

Review

A review of refuse-derived fuel utilisation as an industrial resource: The nigerian perspective

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Abstract: Municipal solid waste (MSW) generation in Nigeria has increased significantly due to rapid urbanisation, population growth, and changing consumption patterns, creating serious environmental and waste management challenges. Refuse-derived fuel (RDF), which is produced from the combustible fraction of MSW, has emerged as a sustainable alternative fuel for industrial applications, particularly in cement manufacturing, steel production, and electricity generation. This review examines RDF production processes, industrial utilisation, and environmental implications, with an emphasis on the Nigerian context. It discusses the generation, composition, and management of MSW, highlighting how waste characteristics influence RDF quality and performance. The review further evaluates the current status of RDF utilisation in Nigeria, identifies key technical, economic, and policy barriers limiting its adoption, and explores opportunities for wider implementation. The findings indicate that Nigeria possesses substantial potential for RDF development owing to its abundant MSW resources and growing industrial energy demand. Strengthening waste segregation, supportive policies, and investment in processing infrastructure will be critical to advancing RDF utilisation and promoting a circular economy.

Keywords: refuse-derived fuel (RDF); municipal solid waste (MSW); waste-to-energy (WtE); industrial fuel; energy recovery; sustainable waste management; circular economy; Nigeria

1. Introduction

Municipal Solid Waste (MSW) has become an increasingly pressing environmental problem due to the growth of populations and changes in consumption patterns. The yearly production of MSW has now gone above 2 billion tonnes globally and it is expected to grow rapidly because of future population growth and development (Kaza et al., 2021). In Nigeria, the country's urbanisation process and weak waste management facilities, is causing serious difficulties related to waste management, while Nigeria also experiencing difficulties in supplying its citizens with energy sources (Nelson, 2014; Yusuf et al., 2024). This has led to growing interest in recovering material and energy from the waste.

Refuse-derived fuel (RDF) is a good option for capturing energy from the combustible portion of MSW. RDF is created by treating waste material through processes such as sorting, sizing, drying, and densification to produce a fuel suitable for energy use. RDF is used as a fuel in alternative and supplementary ways in many applications, such as cement manufacturing, industrial boiler fuel, and power generation. Therefore, the use of RDF can contribute to waste minimization, resource recovery, and the substitution of conventional fuel resources. However, the production of RDF relies heavily on the composition and quality of the waste material, moisture

levels, the efficiency of waste collection, segregation practices, the RDF processing facilities, and appropriate environmental regulations. Some research in Nigeria has shown high energy potential in MSW but also highlighted limitations due to a poor waste collection system, a lack of appropriate facilities, finances, and policies (Nelson, 2014; Yusuf et al., 2024). This review is aimed at investigating RDF production, its use in industrial sectors, assessing environmental impacts, and providing the necessary conditions for RDF utilisation in Nigeria.

2. Materials and methods

This article is a narrative review of published and publicly available literature addressing municipal solid waste generation and composition, waste-management practices, RDF production, industrial utilisation, environmental impacts and the Nigerian waste-to-energy context. The review reports literature from peer-reviewed articles, institutional reports and other publicly available technical sources. Evidence was organised thematically around MSW characteristics, RDF processing, industrial applications, environmental implications and barriers to deployment in Nigeria. International examples were considered alongside Nigerian evidence to identify practices and conditions relevant to local implementation.

3. Results and discussion

3.1. Generation, composition, and management of MSW

Refuse-derived fuel is a product of MSW generation, composition and management; therefore, the availability of RDF largely depends on efficient MSW management practices.

3.1.1. Generation

Globally, MSW generation has been steadily rising, driven primarily by population growth, rapid urbanisation, and rising standards of living (Zhang et al., 2024). The World Bank estimates that global MSW generation exceeded 2.24 billion tonnes in 2020 and is projected to rise to about 3.4 billion tonnes by 2050 if current consumption and production patterns persist (Kaza et al., 2021).

The waste generation rates differ from one region to another since they are dependent on factors such as income, degree of urbanization, and lifestyles. High-income countries generate more waste per person compared to low- and middle-income countries because of increased consumption of packaged and processed products. Despite that, low- and middle-income countries, which comprise most Sub-Saharan African countries, have been increasing at a high rate regarding waste generation (Nyumah et al., 2021; Valavanidis, 2023). Urbanisation and waste production have a close relationship because urban populations consume more packaged goods and generate more waste per capita than rural populations (Chen, 2018).

Other variables that influence the production of waste include economic development, industrial activities, seasonality, and effectiveness of waste reduction efforts. Economic development and higher disposable incomes play a role in the production of waste as people tend to shift from reusable to disposable packaging and

consumption of processed goods. In underdeveloped regions, market and commercial activities play a significant role in the production of waste.

3.1.2. Composition and properties

The nature of municipal solid waste (MSW) in Nigeria depends on various elements like population density, degree of urbanization, economic activity, and lifestyle, among others. The municipal solid waste produced in the major cities and towns of Nigeria comprises biodegradable organic matter, plastics, paper, textiles, metals, glass, and other inert materials. Although the proportions vary by region, organic waste accounts for the largest share overall, reflecting the large volume of food and agricultural products consumed, while plastic waste has risen significantly with growing urbanization and consumption patterns (Kaza et al., 2018; Iorhemen et al., 2016).

Table 1 presents the typical composition of municipal solid waste reported for Nigerian urban areas based on recent literature.

Table 1. Typical composition of municipal solid waste in Nigerian cities and townships (Kaza et al., 2018; Khadija et al., 2023).

Waste component	Typical composition (%)
Organic waste (food and yard waste)	45–65
Plastics	10–20
Paper and cardboard	5–12
Textiles	2–8
Wood	1–5
Glass	2–6
Metals	2–5
Others (ceramics, dirt, ash, etc.)	5–15

The nature of MSW is a major determinant of both the production of refuse-derived fuel (RDF) and its performance. Components such as plastics, paper, cardboard, cloth, and wood are combustible elements of MSW and thus make good materials for RDF production. Plastics and paper are especially important due to their higher carbon and hydrogen content (Khadija et al., 2023). Conversely, high proportions of food waste, moisture-rich organic matter, glass, metals, and soil reduce RDF fuel quality by lowering its heating value, increasing ash generation, and requiring additional processing during waste preparation.

The presence of large amounts of biodegradable organic waste in Nigeria's MSW presents both a challenge and an opportunity for RDF production. While this organic waste is an excellent energy source because of its combustibility, its moisture content means the waste must be separated and dried first. In addition, the lack of waste separation in Nigeria leads to contaminated waste streams and, hence, inconsistent RDF quality. Proper waste separation and recycling of other materials prior to RDF

production will lead to improved RDF fuel quality and greater energy recovery efficiency.

3.1.3. Waste management practices

Effective MSW management is generally guided by the waste management hierarchy, which ranks practices by their environmental desirability. The hierarchy prioritises waste reduction and reuse at the top, followed by recycling, energy recovery, and, as a last resort, final disposal through landfilling (Aslan et al., 2025).

The goal of “reduce and reuse” is to ensure that waste is not created at all or to make sure that it lasts as long as possible before being made into waste. Reduce and reuse are seen as the most environmentally friendly methods since they prevent other environmental costs that come along after treatment and disposal of the waste. Some examples include reduction in packaging, creating durable and repairable products, and reusing containers and other materials.

The concepts of waste reduction and reuse have become an emerging focus in resource management in Nigeria. Examples of waste reduction and reuse activities include repairing household products, reusing containers, and recovering waste from waste collection, among others. However, due to a lack of awareness among the public and inadequate infrastructure, waste reduction and reuse practices are not common (Adesua-Lincoln, 2025).

Recycling is the process of collecting, sorting, and processing used materials such as plastic, metals, paper, and glass to create new materials, thereby conserving raw material resources. Recycling rates vary widely across countries, influenced by factors such as sorting capacity, market demand for recycled products, and consumer participation. In most developing nations, informal sector stakeholders, such as waste pickers, contribute to recycling by recovering useful materials from waste (Green Habitat Initiative, 2024).

Waste composting in Nigeria has gradually gained attention as a sustainable approach to managing the country’s predominantly organic municipal solid waste (MSW). Studies increasingly highlight composting as an effective strategy for reducing reliance on landfills, improving soil fertility, and supporting climate-smart agriculture (Ogunseye et al., 2017). Yet it remains underutilized because of inefficiencies in source separation, improper waste collection, ineffective policy enforcement, limited public awareness, and inadequate investment in composting technologies. Recent research suggests that composting can be integrated into Nigeria’s circular economy through decentralized composting plants and public-private partnerships, among other solutions (Olaitan et al., 2026).

Composting is a biological treatment process applied to the organic fraction of MSW, converting biodegradable waste into a stable, humus-like product that can be used as a soil amendment. Composting is particularly suited to waste streams with a high proportion of organic material, such as those typically generated in developing countries, and offers the dual benefit of diverting waste from landfills while producing a beneficial agricultural input. Waste composting in Nigeria remains low and underutilised despite high volumes of organic refuse. Open dumping accounts for roughly 80% of waste disposal, while formal composting remains minimal (Alamu, 2025).

Waste-to-Energy (WtE) technologies such as incineration, gasification, pyrolysis, anaerobic digestion, and RDF (Refuse-Derived Fuel) generation fall under the recovery phase of the waste management hierarchy. These technologies focus on waste that cannot be recycled or composted but still has energy value, converting it into electricity, heat, and fuel. Energy recovery from waste not only reduces the amount of waste requiring disposal but also helps address the country's energy shortage (Abedin et al., 2025).

However, WtE technology in Nigeria remains in its infancy, as there is no significant large-scale commercial adoption. While municipal solid waste offers significant potential for energy generation, the lack of proper collection, inadequate separation, insufficient investment, and poor infrastructure have hindered its development. Current research identifies possible avenues for implementing integrated WtE technology, especially incineration and anaerobic digestion, among others (Onungwe et al., 2023).

However, landfilling is regarded as the least desirable option in the waste disposal hierarchy due to associated environmental hazards, including methane emissions, groundwater contamination by leachates, and the loss of land resources. Despite these hazards, landfilling and open dumping remain the most common waste management methods in many developing countries, such as Nigeria (Diamond, 2024). The persistence of disposal as the default practice in such contexts underscores the urgency of developing viable alternatives, such as RDF production, which can simultaneously reduce reliance on landfills and generate usable energy from the combustible fraction of MSW.

3.2. Production of RDF

The production of RDF requires consideration of several relevant concerns.

Overview of Refuse-Derived Fuel (RDF)

RDF is a man-made fuel produced from MSW through mechanical and biological processing to enhance its heating value (Santos, Nobre, et al., 2023). Unlike MSW, which contains significant amounts of inert substances and is a rather diverse material, RDF is created after sorting out these substances (e.g., metals, glass, wet organics), thereby providing a homogeneous and fuel-rich material (Sharma et al., 2024). The main goal of RDF generation is to produce fuel from waste that can partially replace fossil fuels across various industries.

The main criteria for classifying RDF include the material's physical state, treatment level, and calorific value. RDF classifications include RDF-1, RDF-2, RDF-3, RDF-4, RDF-5, RDF-6, and RDF-7.

RDF-1 refers to unprocessed or minimally processed waste. RDF-2 and RDF-3 are characterized by a higher treatment level, including shredding and sorting. RDF-4 and RDF-5 denote highly treated RDF, with powder generation, pelletization, and briquetting. RDF-6 and RDF-7 relate to highly processed RDF, such as liquid and gas RDF (Rahayu et al., 2025).

Among these types, one may distinguish RDF fluff, RDF pellets, and RDF briquettes. Fluff RDF is mostly used in large combustion plants, while RDF pellets and briquettes have advantages over RDF fluff because they share similar properties

but have higher density, making them easier to transport (Rezaei et al., 2020). RDF classification plays a key role because it allows us to distinguish the best type of RDF for specific facilities.

Advantages and Limitations of RDF

The use of RDF offers significant environmental and energy benefits. First, it reduces the amount of waste sent to landfill sites by relieving pressure on land and minimising the negative impacts associated with the disposal and deterioration of solid waste (Sari & Zahra, 2025). Second, converting waste into a reusable energy resource supports the circular economy and reduces reliance on fossil fuels (Aslan et al., 2025).

From an energy perspective, RDF can serve as a fuel substitute in industrial operations, particularly in cement manufacturing (Hemidat et al., 2019). Using RDF in place of coal can reduce costs because of its high heating value, which enables the effective conversion of waste into usable energy (Sharma et al., 2024). At the same time, burning RDF can lead to lower greenhouse gas emissions than other fossil fuels (Salaripour et al., 2025).

However, some challenges may be encountered during RDF implementation. The first one is the variation of biomass properties, which affects the quality of fuel produced and could negatively affect the combustion process (Kaczyński & Pełka, 2024). Moreover, RDFs containing high moisture content and harmful substances, such as chlorides and metals, can cause complications, including the formation of corrosive materials and the production of toxic gases (Han et al., 2020). Also, significant investments will be needed to build RDF manufacturing plants, which should include shredders and dryers (Klinghoffer & Castaldi, 2013).

Several obstacles may be encountered while implementing RDF systems in developing countries, such as Nigeria. In particular, improper waste segregation, absence of experience and legislation, among others, may be regarded as serious barriers to RDF technology. The production of RDF consists of the following sequential processes.

Stages in RDF Production

The production of RDF consists of the following sequential processes.

Waste Collection and Segregation

RDF is generated through the collection and separation of municipal solid waste (MSW). This process is illustrated in **Figure 1** and is critical for determining the quality of the RDF produced. Effective collection ensures a steady supply of waste material for RDF production. Waste separation, on the other hand, ensures that only the combustible components of the waste are used to generate RDF, with the rest discarded (Nabi et al., 2024). In highly developed waste generation and management systems, separation occurs at the source (**Figure 1**), where households and institutions classify waste into organic, recyclable, and residual categories (Hajam et al., 2023).

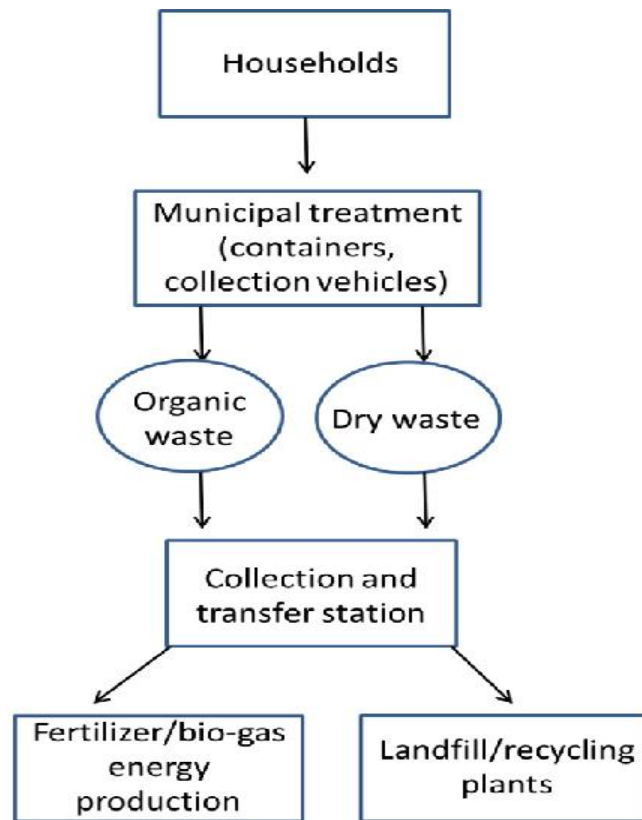


Figure 1. MSW source separation process (Lavee & Nardiya, 2013).

Nevertheless, in many underdeveloped nations like Nigeria, garbage collection is typically associated with heterogeneous waste mixes and inefficiency. The lack of segregation means that garbage will consist of various fractions, which include high-moisture-content organic material and also inorganic fractions like metals, glass, and dirt (Zhang et al., 2024). Therefore, further sorting will need to be done before proper fractions can be used for the manufacturing of RDF. The sorting methods could include manual separation by removing the waste products that will not be useful, or the use of equipment like the magnetic separator and eddy current separator (Sharma et al., 2024).

Fractions suitable for RDF include plastics, paper, cardboard, textiles, and certain types of wood. Organics with high moisture content are usually avoided or biologically dried, using metabolic heat from aerobic microorganisms to rapidly remove moisture from municipal solid waste or wet refuse-derived fuel (RDF) (Wahyanti et al., 2025), thereby lowering their moisture content (Gallardo et al., 2014). The effectiveness of sorting is critical for RDF because impurities can affect the calorific value, ash content, and emissions when RDF is burned (Tahir et al., 2024). Therefore, an effective waste collection and sorting system is essential for producing high-quality RDF.

Mechanical Processing

After collection and initial segregation, the chosen waste fractions then proceed through several mechanical treatment processes intended to improve their physicochemical characteristics with respect to fuel utilisation. The main purposes of mechanical treatment include particle size reduction, removal of any non-combustible

fraction, and homogenization of the feedstock. These processes are crucial for ensuring proper behaviour during combustion (Punin et al., 2013).

The process of particle size reduction generally involves shredding or grinding waste materials, crushing them into smaller, homogeneous particles. This operation may involve the use of primary and secondary shredders, depending on the required particle size (Sharma et al., 2024). While the former type of shredder is used to crush large waste materials into manageable sizes, the latter is used to produce fine particles for densification or direct combustion (Hasselriis & Mahoney, 2012).

Apart from being useful in decreasing the size of waste products, mechanical separation is employed in order to eliminate any impurities still remaining. Screening technology is also used to sort out the materials depending on the particle size. Magnetic and eddy currents are used to classify metal parts, which are removed to lower the ash content (Wang et al., 2024).

Mechanical Densification

Mechanical densification is an important step in creating RDF pellets or briquettes. This method involves compacting RDF under high pressure. Densification transforms loose refuse-derived fuel (RDF) into compact pellets or briquettes, greatly increasing its bulk and energy density. This process improves fuel handling, reduces storage space, and cuts transportation costs, enabling steady feeding into industrial systems like cement kilns (Santos et al., 2023). The densification process allows obtaining material with high bulk density that can be transported easily and requires less space for storage (John et al., 2023).

Thermal and Biological Pre-treatment

Both thermal and biological pre-processing techniques are commonly used to improve RDF quality by removing moisture and stabilizing organic content. Higher moisture content in waste lowers the net calorific value of RDF because some of the energy released during combustion is consumed to evaporate the moisture (Sharma et al., 2024). Therefore, moisture removal is a crucial step in RDF production, especially when the waste composition contains a high proportion of organic materials.

The most frequently utilised technique for moisture removal is thermal drying. In this case, heat is applied directly or indirectly for the purpose of evaporating water content from the waste material (Perazzini et al., 2015). Sometimes, waste heat from industrial or power plant processes is used to increase the efficiency of energy usage (Sarkar, 2015). The solar drying method has also been used for this purpose, but it is applicable only in sunny climates (Ahmad et al., 2021).

The biological pre-treatment is generally incorporated into Mechanical-Biological Treatment (MBT) systems, where the aerobic degradation of organic components occurs. This leads to heat generation by microbes; as a result, water evaporates from the waste, partially stabilising it. In this way, the organic component becomes bio-dried, possessing lower water content and higher calorific value; therefore, the waste is better suited for use as RDF (Al-Ghouti et al., 2020).

Apart from reducing the moisture level, these treatments also lead to odour elimination, pathogen destruction, and stabilisation of the biodegradable fraction (Famielec et al., 2024). However, proper regulation of parameters such as temperature and residence time is essential for achieving good results. Although such pre-

treatments complicate and raise the costs of RDF production, they are extremely important due to their beneficial effect on fuel properties (Edo-Alcn et al., 2024).

3.3. Utilisation of RDF

Refuse-Derived Fuel has found application across a range of energy-intensive industrial sectors as a substitute for conventional fossil fuels. Its utilisation is shaped by the calorific value, moisture content, and contaminant levels of the fuel, as well as the technical requirements of the receiving industrial process. This section reviews the utilisation of RDF in cement manufacturing, steel production, and electric power generation globally, while also examining the state and potential of RDF utilisation specifically within Nigeria.

3.3.1. Utilisation of RDF in cement manufacturing

The cement industry is the largest global consumer of RDF, owing to the enormous thermal energy demand of the clinker production process, which typically requires temperatures in excess of 1,400 °C (Wojtacha-Rychter & Smoliński, 2022). At such high temperatures, cement kilns are capable of achieving complete combustion of RDF and the destruction of organic pollutants and pathogens, while the alkaline environment within the kiln neutralises acidic combustion gases. A further advantage is that the inorganic residues in RDF are incorporated directly into the clinker matrix (Brbulescu & Hosen, 2025), leaving little or no ash requiring separate disposal, which makes cement co-processing one of the cleanest and most efficient pathways for RDF utilisation.

Research has demonstrated that a substantial proportion of the coal traditionally used in cement kilns can be substituted with RDF without compromising clinker quality (Ige & Kabeya, 2025). RDF derived from municipal waste has been reported to achieve calorific values of up to 25.1 MJ/kg, which is comparable to that of coal. In India, which ranks as the world’s second-largest cement producer, the cement sector has set a target thermal substitution rate (TSR) of 25% by 2025–2030, although the current median substitution rate remains between 6% and 10% (Jajal & Mishra, 2022). Europe consumes roughly 12 million tons of SRF/RDF in total, with cement kilns utilising a substantial portion (over 70% of plants co-processing waste). Germany alone utilises over 1.5 million tons annually. Similarly, in China, the largest cement producer globally, provinces such as Henan, Shandong, and Hubei are projected to replace 10–20% of coal usage with RDF by 2025, contributing to reductions in net CO₂ emissions relative to coal-fired kilns (Gao et al., 2024).

3.3.2. Utilisation of RDF in steel production

Beyond cement manufacturing, RDF is increasingly being explored as an alternative fuel and reducing agent in steel production, particularly in electric arc furnaces (EAF) and, to a more limited extent, blast furnaces. In Austria, RDF with a calorific value of 16–20 MJ/kg has been used to partially substitute coal in EAF processes, achieving CO₂ emission reductions of 20–30% alongside cost savings from reduced fossil fuel use and lower landfill disposal charges (Hemidat et al., 2019). Steel plants adopting RDF in place of coal have reported waste-management cost savings in the range of €50–80 per tonne in countries with high landfill taxation, such as Germany and Austria (Sharma et al., 2024).

The utilisation of RDF in steel production is not without technical challenges. Because RDF is compositionally heterogeneous, its variability in moisture content, particle size, and calorific value can disrupt the stable high temperatures required for consistent furnace operation. RDF may also contain trace chlorine and heavy metals, which can promote slag formation if not adequately controlled. As a result, high-performance fuel injection systems and robust emission control technologies are essential prerequisites for the reliable and compliant use of RDF in steel furnaces (Sharma et al., 2024). Research into RDF-derived carbonised material as a substitute for coke breeze in the iron ore sintering process has also shown promise, with pyrolysed RDF exhibiting heating values comparable to coke breeze and producing sintered ore of acceptable mechanical strength, indicating scope for RDF utilisation beyond direct combustion applications in the steel sector.

3.3.3. Utilisation of RDF in electric power generation

RDF is also utilised as a fuel for electricity and heat generation in dedicated Waste-to-Energy (WtE) power plants, typically employing fluidised bed combustion systems capable of accommodating fuels with variable chemical composition. This pathway is particularly valuable in densely populated urban areas where land constraints limit landfill capacity, as it simultaneously reduces the volume of waste requiring disposal while contributing to electricity and district heating supply.

Globally, over 2,500 WtE plants are in operation across more than 40 countries, processing approximately 300 million tonnes of waste annually, with Europe and East Asia dominating the sector due to strict landfill bans and supportive environmental legislation (World Energy Council, 2025). Germany, for instance, operates more than 150 waste treatment facilities that collectively treat over 25 million tonnes of waste per year and generate approximately 10 TWh of electricity annually, in addition to supplying district heating to thousands of households (European Commission, 2022). Japan similarly relies heavily on WtE for power generation, having generated approximately 59.2 TWh of energy from WtE facilities in 2024, driven by land constraints and supportive policy frameworks (Moshkal et al., 2024).

Research has also shown that low-calorific-value waste fractions can be blended with higher-calorific-value combustible materials to produce an RDF suitable for efficient combustion in power plant boilers. In Shanghai, China, such blending practices are used to optimise power generation efficiency from otherwise heterogeneous municipal waste streams (Gao et al., 2024).

3.3.4. Utilisation of RDF in Nigeria

The utilisation of RDF in Nigeria remains at an early and largely exploratory stage compared to its application in more industrialised economies. Nonetheless, growing interest has been observed, driven by the rising cost of imported coal and natural gas and the urgent need to address the approximately 32 million tonnes of MSW generated annually in the country (World Bank, 2024).

The most advanced application of RDF in Nigeria is co-processing in cement kilns. Major cement producers, notably Dangote Cement and Lafarge Africa Plc, have begun testing alternative fuels, including biomass and RDF, on a pilot and partial-substitution basis at plants such as Ibese, Ewekoro, and Obajana. These initiatives remain limited in scale, and full commercial-level co-processing of RDF has yet to

become widespread across the Nigerian cement industry, indicating that the sector remains in a nascent phase of adoption.

Beyond cement kilns, RDF is beginning to attract interest for use in decentralised industrial boilers within medium-scale industries such as food processing and textile manufacturing, where RDF pellets can be fed into specialised boilers to generate process steam. The University of Nigeria, Nsukka (UNN) uses a 500 kVA refuse-derived fuel gasification plant to convert organic waste, sawdust, and agricultural by-products into affordable, clean electricity for its campus (University of Nigeria, Nsukka, 2021). Proposals for RDF-based power generation using fluidised bed combustion have also emerged in densely populated cities such as Lagos, Abuja, and Port Harcourt, although most such projects remain at the feasibility or pilot stage rather than full commercial operation (United Nations Industrial Development Organization, 2021). RDF is also being explored, on a much smaller scale, in the production of low-cost building materials, where the plastic fraction of RDF is melted and combined with sand or ash to produce bricks or tiles.

Nigeria's potential for RDF application is underpinned by both the scale of its waste generation problem and its persistent energy deficit. With a population exceeding 220 million and MSW generation of approximately 32 million tonnes annually, Nigeria possesses a substantial and growing feedstock base for RDF production (World Bank, 2024). Although organic waste currently dominates the Nigerian waste stream, accounting for 50–65% of total MSW, the proportion of plastics and packaging waste is rising with increasing urbanisation and commercial activity, gradually improving the combustible, high-calorific fraction available for RDF production (Aderoju et al., 2019).

On the demand side, Nigeria's energy crisis, characterised by a national grid operating within a range of only 3,000–5,000 MW to serve a population of over 220 million people, creates strong economic incentive for energy-intensive industries such as cement and textiles to adopt lower-cost alternative fuels. The Electricity Act of 2023 has further strengthened the enabling environment for RDF utilisation by decentralising the power sector and providing legislative definitions that support the inclusion of waste-derived fuels in the national energy mix (Orunoye et al., 2024).

The cement sector offers the most immediate and commercially viable opportunity to scale RDF utilisation in Nigeria, given the country's large cement production capacity and the precedent set by pilot co-processing initiatives at major plants. Additional potential exists in decentralised industrial process heating and in emerging RDF-to-power proposals in major urban centres. However, realizing this potential will require overcoming barriers such as high capital costs, limited local technical expertise, inconsistent waste sorting infrastructure, and the absence of dedicated waste-to-power feed-in tariffs at the state level (Maiha & Yusuf, 2025).

3.4. Environmental impact of using RDF as a fuel

3.4.1. Air quality and emissions

The combustion of RDF, like other solid fuels, generates a range of air pollutants whose type and concentration depend on the composition of the waste feedstock and the combustion technology employed. Because RDF is derived from heterogeneous

municipal waste, it may contain trace quantities of heavy metals such as lead, cadmium, and mercury, along with chlorine-bearing materials, primarily from PVC plastics. When combusted without adequate Air Pollution Control (APC) systems, RDF combustion can release particulate matter, hydrogen chloride, hydrogen fluoride, sulfur dioxide, nitrogen oxides, heavy metals, and, in some cases, dioxins and furans (Sharma et al., 2024).

The chlorine content of RDF is of particular concern because it not only contributes to the formation of toxic dioxins and furans but also causes high-temperature corrosion in combustion equipment such as boilers, thereby reducing operational lifespan and increasing maintenance costs. Similarly, elevated ash content from high contaminant levels can lead to slag formation, further compromising combustion efficiency (Sharma et al., 2024).

Despite such risks, there are studies indicating that the use of RDF as a replacement fuel for coal in industrial applications can actually lead to a reduction in the emission of particular pollutants. For instance, burning RDF instead of coal in thermal power stations and cement kilns can reduce sulfur dioxide and nitrogen oxide emissions by up to 15–20%, because RDF has less sulfur than coal and the alkaline environment in cement kilns reduces acidic gases (Sharma et al., 2024). However, it should be noted that to ensure the same effect, it is necessary to implement effective air pollution control systems, such as scrubbers and particulate filters, as well as quality control of RDF feedstock.

3.4.2. Resource conservation and circular economy

Beyond its direct emissions profile, RDF utilisation offers significant environmental benefits through resource conservation and its alignment with circular economy principles. By diverting the combustible fraction of MSW away from landfills, RDF production substantially reduces the volume of waste requiring final disposal, which in turn reduces methane emissions from landfills. Methane is a potent greenhouse gas, with a global warming potential approximately 28 times that of carbon dioxide over a 100-year timescale, making landfill diversion through RDF production a meaningful contributor to climate change mitigation (Wiharja et al., 2024).

The circular economy perspective reframes MSW not as waste to be discarded but as a secondary resource from which materials, nutrients, or energy can be recovered (Geissdoerfer et al., 2018). Within this framework, RDF production exemplifies resource recovery by concentrating the energy-rich fraction of waste, comprising plastics, paper, and textiles, into a usable fuel. In contrast, the RDF production process itself facilitates the prior recovery of ferrous and non-ferrous metals through magnetic and eddy current separation, further conserving virgin material resources that would otherwise require energy-intensive extraction and processing.

By substituting fossil fuels such as coal and natural gas in cement kilns, steel furnaces, and power plants, RDF utilisation also reduces the depletion of non-renewable fossil resources. It lowers the net carbon footprint of the industries adopting it. Studies have shown that integrating RDF into cement kiln operations can reduce CO₂ emissions by 25–30% compared to conventional fossil fuel use, reflecting both the substitution effect and the avoided emissions from landfill methane generation

(Sharma et al., 2024). Collectively, these resource-conservation and circular-economy benefits reinforce the case for RDF as a sustainable waste management and energy recovery strategy, particularly in resource-constrained and energy-deficient contexts such as Nigeria.

4. Conclusion

RDF offers a possible approach to converting the flammable component of Nigeria's increasingly abundant MSW waste stream into an industrial fuel. According to the literature review, RDF has been applied in cement manufacturing, steelmaking, and power generation; the latter is the more relevant option for the country in the short run. However, it must be kept in mind that, at present, the country's waste streams are heterogeneous; their high moisture content, lack of segregation infrastructure, required financial investment, and other technical considerations make the use of RDF on a large scale not feasible.

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