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Review Paper

A Review on the Disposal Methods with Intrinsic Environmental and Economic Impacts of Scrap Tyres in Nigeria

Francis B. Elehinafe[1], **Yebtemiya J. Hassan**[1], **Queen E. Ebong-Bassey**[1], **Adewole J. Adesanmi**[2]

[1]Department of Chemical Engineering, College of Engineering, Covenant University, Nigeria
[2]Laboratory Research and Bio-resources Development Centre, Akoko, Ondo State, Nigeria

francis.elehinafe@covenantuniversity.edu.ng

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Abstract

The rapid increase in the amount of tyres discarded yearly leads to the problem of scrap tyres littering the country, Nigeria thereby leading to environmental pollution. This paper looks at the extent of the menace scrap tyres has caused, the methods of their disposal and the effects on the environment. The study calls for a concerted effort from researchers, industry operators and regulatory bodies to be up and doing in the disposal of scrap tyres in Nigeria to check the degradation of the environment in its three compartments: air, water and land, with a view to upholding environmental sustainability and embedded economic advantages.

Keywords: Tyres; Scrap tyres; Disposal methods; Environment; Regulation

1. Introduction

Waste known as "scrap tyres" otherwise known as "end-of-life tyres" (ELTs) are municipal solid wastes rather than hazardous wastes which have outlasted all of their reuse options and ceased to serve their initial purpose. In their original state, they are non-reusable tyres [1]. The scrap tyres are discarded when they have been confirmed that the used tyres cannot be reused or rebuilt, and then the recycling/recovery process begins [2]. The modern society's vast industrialization and urbanization have led to an increase in the dependency on different vehicles for numerous purposes [3], resulting in the increase of scrap tyres, which pose severe health concerns, and environmental problems owing to disposal process mismanagement [4], [5]. From the early period of a tyre usage, its disposal has been a key environmental problem globally. In many countries today, piles of tyres at scrapyards, landfills and other places are common.

The volume of scrap tyre generated in major cities and towns across Nigeria is gradually increasing due to rapid urbanization and changing ways of life. In Nigeria, approximately 259 million tyres are discarded annually [2]. In 2020, the population of Nigeria was estimated to be 206 million with Lagos State being the most economically and industrialized state in the country, having a population estimate at 14,368,332; making it one of the most populous states in Nigeria [2], [6]. It is the heart of commerce and industry in Nigeria. There are three major landfills serving the Lagos metropolitan and of these three, one is the largest in Africa and the largest in the world.

The production of scrap tyres only in Japan, the EU and USA, the majour suppliers to Nigeria, is about 6 million tons occurs yearly [7]. Study shows there will be an increase in the quantity of waste tyres with continued growth in the allied automotive industry. The disposal of scrap tyres becomes a serious environmental problem, as such this accumulation of discarded waste tyres leads to environmental pollution. Enormous fractions of scrap tyres are dumped in sites where they represent hazards such as diseases and accidental fires. Biologically, rubbers are not degradable, hence, creating problems with its disposal [7].

Tyres are unwelcome in landfills due to their high volumes and 75% vacant space, which quickly consumes space, which is valuable. Open burning with emissions of high pollution may cause accidental fire. Landfilling of waste tyres was widely adopted in the past and it is still practiced in some countries [8]. The disposal of scrap tyres by combustion causes the release of harmful and toxic materials into the environment. The burning of tyres can last a long while due to its properties and its highly flammable nature which allows it to serve as a substitute to fuel in areas where fuel is not readily available or too costly for the people.

Nowadays, technology is growing at alarming rates and scrap tyres in enormous quantities, Nigeria should begin to see scrap tyres as raw materials and not wastes in view of her economic status in comity of nations. In a global environment, there are no wastes, only products as stated in the work of [9]. Scrap tyres contain a large amount of rubber, a polymeric material, that can also be used as feed materials to create new polymeric products. The steel rods in scrap tyres can also be recycled.

2. Methodology

This review paper was prepared considering modern protocols for review and literatures from diverse authors. Research papers were reviewed from different databases like ScienceDirect, ResearchGate, Google scholar, and Scopus as instructed in [10]. The search covers review papers like the term papers, journals and conferences all based in English. The searches cover work from the year 2000 to 2021. The authors conducted an initial analysis of the literature obtained from the keyword search.

3. Tyres and Their Components

Typically inflated or surrounded in an inflated inner tube and covered in a rubber covering, tyres are placed round a wheel to form a soft contact with the road. A component, which is ring-shaped surrounding a wheel's rim in transferring the load of a vehicle through the wheel, from the axle to the ground and making available traction over which the wheel travels on the surface. [11] noted that structural composites, which are highly, engineered, whose performance can be calculated by design to meet the ride, handling, and traction criteria of the vehicle manufacturer, in addition to the performance expectations of the customer and quality.

Natural and synthetic rubber, wire and fabric, alongside carbon black and other chemical compounds are materials of modern pneumatic tyres. Chemical composition majorly for tyres include natural and synthetic rubber polymers, sulfur and sulfur compounds polymers, oil fillers, polymers of phenolic resin, aromatic, petroleum waxes, clay, fabric, paraniffic and naphthenic oil, pigments like oxides of titanium and zinc oxide, fatty acids, carbon black, inert materials then fiber from polyester, nylon, and steel [12]. **Table 1** gives the various ingredients breakdown used in tyre production [13]. While the main components for a typical tyre, are shown in **Figure 1**.

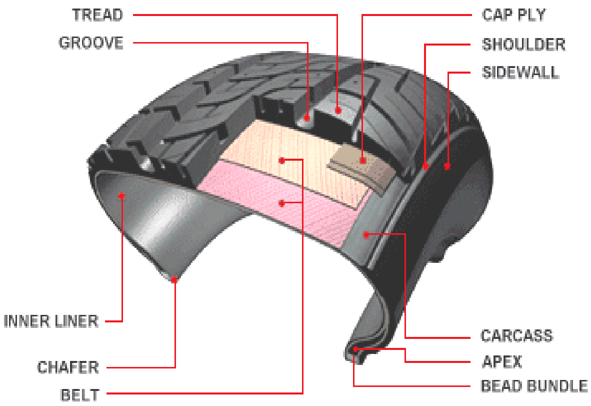

Figure 1. Structure of a tyre [12]

Table 1. Comparison of tyre ingredient breakdown for car and truck

Tyre Ingredient	Car Tyre (%)	Truck Tyre (%)
Natural rubber	14.0	27.0
Synthetic rubber	27.0	14.0
Fillers (carbon black,silica)	26.0 – 28.0	26.0 – 28.0
Plasticizers (oil and resin)	5.0 – 6.0	5.0 – 6.0
Chemical additives (sulphur,etc.)	5.0 – 6.0	5.0 – 6.0
Metal for reinforcement	16.5	25.0
Textile for reinforcement	5.5	-

Source: [6].

Tyres account for the vast majority of rubber products, which explains the focus on reintroducing used tyres into the profitable circuit while avoiding pollution. In today's world, close to a billion tyres are produced each year in over 400 tyre factories. As a result, the recycling millions of used tyres potential is evidently significant [14]. Scrap tyres are a significant indication landfill that, due to their structure, composition, and material quality, may be difficult to dispose of. Rubber accounts for 70-80% of the tyre mass, with the remainder made up of textile overlays and steel belts, which are separated from the rubber during recycling [14]. In Nigeria, heaps of scrap tyres are piled up and disposed of in landfills and open dumpsites. The following are some terms to know when discussing scrap tyres:

4. Methods of Disposal of Scrap Tyres

4.1. *Landfilling*

Dumping into open areas and landfilling are two less desirable options for tyre disposal that have become increasingly unpopular in recent years. Waste tyres of about 4 billion are currently piled up around the world [15]. Massive scrap tyre landfills and piles are management practices which cannot be sustained that cause a slew of environmental and health issues. They not only take up a lot of space (75 percent void space), but they also house a lot of mosquitos, pests, and other creatures that spread unknown contagious diseases [16]. Metal and other material leaching are threatening to the environment because it is eco-toxic and can lead to the adulteration of water and soil. Several research has been conducted to examine the various sides of environmental leaching, and it has been determined from tyre landfills, that the leachate is toxic, being unbearable to aquatic lives. Despite the fact that leachate from crumbed tyres or metal fragments is more toxic, whole tyres are more likely to be landfilled. Some factors can be considered when calculating the amount of pollution caused by tyre landfilling. It is critical to consider the landfilled tyres sizes.

Whenever whole tyres are piled up, the leachate is likely to be slower than when shredded tyres are piled up. Leaching may be accelerated by high permeability soil, while the length of time the water is in contact with the tyres influences leaching [17]. One of the most serious risks of landfilling to both the human health and environment is the possibility of an uncontrolled fire [18]. Igniting tyres are relatively challenging; nonetheless, tyre fires are extremely difficult to put out. The report of several incidents are filed and the likely consequences of pollution and health issues have been recognized. The gases emitted by tyre fires are high in oxides of sulfur, CO_2, CO, and to both humans and the environment, are hazardous. Firefighting and cleanup from tyre fires are expensive. It cost a landfilling area in Queensland, Australia nearly $750,000 (AUD) for fire extinguishing in 1992 and cleaning up of the site. All of these issues indicate that there are advantages moving toward more sustainable management practices from landfilling scrap tyres.

4.2. *Retreading and reuse*

The vulcanizing (outer layer) and replacement of a tyre with a new layer of rubber is Retreading [19]. To uncover whether or not a tyre can withstand the retreading process, the tread must first, be inspected visually. Likewise, the tyres internal construction should be inspected using an X-ray machine. Natural rubber (NR), styrene-butadiene rubber (SBR), polybutadiene rubber (PBR), and chloroprene rubber (CR) for special applications are commonly used to retread tyres [20]. There are two methods for retreading: cold cure and hot cure. Commercial vehicle tyres are subject to the cold cure method. Because it has no effect on the interior structure, this method can be used repeatedly. A layer of rubber mixture containing NR, SBR, and PBR, in the cold method is pressed on the tyre and vulcanizing occurs at 100 °C for 4–5 hours, which is dependent on the tread pattern and size required. Hot cure retreading, on the other hand, can only be used once on passenger car tyres. On the tyre, a new layer of rubber is formed in this method, and the vulcanizing at 150 °C to 180 °C occurs for the entire tyre to mold the tread pattern.

Retreading may be considered a solution to tyre disposal problem [21]. The required energy to manufacture a new tyre completely is greater 2.3 times than it is to retread a used tyre. Owing to truck tyres high resistance, retreading may occur three to four times, so it may be justified from an economic standpoint. Retreaded tyres, on the other hand, for passenger cars, racing cars, and airplanes are commonly undesirable owing to their quality which is low [22]. End-of-life tyres not fit for retreading are reused in their novel form for a variety of purposes. Owing to their highly elastic nature, scrap tyres are an abundant and inexpensive material suitable for shock and vibration absorbers (example, in motor racing circuits). Preventing knocks on the sides of boats is another application. Scrap tyres can also be used to make highway embankments, concrete mixtures for asphalt pavements and building foundations [23].

4.3. *Energy recovery*

With 29 – 39 MJ/kg which is considered to be a high heating value, waste tyres are approximately composed of 90 percent organic materials, allowing them to be used as a great fuel source (known as tyre derived fuel-TDF) through incineration in a variety of applications [24]. Tyres can be used whole (without being downsized) or processed into shredded powder or pieces. Because TDF has a higher heating value than coal, it is an excellent fuel for use in a variety of combustion applications such as boilers, smelters, and cement kilns. The combustion of TDF is less hazardous to the environment than coal combustion due to emissions, which are lower [25]. Due to the obvious extreme temperatures of cement kilns, tyres can be used exclusively instead of coal in this industry [26]. Coal combustion emissions have been identified as a major environmental issue in recent years, and extensive efforts have been made to resolve this issue for clean coal combustion. Tyre-coal co-combustion is an efficient energy recovering technique from waste tyres while also facilitating waste disposal and lowering air pollution. Scrap tyres, whether shredded or ground, can be co-combusted with coal in other industries such as boiler and furnace thermal efficiency increase, lowering emissions, and electricity generation [26]. Many researchers proposed co-firing pulverized coal and scrap tyre particles to reduce CO_2.

Using a pilot plant (80 kW), [25] investigated the tyre rubber co-firing and pulverized coal. This demonstrated the reduction of pollution to about 80 percent and that co-firing of coal and tyres directly led to a reduced production in NO quantity. In a related research, [24] investigated NO_x emissions from the re-burning of waste tyre pulverized fuel. Owing to over 60% of its high volatile hydrocarbon content, scrap tyres have the potential to be used as fuel. Furthermore, as sources rich in hydrocarbon radicals, as well as the presence of hydrocarbons gas such as CH_4, C_2H_6, C_3H_8, C_4H_8 and C_4H_{10}, has transformed tyres into a potential material capable of reducing NOx. Different particle sizes were tested on tyres, and 250 m particles were found to be suitable. Using waste shredded tyre, a reduction in NO_x was reported of about 81 percent. [27] investigated a mixture of 95 percent coal and 5 percent shredded scrap car tyre combustion in a stoker boiler and discovered that when the scrap tyre was added, there was insignificant reduction in CO emissions.

Presently, a significant portion of scrap tyres is maximized in energy recovery, particularly in cement kilns. Cleaner combustion with lower nitrogen oxide emissions is expected due to high temperatures in kilns and lower nitrogen contents in tire-derived fuel. Furthermore, steel contained in tires provides a rich source of iron for the production of cement, reducing the need for shales and clays and, as a result, nitrogen oxide emissions [28]. Despite the fact that it consumes a large volume of tires and saves fossil fuels, energy recovery is not considered an optimal solution from an environmental standpoint. Compared to only 2% in recycling, there is a loss of three-quarters of the energy required in new tyre production in controlled combustion of tyres for energy recovery results [29]. There is also concern about the emissions of air pollutants such as sulphur dioxide in the combustion of tire-derived fuel, which contains a similar amount of sulphur as fossil fuels. High costs are required to develop the required technology as well as install and operate special types of incinerators in order to control the amount of air pollutants produced. According to [30], energy recovery is less advantageous than retreading and mechanical recycling in terms of energy savings and carbon dioxide (CO_2) emissions. When compared to incineration in a cement kiln, energy saved and CO_2 reduction by retreading can be as high as 80 GJ and 6.0 ton per ton waste, respectively, whereas mechanical recycling saves 55 GJ of energy and reduces 3.5 ton of CO_2 per ton waste.

4.4. *Scrap tyre recycling*

Recycling is certainly a disposal strategy, but it can be viewed as one current example of implementing the concept of industrial ecology [31]; however, in a global environment, there are no wastes, only products [9]. Because waste tyres contain a large amount of rubber, a polymeric material, they can also be used as feed material to create new polymeric products. Scrap tyres must first be shredded or ground before they can be blended into a polymeric raw material. Diverse shredding modalities could help us reduce the size of this tough material in order to prepare tyres for new polymeric production. Grinding is a complex process, and because tyres have a good tensile property, highly specialized mechanical equipment capable of shredding and grinding tyres to an appropriate size and purity is required [32]. Crumb rubber is created by grinding scrap tyres into extremely fine particles, and it is being used as a feedstock for producing other rubber materials, fuels [33]; [34] and other components. The main drawback of this approach is that the textile and steel used in tyre manufacturing must first be removed. It's worth noting that the removed textile and steel are both recyclable and sellable materials. Furthermore, after cleaning, the textile can be repossessed either by saving energy (textile combustion) or by producing insulation [34]. Grinding techniques include cryogenic, high-pressure, wet, and mechanical grinding.

4.5. *Open burning*

Landfills across the country are overflowing with scrap tyres that have been discarded there for disposal or recycling. Scrap tyres do not degrade on their own and actions have not been taken to handle the safe disposal or recycling of the tyres for other purposes. Scrap tyres are made of not only rubber but also other aggregates like steel cords. So, the open burning (**Figure 2**) of tyres cause hazardous emissions and other chemicals to release into the air without control or treatment [35]. The major environmental problems faced are air, water and land pollution. Open burning of scrap tyres producing uncontrolled fires are difficult putting out and threatening safety, environment, and health of the public. Thick black toxic smoke and residues and hazardous gaseous emissions from the uncontrolled burning of scrap tyres pose a direct threat to the public [36].

The chemical run-off released during burning can contaminate rivers, ground water and surface water causing problems to health and providing a suitable breeding ground for mosquitoes. There are by-products of burning tyres which are ash, black carbon, pyrolytic oil, smoke and other substances that adversely affect public health. The amount of heat produced during the burning of tyres are in large amounts and this causes pyrolytic reactions to occur leading to pyrolytic oil production as well as other chemical compounds like benzenes, polycyclic aromatic, naphthalene, ethyl benzene, toluene, thiazoles, anthracene, furans, dioxins, furans, amines variety of petroleum hydrocarbons [37], [38]. Some major by-products and heavy metals are zinc, chromium, cadmium, carbon monoxide, nickel, Semi-volatile Organic Compounds (SVOCs), Volatile Organic Compounds (VOCs), nitrogen oxides, particulate matter, Polynuclear Aromatic Hydrocarbons (PAHs), sulfur, sulphates, acid gases and others.

The burning of scrap tyres at landfills close to residential areas increases the mortality rate as inhaling of the fumes and smoke released from the burning regularly leading to possible health complications as breathing problems and other related problems [39]. Within residential quarters, the posed risk by fires from landfill in Nigeria is high where landfills are sited, lacking systems of landfill gas collection and harboring large volume of scrap tyres. These fires burning for long allows buildup of the by-products of burning around surrounding homes. The release of emissions into

Figure 2. A typical open burning scenario in Nigeria

the air by the act of burning of scrap tyres causes an increase in the amount of pollutants present in the air at any given time. This affects the environment by reducing the air quality of the surrounding area to dangerous levels which is determined by the set AQI standards and the respective health messages. The higher the AQI values the higher the mortality rate as the contaminated air is breathed in which could result in various health challenges which sensitive groups are more susceptible to; infants, women pregnant and the elderly are.

5. Conclusion.

It is evident that there is rapid increase in the amount of tyres discarded yearly which causes the problem of scrap tyres littering the country, Nigeria thereby leading to environmental pollution. The methods of disposal highlighted have merits and demerits. Nigeria should begin to see scrap tyres as raw materials and not wastes in view of her economic status in comity of nations. This can provide jobs for the teaming youths and reduction in importation. In a global environment, there are no wastes, only products. Scrap tyres contain a large amount of useful contents that can also be used as feed materials to create new products.

6. Recommendation

Going by the environmental impacts of scrap tyres. It is recommended that recycling and retreading and reuse methods of disposal be adopted in Nigeria which will even enhance her economic status. This can provide job opportunities for the teaming youths and reduction in importation. The political will of the government is imperative to curb the current environmental menace emanating from scrap tyres from various automotive engines plying roads in Nigeria. Nigerian government has put mechanisms of regulation in place for collection of the scrap tyres to the designated centres for recycling and retreading.

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Contribution to the SDGs

The research contributes to the SDGs in the following categories:

- The environmental pollution due to scrap tyres is highlighted.
- The methods of disposal are identified for control.

Author's Declaration

Authors' contributions and responsibilities

First author conceived the idea, second author critically reviewed the manuscript and corrected the errors, third author gathered the materials for the review while the fourth author put the materials together.

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