. 19, Issue 14). https://doi.org/10.3390/ijerph19148752

Messie Pondie, T., Engwali, F. O. N. D., Ongo Nkoa, B. E., & Noubissi Domguia, E. (2024). Energy poverty and respiratory health in Sub-Saharan Africa: Effects and transmission channels. *Energy*, *297*, 131158. https://doi.org/https://doi.org/10.1016/j.energy.2024.131158

Mignogna, D., Ceci, P., Cafaro, C., Corazzi, G., & Avino, P. (2023). Production of biogas and biomethane as renewable energy sources: a review. *Applied Sciences*, *13*(18), 10219. https://doi.org/10.3390/app131810219

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. Bin, Nainu, F., Khusro, A., Idris, A. M., Khandaker, M. U., Osman, H., & Alhumaydhi, F. A. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science*, *34*(3), 101865. https://doi.org/10.1016/j.jksus.2022.101865

Møgelmose, S., Neels, K., Beutels, P., & Hens, N. (2023). Exploring the impact of population ageing on the spread of emerging respiratory infections and the associated burden of mortality. *BMC Infectious Diseases*, *23*(1), 767. https://doi.org/10.1186/s12879-023-08657-3

Mubarok, F. (2025). *Sampah jadi Energi, Bagaimana Dampak Lingkungan?* https://www.mongabay.co.id/2025/03/25/sampah-jadi-energi-bagaimana-dampak-lingkungan/

Murphy, J. D., & Power, N. M. (2006). A technical, economic and environmental comparison of composting and anaerobic digestion of biodegradable municipal waste. *Journal of Environmental Science and Health Part A*, *41*(5), 865–879. https://doi.org/10.1080/10934520600614488

Ningsih, R. Y., Goembira, F., Komala, P. S., & Putra, N. P. (2019). Emission and heavy metal content characteristic of densified refused derived fuels of oil sludge and biomass combination as an alternative fuel for cement plant. *Indonesian Journal of Environmental Management and Sustainability*, *3*(3), 100–105. https://doi.org/10.26554/ijems.2019.3.3.100-105

Ojha, A., & Tiwary, D. (2021). *Chapter 16 - Organic pollutants in water and its health risk assessment through consumption* (A. Ahamad, S. I. Siddiqui, & P. B. T.-C. of W. Singh (eds.); pp. 237–250). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-824058-8.00039-6

Payomthip, P., & Wangyao, K. (2024). Evaluating the key success factors for low-carbon waste management of local administrative organizations: RDF production and semi-aerobic landfill in Thailand. *Journal of Material Cycles and Waste Management*, *26*(4), 2071–2083. https://doi.org/10.1007/s10163-024-01941-7

Prariesta, D., Edahwati, L., & Karaman, N. (2023). Analisis Emisi dari Penggunaan Refuse Derived Fuel sebagai Bahan Bakar Alternatif di Industri Semen (Studi Kasus di PT Solusi Bangun Indonesia Cilacap). *Envirotek: Jurnal Ilmiah Teknik Lingkungan*, *15*(2), 194–199. https://doi.org/10.33005/envirotek.v15i2.282

Praud, D., Deygas, F., Amadou, A., Bouilly, M., Turati, F., Bravi, F., Xu, T., Grassot, L., Coudon, T., & Fervers, B. (2023). Traffic-related air pollution and breast cancer risk: a systematic review and meta-analysis of observational studies. *Cancers*, *15*(3), 927. https://doi.org/10.3390/cancers15030927

Prihartanto, P., Trihadiningrum, Y., Kholiq, M. A., Bagastyo, A. Y., & Warmadewanthi, I. D. A. A. (2023). Characterization of landfill-mined materials as a waste-to-energy source at integrated solid waste treatment facilities of Jakarta

@The Author(s). 2025. Published by CBIORE

Province, Indonesia. *Journal of Material Cycles and Waste Management*, *25*(6), 3872–3884. https://doi.org/10.1007/s10163-023-01810-9

Qaseem, F. I. (2024). Social and Environmental Externalities of the Landfill: A Case Study of Bantargebang Landfill in Bekasi, Indonesia. *Journal of Arts, Humanities and Social Sciences (ISRGJAHSS),* II(V), 254-259. https://doi.org/ 10.5281/zenodo.13860650

Qonitan, F. D., Wayan Koko Suryawan, I., & Rahman, A. (2021). Overview of Municipal Solid Waste Generation and Energy Utilization Potential in Major Cities of Indonesia. *Journal of Physics: Conference Series*, *1858*(1). https://doi.org/10.1088/1742-6596/1858/1/012064

Randhawa, P., Marshall, F., Kushwaha, P. K., & Desai, P. (2020). Pathways for sustainable urban waste management and reduced environmental health risks in India: winners, losers, and alternatives to waste to energy in Delhi. *Frontiers in Sustainable Cities*, *2*, 14. https://doi.org/ 10.3389/frsc.2020.00014

Reynard, C., James, C., Adam L, G., George, K., Hui-Hsuan, L., Alex, R., Andrew, V., Dexter J, W., Hannah, W., & and Ellsbury, G. (2024). Adult risk groups for vaccine preventable respiratory infections: an overview of the UK environment. *Expert Review of Vaccines*, *23*(1), 1052–1067. https://doi.org/10.1080/14760584.2024.2428243

Reza, B., Soltani, A., Ruparathna, R., Sadiq, R., & Hewage, K. (2013). Environmental and economic aspects of production and utilization of RDF as alternative fuel in cement plants: A case study of Metro Vancouver Waste Management. *Resources, Conservation and Recycling*, *81*, 105–114. https://doi.org/https://doi.org/10.1016/j.resconrec.2013.10.009

Robin, Kaur, P., Kaur, J., & Bhat, S. A. (2023). Chapter 9 - Solid waste management: challenges and health hazards. In B. Ravindran, S. K. Gupta, S. A. Bhat, P. S. Chauhan, & N. B. T.-R. T. in S. W. M. Tyagi (Eds.), *Advances in Pollution Research* (pp. 171–195). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-443-15206-1.00002-5

Sakka, M., Kimura, T., & Sakka, K. (2006). Comparison of microbial consortia in refuse-derived fuel (RDF) preparations between Japan and Germany. *Bioscience, Biotechnology, and Biochemistry*, *70*(12), 2868–2873. https://doi.org/10.1271/bbb.60261

Sharma, P., Bano, A., Singh, S. P., Varjani, S., & Tong, Y. W. (2024). Sustainable organic waste management and future directions for environmental protection and techno-economic perspectives. *Current Pollution Reports*, *10*(3), 459–477.

Sharma, U., Sharma, D., Kumar, A., Bansal, T., Agarwal, A., Kumar, S., Hussian, A., Kamyab, H., & Haq, M. (2025). Utilization of refuse-derived fuel in industrial applications: Insights from Uttar Pradesh, India. *Heliyon*, *11*(1). https://doi.org/10.1016/j.heliyon.2024.e41336

Shehata, N., Obaideen, K., Sayed, E. T., Abdelkareem, M. A., Mahmoud, M. S., El-Salamony, A.-H. R., Mahmoud, H. M., & Olabi, A. G. (2022). Role of refuse-derived fuel in circular economy and sustainable development goals. *Process Safety and Environmental Protection*, *163*, 558–573. https://doi.org/https://doi.org/10.1016/j.psep.2022.05.052

Shiam Babu, R., Prasanna, K., Senthil Kumar, P., & Rangasamy, G. (2025). Comprehensive assessment of current municipal solid waste management in Chennai, India: a critical case study with real-time analysis. *International Journal of Environmental Science and Technology*, *22*(7), 5729–5746. https://doi.org/10.1007/s13762-024-06009-5

Singer, J., Kieu, K. T., & Pravitasari, A. E. (2019). *Solid Waste Management in Tourist Destinations in Developing Nations: Case Studies in Hoi An, Vietnam, and Puncak, Indonesia BT - Environmental Sustainability and Education for Waste Management: Implications for Policy and Practice* (W. W. M. So, C. F. Chow, & J. C. K. Lee (eds.); pp. 189–206). Springer Singapore. https://doi.org/10.1007/978-981-13-9173-6_11

Singh, N., Shreshtha, I., Rishabh, & Nigam, V. K. (2022). *Chapter 21 - Integrated biomedical waste degradation and detoxification* (V. Kumar & M. B. T.-I. E. T. for W. T. and S. D. Kumar (eds.); pp. 481–508). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-323-91180-1.00005-3

Sombiri, S., Balhara, N., Attri, D., Kharb, I., & Giri, A. (2024). An overview on occurrence of polycyclic aromatic hydrocarbons in food chain with special emphasis on human health ailments. *Discover Environment*, *2*(1), 87.

https://doi.org/10.1007/s44274-024-00121-6

Somya, A., Peter, A., Varshney, A. P., & Thakur, A. (2024). Recent Technologies Used in Waste Management. In *Municipal Solid Waste Management and Recycling Technologies* (pp. 177–202). IGI Global.

Srivastava, R. P., Kumar, S., & Tiwari, A. (2024). Continuous emission monitoring systems (CEMS) in India: Performance evaluation, policy gaps and financial implications for effective air pollution control. *Journal of Environmental Management*, *359*, 120584. https://doi.org/https://doi.org/10.1016/j.jenvman.2024.120584

Suhardono, S., Lee, C.-H., & Suryawan, I. W. K. (2024). Trends in citizen influencing willingness to participate in marine debris management and social well-being in Bali metropolitan, Indonesia. *Urban Governance*. https://doi.org/https://doi.org/10.1016/j.ugj.2024.12.005

Suhardono, S., Lee, C.-H., & Suryawan, I. W. K. (2025). Influence of adaptive management indicators on willingness to adapt to single-use plastic ban. *Environmental Economics and Policy Studies*. https://doi.org/10.1007/s10018-025-00439-2

Suhartini, S., Rohma, N. A., Elviliana, Santoso, I., Paul, R., Listiningrum, P., & Melville, L. (2022). Food waste to bioenergy: current status and role in future circular economies in Indonesia. *Energy, Ecology and Environment*, *7*(4), 297–339. https://doi.org/10.1007/s40974-022-00248-3

Suryawan, I. W. K., & Lee, C.-H. (2023). Citizens' willingness to pay for adaptive municipal solid waste management services in Jakarta, Indonesia. *Sustainable Cities and Society*, *97*. https://doi.org/https://doi.org/10.1016/j.scs.2023.104765

Suryawan, I. W. K., & Lee, C.-H. (2024). Achieving zero waste for landfills by employing adaptive municipal solid waste management services. *Ecological Indicators*, *165*, 112191. https://doi.org/https://doi.org/10.1016/j.ecolind.2024.112191

Suryawan, I. W. K., & Lee, C.-H. (2025). Green transition management: The key role of community participation in developing resilient waste management policies for coastal and inland communities. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-025-36185-x

Suryawan, I. W. K., Septiariva, I. Y., Widanarko, D. U. F., Qonitan, F. D., Sarwono, A., Sari, M. M., Prayogo, W., Arifianingsih, N. N., Suhardono, S., & Lim, J.-W. (2024). Enhancing energy recovery from Wastewater Treatment Plant sludge through carbonization. *Energy Nexus*, *14*, 100290. https://doi.org/https://doi.org/10.1016/j.nexus.2024.100290

Suryawan, I. W. K., Sianipar, I. M. J., & Lee, C.-H. (2025). Community importance-performance preferences and policy adaptiveness in marine debris management: A case study from the Komodo Subdistrict, Indonesia. *Marine Policy*, *174*, 106592. https://doi.org/https://doi.org/10.1016/j.marpol.2025.106592

Suryawan, I. W. K., Suhardono, S., & Lee, C.-H. (2024). Boosting beach clean-up participation through community resilience hypothetical scenarios. *Marine Pollution Bulletin*, *207*. https://doi.org/10.1016/j.marpolbul.2024.116853

Sutthasil, N., Chiemchaisri, C., Chiemchaisri, W., Ishigaki, T., & Gheewala, S. H. (2023). Life cycle greenhouse gas emissions of emerging municipal solid waste management options: a case study in Thailand. *Journal of Material Cycles and Waste Management*, *25*(2), 662–673. https://doi.org/10.1007/s10163-022-01584-6

Traboulsi, H., Guerrina, N., Iu, M., Maysinger, D., Ariya, P., & Baglole, C. J. (2017). Inhaled Pollutants: The Molecular Scene behind Respiratory and Systemic Diseases Associated with Ultrafine Particulate Matter. In *International Journal of Molecular Sciences* (Vol. 18, Issue 2). https://doi.org/10.3390/ijms18020243

Tripathy, R. K., Srivastava, K., & Jalem, K. (2025). Navigating the Circular Economy in Sustainable Development: A Creative Framework based on People First PPP for Waste-to-Energy Projects in India. In *Recent Trends In Engineering and Science for Resource Optimization and Sustainable Development* (pp. 304–313). CRC Press.

Vandana, Priyadarshanee, M., Mahto, U., & Das, S. (2022). *Chapter 2 - Mechanism of toxicity and adverse health effects of environmental pollutants* (S. Das & H. R. B. T.-M. B. and B. (Second E. Dash (eds.); pp. 33–53). Elsevier.

https://doi.org/https://doi.org/10.1016/B978-0-323-85455-9.00024-2

Wan, M. L. Y., Co, V. A., & El-Nezami, H. (2022). Endocrine disrupting chemicals and breast cancer: a systematic review of epidemiological studies. *Critical Reviews in Food Science and Nutrition*, *62*(24), 6549–6576. https://doi.org/10.1080/10408398.2021.1903382

Xie, S., Tran, H.-T., Pu, M., & Zhang, T. (2023). Transformation characteristics of organic matter and phosphorus in composting processes of agricultural organic waste: Research trends. *Materials Science for Energy Technologies*, *6*, 331–342. https://doi.org/https://doi.org/10.1016/j.mset.2023.02.006

Yang, B.-C., Lee, C.-H., & Suryawan, I. W. K. (2025). Resilient socio-technical systems for adaptive consumer e-waste management. *Sustainable Cities and Society*, 106026. https://doi.org/https://doi.org/10.1016/j.scs.2024.106026

Yang, H.-H., Cheruiyot, N. K., Lin, C., & Wang, L.-C. (2022). Control of extreme brominated persistent organic pollutant emissions from start-ups of waste-to-energy incinerators. *Journal of Cleaner Production*, *345*, 131108. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.131108

Zhu, Y., Zhang, Y., Luo, D., Chong, Z., Li, E., & Kong, X. (2021). A review of municipal solid waste in China: characteristics, compositions, influential factors and treatment technologies. *Environment, Development and Sustainability*, *23*(5), 6603–6622. https://doi.org/10.1007/s10668-020-00959-9.

Zulkepli, N. E., Muis, Z. A., Mahmood, N. A. N., Hashim, H., & Ho, W. S. (2017). Cost benefit analysis of composting and anaerobic digestion in a community: A review. *Chemical Engineering Transactions*, *56*, 1777–1782. https://doi.org/10.3303/CET1756297

@The Author(s). 2025. Published by CBIORE