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ENVIRONMENTAL IMPACTS OF PETROLEUM PRODUCT DISTRIBUTION ON SOIL QUALITY AND ECOSYSTEMS IN NIGERIA: A BRIEF REVIEW

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Abstract

This review explores the effects of petroleum product distribution on soil quality and ecosystems in Nigeria. This paper examines the adverse impacts of distributing petroleum products on the environment, with a specific emphasis on soil ecosystems. The harmful hydrocarbons in the soil have negative consequences for soil nutrient levels, water-holding capacity, and microbial function, with potential impacts on agriculture, biodiversity, and human well-being. Previous studies show that soil contamination in Nigeria due to petroleum product distribution presents complex challenges, such as insufficient monitoring and enforcement, limited financial resources for clean-up, and a fragmented regulatory framework. Thus, this review emphasizes the importance of improving regulatory frameworks, monitoring and enforcement mechanisms, and public awareness and education initiatives to reduce the negative impacts of petroleum product distribution on soil. Efficient measures are required to prevent and restore soil contamination, including spill response protocols, infrastructure maintenance, and cooperative relationships among governmental entities, industries, and local communities. Recommendations were drawn on the significance of pollution control, sustainable management practices, and community engagement in preserving environmental quality and supporting ecosystems for the benefit of nature and communities.

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Keywords: Heavy Metal, Soil Pollution, Environmental Effects, Petroleum Products Distribution, Ecosystems.

1.0 BACKGROUND OF STUDY

The issue of environmental pollution and contamination arising from the distribution of petroleum products in Nigeria has emerged as a prominent area of concern in recent years (Ogundele et al., 2019; Olatunji & Afolabi, 2020; Peter et al., 2023). Mafulul et al. (2022) opined that adverse consequences of the infiltration of hazardous hydrocarbons into the soil have been extensively studied due to their detrimental impact on various soil properties and processes. These hydrocarbons, which include toxic compounds derived from petroleum and other sources, have been found to significantly affect soil nutrient availability, water retention capacity, and microbial activity. Consequently, these effects can have far-reaching implications for crucial aspects such as agriculture, biodiversity, and human health (Ogundele et al., 2019). The present review seeks to investigate the potential environmental consequences associated with the distribution of petroleum products in Nigeria, specifically focusing on its effects on soil quality and ecosystems. This study utilizes a review of published journal articles in Scopus, google scholar and other material related to environmental concerns to analyze the available data and identify the central theme. It emphasizes the importance of implementing more robust regulatory frameworks, monitoring and enforcement mechanisms, as well as public awareness and education initiatives to address the negative impacts associated with the distribution of petroleum products on soil.

Furthermore, an extensive review of the adverse effects related to the distribution of petroleum products, with a particular emphasis on its impact on soil ecosystems. The prevention and restoration of soil contamination have become critical concerns in environmental research. It is imperative to adopt a comprehensive approach that includes the development of effective spill response protocols, the allocation of resources for infrastructure maintenance, and the promotion of collaborative partnerships among governmental bodies, industries, and local communities. The study findings tend to highlight the significance of pollution control, sustainable management practices, and community engagement in preserving environmental quality and promoting the well-being of ecosystems and communities. Several studies (Matemilola et al., 2019; Oyibo et al., 2018; Peter et al., 2023) have reached a consensus regarding the effects of petroleum products on the environment. However, there has been a lack of research on the environmental repercussions related to the distribution of petroleum products in Nigeria, specifically concerning soil quality and ecosystems. Through the process of conducting a comprehensive analysis, this research brings attention to the pressing need for enhanced regulatory frameworks, monitoring and enforcement mechanisms, and public awareness and education initiatives. The implementation of these measures is of utmost importance to adequately tackle and reduce the harmful consequences resulting from the spread of petroleum products on soil. The objective of this study is to enhance the current understanding by analyzing the effects of pollution in the areas under investigation. The results obtained provide valuable insights into the degree of pollution and emphasize the

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importance of recognizing both local and widespread origins of heavy metal pollution. The understanding of these insights is essential for the advancement and execution of efficient pollution control strategies.

2.0 NIGERIA'S PETROLEUM INDUSTRY

The petroleum industry in Nigeria is an essential part of the economy of the country since it is the primary generator of revenue and a significant contributor to earnings in foreign currency (Gokay, 2019). However, the oil and gas industry in Nigeria has a considerable impact on the surrounding environment due to the transportation of petroleum products (Yang et al., 2013). Globally, the distribution of petroleum products has a varied impact on the environment and causes a variety of problems for the country's ecosystems (Hack et al., 2014). The process of distribution comprises moving crude oil, refined products, and natural gas via pipelines, tankers, trucks, and other modes of conveyance (Jishin Jayan et al., 2021). This movement can take place in a variety of locations. Unfortunately, this distribution infrastructure frequently suffers from operational failures, inadequate maintenance, and unintentional spills, which result in the pollution of soil, water, and air, as well as the deterioration of ecosystems (Hewelke et al., 2018). According to Amadi et al. (2021), the petroleum industry in Nigeria is an essential part of the economy of the country since it is the primary generator of revenue and a significant contributor to earnings in foreign currency. Because of its vast oil reserves, Nigeria is one of the most important oil-producing countries in Africa (National Bureau of Statistics, 2021). Nigeria is well known for its massive oil reserves (Oyeneyin, 2014).

On the other hand, the transportation of petroleum products throughout the country has significant effects on the environment that cannot be ignored (Oluwole & Ojekunle, 2016). This paper, therefore, offers a brief review of the petroleum sector in Nigeria, with a particular emphasis on the adverse effects on the environment that are created by activities related to transportation. The discovery of oil in the Niger Delta region in the 1950s was the beginning of a prosperous era for the petroleum sector in Nigeria, which has a long and illustrious history (Anyanwu, 2012). Since that time, the industry has been an essential contributor to the formation of the economic landscape of the country. Multinational oil firms control the majority of Nigeria's petroleum industry, and the organization, as mentioned above, works in conjunction with the Nigerian National Petroleum Corporation (NNPC) to produce oil and natural gas through joint ventures and production (Zhang et al., 2019).

2.1 Environmental Impacts of Nigeria's Petroleum Industry

These environmental repercussions have far-reaching ramifications that affect biodiversity, human health, and the general sustainability of natural resources (Akhigbe et al., 2019). These environmental challenges must be addressed. It necessitates the adoption of stringent regulations, the construction of improved infrastructure, and the strengthening of monitoring and enforcement mechanisms in order to reduce the negative impact that petroleum product transportation has on the surrounding environment (Gorelova et al., 2022). In the petroleum industry, one of the most essential links in the

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value chain is the transportation of various petrochemical products (Ezemonye et al., 2019). It entails transporting crude oil from producing sites to refineries and then distributing refined petroleum products to a variety of markets located throughout the nation (Zhu, 2022). Pipelines, marine vessels in the form of tankers, and road tankers are all components of Nigeria's transport infrastructure.

Nevertheless, there are significant environmental repercussions associated with the transportation of petroleum products in Nigeria. The spilling and leaking of oil during distribution is one of the activities that has the most significant impact on the environment (Xin et al., 2022). Accidents, pipeline corrosion, vandalism, or inadequate maintenance of infrastructure can all lead to these types of spills. However, Ansa & Akinrotimi (2018) argued that oil spills can contaminate agricultural fields, wetland areas, and water bodies, which can have catastrophic effects on the ecosystem. The spills not only endanger aquatic life but also have an adverse effect on the means of subsistence for residents who are dependent on the resources that were contaminated. However, Okhimamhe & Okelola, (2013) opined that another unfavourable effect of activities related to the transportation sector of the petroleum industry is air pollution. Pollutants like sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter, and volatile organic compounds (VOCs) are released into the atmosphere when marine boats, tankers, and trucks release their emissions into the atmosphere. These emissions contribute to air pollution.

Consequently, the study by Weldeslassie et al. (2017) opined that these pollutants have a negative impact on air quality and have been linked to an increased risk of respiratory illnesses, cardiovascular diseases, and other health problems in populations that are in close proximity to them. In addition, the distribution of petroleum products in Nigeria presents additional dangers, including the possibility of accidents and explosions (Ambituuni et al., 2015a). It is not uncommon for tanker trucks that are transporting petroleum products to be involved in road accidents, which frequently result in fatalities, injuries, and property damage. These occurrences not only result in human casualties but also lead to fires and explosions, which further exacerbate the impact on the environment and pose a threat to the populations that are located nearby (Obasanjo et al., 2014).

2.2 Petroleum Distribution and the Environment

The relationship between transportation and environmental systems is a contradiction due to the fact that transportation has significant positive effects on socioeconomic systems while at the same time having a negative impact on environmental systems (Yılmaz et al., 2016). On the one hand, distribution activities are associated with environmental consequences resulting from transport activities that support growing mobility demands for passengers and goods. In addition, environmental factors affect distribution systems in terms of operating conditions and requirements for infrastructure, such as building and maintenance. The increased mobility of both passengers and goods has increased the importance of transport as a contributor to the release of pollutants into the atmosphere. According to Anifowose & Odubela (2015), the total contaminants are more of a function of the pollution factor of each mode of transportation than the activity level of those modes,

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which implies a wide range of adverse effects on the surrounding environment. These effects can be broken down into three categories:

1. Effects felt immediately. The direct and immediate impact that transport activities have on the surrounding environment, where the link between cause and effect is generally transparent and well recognized, Noise and carbon monoxide emissions are two examples of things that are well known to have direct negative consequences.
2. Effects on third parties: the effects that transport activities have on environmental systems at a secondary or even tertiary level have a more significant influence than direct impacts, despite the fact that the linkages involved are sometimes misunderstood and are more challenging to demonstrate. For instance, particles, which are predominantly the result of incomplete combustion in an internal combustion engine, are indirectly related to respiratory and cardiovascular illnesses due to the fact that they contribute, amongst other variables, to the development of such conditions.
3. Consequences piled up over time. The cumulative, additive, multiplicative, or synergistic effects of actions related to transportation of various repercussions, both direct and indirect, that an impact may have on an ecosystem, which can frequently be unforeseen. The result of climate change is the cumulative effect of a number of elements, both natural and artificial, including transportation, which plays a role. The causes and effects of climate change are complicated. The percentage of the world's total CO_2 emissions that are caused by transportation is growing. The transportation industry is responsible for 22% of the world's total CO_2 emissions, with this percentage hovering somewhere around 25% in developed economies like the United States.

Because of the intricacies of the repercussions, there has been a lot of disagreement regarding environmental legislation, the role that transportation plays, and mitigation efforts (Obike et al., 2020). This situation is made considerably more difficult by the fact that the relative importance of environmental and economic concerns might alter over time, which can affect public policy (Sanni, 2014). The transport industry is frequently the recipient of government subsidies, in particular for the building and upkeep of road infrastructure, which is typically open to the public at no cost. Environmental concerns can occasionally come into conflict with public interests in various modes of transportation, ports, and infrastructure. There is a possibility that regulations will not be adhered to appropriately if the owner and the regulator are the same entity, that is, distinct branches of the government (Siddiqui et al., 2018).

Furthermore, users typically do not take full responsibility for all of the expenses associated with transportation activities, most notably the damage done to the environment, as a number of environmental issues would have been avoidable if proper consideration had been given to the actual costs of transportation, (Petrova et al., 2022). Nevertheless, there is a complicated hierarchy of costs involved (Orji et al., 2019), which range from internal (primarily operations), compliance (abiding by regulations), contingent (risk of an incident such as a spill), to external (assumed by society). For example, more than thirty per cent of the total anticipated costs associated with owning and operating a car are attributable to external factors. If the costs to the environment are not factored into

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this evaluation, then the use of automobiles is effectively subsidised by the general public, and prices in the form of pollution continue to mount (Liu et al., 2023).

2.3 Petroleum Products and its Environmental Effects in Soil

According to Edao (2017), human activities are the primary cause of substantial soil degradation concerns. Studies (Araka et al., 2019; Mahmoud & Bagy, 2019; Truckell et al., 2019) have shown that these issues are frequently connected to agricultural and industrial practises that lead to aggregation, compaction, salinization, desertification, or changes in the carbon supply of the soil. According to Owulaku & Tetteh (2022), soil pollution is one of the significant sources of chemical degradation, which can impact soil physiochemical processes and affect biological activity (by increasing toxicity or interfering with nutrient availability or uptake). Additionally, soil pollution has the potential to become a contamination source for other environmental compartments. According to Javaid et al. (2020), the most recent data identified that the industries that have contributed the most to soil pollution are waste disposal (municipal and industrial) with (37.2%), industrial and commercial activities (mining, petroleum extraction and production, and power plants) with 33.3% and storage (fuel storage, obsolete chemical storage, and other storages) with 10.5%. According to these findings, the most prevalent soil contaminants are heavy metals (such as lead, cadmium, chromium, cobalt, copper, mercury, nickel, zinc, etc.) and mineral oil, which together are responsible for almost 60% of the soil's contamination.

2.4 Environmental Behaviour of Petroleum Pollutants in Soil

The human habitat is not complete without the presence of healthy soil as it is a complicated multi-medium system that consists of biology as well as solids, liquids, and gases (Liu et al., 2019). According to Hu (2020), migration, adsorption, and degradation are the three primary environmental behaviours that are associated with oil in soil. Pollutants, such as petroleum, will permeate and persist in the soil regardless of whether or not they are subjected to an environmental impact assessment of the substance's harmfulness (Athanasopoulou et al., 2014). Also, pollutants that enter the soil are continuously adsorbed, degraded, moved, and altered as a result of the physical, chemical, and biological processes that occur in the soil (Gupta et al., 2020). However, this is because the soil contains a significant number of organic and inorganic colloids, soil plants, animals, and microorganisms (Kim & Park, 2017). In most cases, the ability of oil to migrate through the soil is somewhat limited, and the vast majority of it is absorbed by and concentrated on the soil's surface (Mama et al., 2021). The oil that is on the surface of the soil has the potential to self-purify through the process of volatilization. Hence, it becomes possible for pollutants to enter the groundwater aquifer when the intensity of the pollution is high, and there is a large concentration of tiny molecules of hydrocarbons.

2.5 Pollutants from Petroleum Transport to the Soil

According to Malysheva et al. (2017) study, with the flow of water, petroleum pollutants can migrate to the deep soil layer relatively freely or have planar diffusion motion, while the part that is adsorbed on the particles does not migrate significantly under the condition that the soil layer is not destroyed as being feasible only if the soil layer is not wasted.

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Korelskiy et al. (2020) opined that gravity primarily influences the flow of petroleum pollutants in the direction of soil depth. In contrast, capillary force primarily affects the movement of petroleum pollutants in the plane of diffusion. However, Sharifi Haddad et al. (2012) argued that the adsorption quantity of soil particles is limited, and a significant number of petroleum pollutants do not exist in the soil and that in the event that it rains, some of these pollutants will accelerate under the action of infiltration water's deep penetration into the soil. Consequently, according to Kadlec (2019), after a significant amount of time, under the influence of factors such as hydraulics, gravity, diffusion, and mixing, they will gradually form a more stable state. If the water table is buried at a deeper depth, there will be a greater quantity of oil pollutants on the surface, and the hydrodynamic drive will be superb as well. The oil pollutants will permeate further into the soil under some conditions, and the infiltration front may even reach the water table. Petroleum pollutants will migrate and expand relatively significantly transversely in the capillary zone near the groundwater level. These expansions will be more significant than those along the groundwater level and transversely along the direction of groundwater flow (Malysheva et al., 2017). As well, the petroleum pollutants will migrate and expand quite significantly sideways in the capillary zone near the groundwater level.

2.6 Soil Pollutants Originating from Petroleum Sources and its Degradation

The anthropogenic origin of environmental pollution caused by petroleum and its products is well-established, as significant quantities of petroleum are lost annually, amounting to millions of metric tonnes, primarily during the processes of mining, transportation, and storage (Bosikov et al., 2020 Bykova et al., 2019; Oyedepo, 2012). According to Mohapatra & Phale (2021), pollutants from petroleum can be changed and degraded by three natural pathways after they have been released into the soil environment and are volatilized into the atmosphere: self-oxidation and biodegradation. The process of deterioration, which primarily consists of biodegradation, photolysis, and mechanical degradation, takes a very long time (Premnath et al., 2021). Furthermore, according to Weldeslassie et al. (2017), there is a lot of evidence that petroleum is harmful to different organisms, and this is usually linked to the fact that petroleum breaks up the lipid bilayer of the plasma membrane. However, the breakdown of oil by microbes in the environment is essentially its last stop on its journey through the ecosystem. When hydrocarbons from petroleum are released into the environment, a wide variety of microorganisms will contribute to the process of biodegradation (Pathak et al., 2017). Petroleum can be used as a source of nutrition for microbes, which then either transform it into organic components or reproduce it to create more bacteria. The remainder is oxidised and broken down into essential organic or inorganic substances, such as methane, carbon dioxide, and water, among other things (Zamanpour et al., 2020). When petroleum compounds reach the cells of microorganisms that are responsible for their breakdown, these compounds are broken down through one of three assimilation processes: aerobic respiration, anaerobic respiration, or fermentation (Bhavana et al., 2023). The assimilation mechanism that is used depends on the type of petroleum compound that has entered the cell (Osimani et al., 2019). Furthermore, it has been observed that petroleum has the potential to disrupt genetic processes within cellular systems (Ghasemi & Pourbalighy,

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2016). The widespread use and high toxicity of petroleum have earned it a reputation as a dangerous pollutant in the natural environment. Petroleum and its byproducts and waste materials are ranked as the second most damaging factor, behind radiation, due to their adverse effects (Khlynovsky & Rozanova, 2013). Petroleum spills arising from mining and processing accidents inflict significant harm on ecosystems, leading to substantial damage (Cappello et al., 2019). The soil is predominantly affected due to its ability to accumulate substantial amounts of pollutants due to its expansive adsorptive surface area. The presence of petroleum pollution has adverse consequences for soil biocenosis, resulting in notable changes in the chemical composition, structure, and properties of the soil (Zabbey et al., 2017). Addressing this issue poses a considerable challenge. Within an aerobic setting, the process of oxygenation occurs as molecular oxygen is assimilated into the matrix through the catalytic activity of oxygenase. This results in the generation of oxygen-containing intermediates, which subsequently undergo conversion into diverse compounds (Cocârţă et al., 2017). Ranjbar et al. (2018) posits that during the degradation of alkanes, the introduction of an oxygen atom occurs in the process of breaking down aromatic hydrocarbons. However, it is observed that the formation of the aromatic ring involves the combination of two oxygen atoms (Liu et al., 2023). Due to the heterogeneous nature of oil, its degradation necessitates the concerted involvement of diverse microbial communities. Bacteria, possessing unique metabolic pathways and mechanisms, play a crucial role in the breakdown of the numerous hydrocarbon constituents comprising petroleum (Wang et al., 2018). Consequently, this leads to a decline in the fertility of the soil and the agricultural productivity. Petroleum spills possess the capacity to induce a transformation in soil, resulting in the emergence of technogenic deserts that exhibit a notable deficiency in biological activities. Soils that have undergone petroleum contamination exhibit unsuitability for agricultural and recreational applications, thereby presenting a potential hazard of contaminating both surface and groundwater reservoirs, (Irandoost et al., 2021).

2.7 Challenges in Petroleum Products Distribution in Nigeria

Ogunleye et al. (2018) assert that the road infrastructure in Nigeria is often characterised by substandard conditions, insufficient maintenance, and limited capacity, collectively contributing to the country's challenging road conditions. Due to the pervasive existence of potholes, numerous highways are presently unsuitable for the transportation of petroleum industry-derived goods. According to Ambituuni et al. (2015b), the likelihood of accidents and vehicle breakdowns increases, and there is a potential for delays in the supply of petroleum resources if road maintenance is not effectively carried out. In addition, the high level of crime present in the nation and the distribution of petroleum products in Nigeria raises safety concerns (Olawuyi et al., 2023). Tanker trucks responsible for distributing precious petroleum products are often subjected to criminal activity, encompassing theft, damage, and even physical assaults (Sanni, 2014). Omodero & Okezie (2022) assert that security threats not only endanger the lives of drivers and road users but also engender disruptions in the supply chain, thereby leading to subsequent delays, increased expenses, and potential fuel shortages.

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Logistics and supply chain management inefficiency, as reported by Oyesiku et al. (2020), that petroleum product transportation on Nigerian roads is poorly coordinated and managed, which leads to inefficiencies and a lack of adequate logistics. Also, it can cause delays at loading terminals and depots as well as a lack of visibility into the flow of products. The inadequate management of the supply chain, which contributes to delays, gasoline adulteration, and diversion, among other challenges, is one reason why (Amadi et al., 2021; Awonusi, 2007; Ikuabe et al., 2021) identified various factors contributing to the gap, such as inadequate transportation infrastructure, including roads and railways, which hinder economic activities. Although petroleum products are being transported safely, Nigeria usually has trouble both satisfying compliance criteria and enforcing safety laws. Some tanker trucks may not meet the required safety standards when transporting hazardous materials. Proper vehicle maintenance, adequate driver training, and following all applicable safety regulations are all necessities, and the possible risk of environmental contamination, accidents, and spills increases as a result (Oluwaseyi & Gbadamosi, 2017).

Tanker trucks and other essential pieces of equipment for the transportation of petroleum products are not always in sufficient supply in Nigeria due to the country's limited capacity for the operation of these vehicles (Sanni, 2014). Inadequate fleet capacity makes it difficult to distribute products in a timely and effective manner, which is especially problematic during times of heightened demand. The difficulties that are experienced in the transportation of petroleum products are made much more complicated since there is a shortage of tanker trucks that are acceptable and well-maintained (Strogen et al., 2016). To effectively address these difficulties, collaborative efforts from a wide variety of stakeholders are required. It is essential to make investments in the improvement of road infrastructure, which includes repairs and maintenance, in order to provide transport routes for petroleum products that are safe and reliable. Increasing the amount of security along transportation routes, such as the amount of surveillance or the presence of police, can help prevent criminal activity from occurring (Obasanjo et al., 2014). Increasing the effectiveness of logistics and supply chain management systems by using modern tracking and monitoring technologies can help cut down on delays while also improving efficiency. In addition, mitigating hazards and ensuring compliance with safety rules can be accomplished by the implementation of stringent safety standards, the performance of routine inspections, and the promotion of training programmes for drivers and operators (Hillebrand et al., 2016).

2.8 Nigeria's Petroleum Distribution Infrastructure Deficit

The infrastructure deficit in Nigeria has emerged as a significant concern over time, prompting estimations that the country will need an annual investment ranging from $100 to $150 billion for a minimum of ten years in order to address this gap (Oladokun & Komolafe, 2017). Additionally, there are deficiencies in power generation, transmission, and distribution systems, as well as deteriorating public educational facilities, government-owned hospitals (including tertiary healthcare facilities), and airports, among other issues. Infrastructure serves as the fundamental basis upon which economic

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activities flourish, as inadequate infrastructure exerts a negative influence on economic growth (Bolawole et al., 2020).

According to (Ogunleye et al., 2018), due to poor infrastructure, such as roads, storage facilities, pipelines, and depots, road transport in Nigeria is fraught with difficulties.

Problems hamper the practical and secure transfer of petroleum products across the country. According to (Mahmud et al., 2020), Nigeria faces significant infrastructural challenges, particularly in the form of poor road conditions characterised by the presence of potholes, insufficient maintenance, and inadequate capacity. These issues have a direct impact on the transportation of petroleum goods, resulting in prolonged delivery times, increased vehicle wear and tear, and a heightened risk of accidents. The overall efficiency and dependability of the supply chain are compromised due to the current condition of the road infrastructure (Adedeji et al., 2014). In order to ensure the efficient distribution of petroleum products, it is imperative to have adequate storage facilities in place at various locations. Nevertheless, Nigeria is currently facing a scarcity of contemporary warehouses situated in strategic locations.

Consequently, this scarcity has resulted in inadequate storage space, leading to bottlenecks in the supply chain. When there is a high demand for petroleum products but insufficient storage capacity, it results in delays, congestion, and challenges in meeting the demand for these products (Adoga & Valverde, 2014). According to Smallwood (2017), the infrastructure of Nigeria's pipeline and storage facilities is characterised by age and susceptibility to incidents such as breakages, theft, and vandalism. These issues pose a threat to the environment as they impede the regular transportation of petroleum products. The occurrence of frequent pipeline failures can lead to spills, product losses, and environmental damage due to insufficient maintenance and security protocols. The existing transport infrastructure is currently experiencing strain as a result of the substantial demand for services and the limited number of strategically located depots. The resolution of these infrastructural challenges necessitates a comprehensive approach. Allocating financial resources towards road infrastructure, including the maintenance and expansion of existing roads as well as the construction of new roads, should be regarded as the paramount objective for governmental entities and relevant stakeholders. The construction and upkeep of superior road infrastructure can enhance the effectiveness and safety of transporting petroleum commodities. However, (Nath et al., 2023), it is imperative to allocate resources towards the establishment or expansion of storage facilities such as depots and tank farms at strategic locations throughout the nation.

Finally, enhancing pipeline infrastructure is essential to ensuring the dependability and safety of pipeline networks, according to a study by (Cui et al., 2020). This upgrade will result in improved reliability in the distribution of petroleum products, reduced traffic congestion, and increased availability of storage space. The implementation of routine maintenance and repair protocols and the incorporation of state-of-the-art technology for the purpose of detecting leaks and enhancing security systems have the potential to mitigate pipeline failures, instances of theft, and environmental hazards. The

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enhancement of pipeline infrastructure presents an opportunity to improve the efficiency and security of petroleum product transportation. In order to address infrastructure challenges, public, private, and international entities must collaborate. Public-private partnerships (PPPs) have the potential to provide significant advantages to road networks, storage facilities, and pipeline infrastructure. These partnerships can facilitate the infusion of funding, expertise, and state-of-the-art technology. Nigeria has the potential to address its challenges in the realm of petroleum product road transport by emphasizing the enhancement of its infrastructure. The enhancement of road networks, the establishment of adequate storage facilities, and the upgrading of pipeline systems can contribute to the development of a more efficient, reliable, and environmentally sustainable petroleum product distribution network nationwide.

2.9 Supply Chain of Petroleum Product Distribution in Nigeria

The ineffective management of the supply chain that is involved in the distribution of petroleum products in Nigeria has substantial repercussions for the environment, particularly in regard to the contamination and pollution of the soil, (Ante & Ante, 2019). The distribution of products across the country is primarily dependent on transportation, which the petroleum industry significantly relies on. Inefficiencies in supply chain management contribute to a variety of environmental concerns that have an influence on soil health and the integrity of ecosystems. The occurrence of spills and leakages during the transportation of petroleum products is one of the most significant environmental repercussions that might be a direct result of ineffective management of supply chains. Accidental spills can happen for a number of reasons, including inadequate handling practises, poor loading and unloading processes, and equipment failure, (Ikeogu et al., 2013). As a result of these spills, harmful hydrocarbons are released into the environment, which have the potential to poison the soil. The pervasive presence of petroleum contaminants changes the soil's physical, chemical, and biological qualities, which in turn have an effect on the fertility of the soil, the availability of nutrients, and the health of the environment as a whole, (Palansooriya et al., 2023).

Inadequate upkeep of transport infrastructure also increases the likelihood of leaks and spills occurring. Pipelines that are getting older are more likely to suffer from corrosion. If tanker trucks are not properly inspected and maintained, this can result in fuel leaking out at the same time they are being transported (Alabi et al., 2019). These problems with the infrastructure contribute to soil contamination by allowing petroleum products to seep into the ground, which has the potential to contaminate groundwater as well as the ecosystems in the surrounding area. Pollution of the soil can have long-term effects on agricultural output because it interferes with the availability of essential nutrients and reduces the soil's capacity to foster the growth of plants (Liverpool-Tasie et al., 2020). In addition, ineffective management of supply chains offers opportunities for criminal activity and adulteration within the process of transporting petroleum products. In the practise of adulteration, petroleum products are purposefully mixed with other substances that are either less expensive or of worse quality. Fuels that have been tampered with not only have a decreased energy level but also contain pollutants that are detrimental to the health of the land. The contamination of soil and the reduction or elimination of crop yields

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can be caused by the use of adulterated fuels in agricultural machinery and other types of equipment (Ezeudu et al., 2021).

According to Rotich (2013), ineffective management of supply chains can have negative effects on the environment, and illegal activities like fuel smuggling and diversion are major contributors to this problem. These operations cause disruptions in supply networks and potential damage to the environment by diverting petroleum products away from their intended destinations. Smuggling fuel, which refers to the illegal transportation of petroleum products in order to avoid paying taxes or price differentials, can result in the usage of inferior or low-quality fuels, which can have a negative impact on the health of the soil and the productivity of agricultural land, (Haggblade et al., 2022). The ineffective management of the supply chain that occurs in the transportation of petroleum products can have far-reaching effects on the surrounding environment. Contaminated soil can result in decreased agricultural yields, which can have an impact on both the production of food and people's ability to make a living. Groundwater can get contaminated by contaminated soil, which poses a threat to both ecosystems and the sources of drinking water. In addition, the depletion of soil biodiversity and the disruption of soil ecosystems can have a domino impact on the overall health and resiliency of an ecosystem, (Sibomana et al., 2019).

Improving supply chain management in the transportation of petroleum products should be the primary focus of efforts made to address the environmental concerns currently facing the world, including strengthening regulatory oversight to ensure compliance with environmental standards, implementing and enforcing stringent monitoring and reporting mechanisms to detect and respond promptly to spills and leakages, and investing in infrastructure maintenance and upgrades to minimise the risk of leaks and spills, (Omokpariola & Omokpariola, 2021). In addition, this includes ensuring that environmental standards are met. It is of the utmost importance to encourage education and awareness among industry stakeholders, carriers, and the general public regarding the significance of environmentally responsible transportation practises and the environmental repercussions of inefficient supply chain management. It is accomplished through the implementation of specialised training programmes, public awareness campaigns, and the sharing of successful strategies. If sustainable supply chain management practises are given priority in Nigeria, the country would be able to reduce the adverse effects on the environment caused by the transportation of petroleum products and contribute to the development of a petroleum sector that is friendlier to the environment and more resilient, (Chen et al., 2021).

2.10 Corruption and Illegal Activities

According to Kola-Olusanya & Mekuleyi (2018), illicit activities and corruption pose significant challenges to the petroleum industry, the economy, and the overall welfare of the nation. Fuel smuggling entails the illegal transportation of petroleum products across national borders with the intention of circumventing taxes, tariffs, or disparities in pricing. The operation of unlawful enterprises that capitalise on fuel price disparities across nations not only leads to substantial revenue losses for the government but also

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engenders unfair competition for law-abiding enterprises (Oluwole & Ojekunle, 2016). The act of fuel smuggling undermines the established regulatory framework, disrupts the stability of the market, and possesses the capacity to induce shortages in regions characterised by significant demand for this commodity. In line with Olotu et al. (2021), the practise of adulterating petroleum products involves the blending or dilution of these products with less expensive or lower-quality substances, commonly known as "adulteration". Common types of contaminants include kerosene, water, and lower-quality additives, which are driven by the objective of enhancing profit margins. However, it poses significant risks to consumers due to the potential damage that contaminated fuel can inflict upon motor vehicles, machinery, and engines. The adulteration of petroleum products has detrimental effects on the environment as well as diminishing the overall quality and performance of the products (Dunmade, 2019). Diversion refers to the unauthorised redirection or misallocation of petroleum products originally intended for specific purposes or destinations. The term "diversion" is commonly used to describe instances where an item is redirected from its intended path, and this can occur during various stages, including transportation and storage. According to Wang et al. (2008), there is a phenomenon known as diversion, where products initially designed for legal markets, such as the commercial or industrial sectors, can be illicitly redirected to the black market. The act of diversion leads to a decrease in the number of supplies that are accessible, an unpredictable market price, and a decline in revenue for both the government and legitimate companies that are dedicated to addressing the issue of bribery and other illicit activities in the petroleum industry. The necessity of a collective effort and the implementation of comprehensive strategies to effectively address corruption and illegal activities is imperative to enhance the regulatory frameworks and bolster their enforcement mechanisms. It encompasses the enforcement of stringent regulations pertaining to licencing, pricing mechanisms, and quality control criteria. Furthermore, the implementation of these limitations through rigorous surveillance, evaluations, and sanctions for transgressors will function as a preventive measure for individuals who opt to behave contrary to the established regulations (Cao et al., 2022).

As stated by (Nnadi et al., 2014), enhancing transparency and accountability within the petroleum industry is crucial to mitigating corruption. This can be achieved through various measures, including the public dissemination of information, the establishment of well-equipped anti-corruption entities capable of investigating and prosecuting wrongdoers, and the implementation of transparent bidding procedures for contracts and licences. Practical strategies to address corruption and illicit activities within the petroleum sector necessitate collaboration among government authorities, industry stakeholders, and foreign partners. This collaboration is crucial for the exchange of best practises, intelligence, and areas of expertise. By strengthening anti-corruption measures and efforts to combat fuel smuggling and enhancing cross-border cooperation, the petroleum sector can effectively combat these challenges (Orisakwe, 2021). The dissemination of education and knowledge to the general public holds great importance. It is crucial to provide the public with information regarding the adverse consequences associated with corruption and illegal activities. By increasing public awareness of these effects, there is a potential to decrease the demand for illicit petroleum products. In addition, it is

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imperative to underscore the significance of obtaining goods from reputable vendors (Rivera-Parra et al., 2021). The mitigation of challenges arising from illicit activities and corruption within the petroleum industry can be achieved through the successful implementation of comprehensive anti-corruption measures in Nigeria, and this can be facilitated by enhancing transparency and fostering public awareness. These efforts will contribute to the establishment of a more transparent, accountable, and environmentally sustainable petroleum sector. Such developments will not only bolster the economy but also guarantee consumers access to high-quality petroleum products (Quayson et al., 2021).

2.11 Regulatory Issues

The regulatory concerns pertaining to the transportation of petroleum products in Nigeria, as well as the environmental impacts of this transportation on the nation's soil, are of significant concern and necessitate prompt attention, as highlighted by (Anetor, 2016). A comprehensive examination, uncovering multiple significant deficiencies, raises doubts regarding the efficacy of the regulatory framework governing the transportation of petroleum products. Insufficient implementation and adherence strategies play a role in the occurrence of recurrent spills, leaks, and soil contamination, thereby presenting substantial hazards to the long-term sustainability of the environment. The lack of stringent penalties and mechanisms for holding businesses accountable exacerbates the issue by allowing them to evade accountability for the repercussions of their actions. The environmental consequences arising directly from these regulatory issues are highly problematic. Soil contamination resulting from leaks and spills not only disrupts the intricate balance within ecosystems but also poses risks to agricultural productivity and public health. Soil pollution can have significant long-term consequences, leading to adverse effects such as reduced agricultural productivity, groundwater contamination, and biodiversity depletion. Furthermore, the socioeconomic negative implications arising from soil degradation, including diminished agricultural output and escalating healthcare costs, impose an additional strain on the already vulnerable communities in Nigeria (Anetor, 2016).

The implementation of substantial reforms in the regulatory framework is crucial in order to effectively address these pressing challenges and ensure the accountability of organisations engaged in the transportation of petroleum products. It necessitates the enactment of additional legislation (Olatoye, 2013). Regulations must encompass a comprehensive array of monitoring systems, periodic inspections, and stringent penalties to be imposed upon non-compliant companies. Furthermore, it is imperative to emphasise the need for increased public participation and transparency in decision-making procedures to ensure the accountability of regulatory agencies and promote the principles of environmental justice. The allocation of resources towards the enhancement of infrastructure, exemplified by the construction of meticulously maintained pipelines and storage facilities, possesses the potential to mitigate the risk of spills and leaks.

Consequently, this proactive approach serves to safeguard the environment and preserve the integrity of the soil, thereby promoting ecological well-being. The transportation of

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petroleum products in Nigeria is accompanied by significant regulatory challenges, which have notable environmental implications, particularly with regard to soil quality. The current regulatory framework exhibits limitations in effectively addressing environmental concerns, leading to soil contamination, a decline in agricultural productivity, and adverse impacts on socioeconomic conditions. It is crucial to implement prompt modifications aimed at bolstering enforcement mechanisms, augmenting transparency, and allocating resources to infrastructure development. These measures are necessary to mitigate the adverse environmental impacts and ensure the sustainable expansion of the petroleum industry in Nigeria. In order to effectively preserve Nigeria's soil resources and safeguard the environment for future generations, the country must adopt assertive and proficient regulatory strategies (Adebayo et al., 2020).

The petroleum industry in Nigeria plays a substantial role in the country's economy, as indicated by its contribution of 35% to the Gross Domestic Product. Nevertheless, the transportation of petroleum products has been found to have adverse impacts on the ecosystem, particularly with regard to soil quality. The efficacy of the command-and-control regulatory framework in the Nigerian oil and gas industry has proven inadequate in addressing challenges related to pricing templates, inefficiencies in petrol price control systems, and deficiencies in administrative and leadership practises within the nation. The proposition aims to address the issue of artificial scarcity of refined petroleum products, enhance the well-being of Nigerians, and ensure a robust economy by discontinuing the importation of refined petroleum products at excessively high prices to meet domestic demand. The achievement of these objectives could be facilitated through the deregulation of the downstream petroleum industry, which would effectively eliminate the practise of importing refined petroleum products at excessively high prices. (Ambituuni et al., 2014) Argues that businesses must ensure the consistent enforcement of their current legal framework. The Petroleum Industry Act (PIA) in Nigeria comprehensively overhauls the existing framework governing the oil and gas sector of the economy, thereby introducing significant changes to the rules and regulations. The legal framework establishes two regulatory bodies, namely the Nigerian Upstream Regulatory Commission and the Nigerian Midstream and Downstream Petroleum Regulatory Authority. Both of these entities are tasked with the responsibility of overseeing and enforcing regulations within the oil and gas sector in Nigeria. The mission of the PIA encompasses a wide range of objectives, and the report in question is characterised by its complexity and challenges in providing a concise summary. The Petroleum Industry Act (PIA) represents a strategic initiative undertaken by the foremost oil-producing nation in Africa in response to the observed fluctuations in environmental circumstances. Nigeria, akin to other global regions, has experienced a decline in investment within the oil and gas sector due to mounting apprehensions regarding the adverse ramifications of climate change. The achievement of the objectives outlined by the Petroleum Industry Act (PIA) relies on the capacity of Nigeria's political and industrial elites in the oil sector to overcome significant challenges (Kumar & Barua, 2022).

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2.12 Socioeconomic Factors: Population Growth, Urbanization, And Income Disparities

The transportation of petroleum products in Nigeria is influenced by both technical and logistical factors, as well as a range of socioeconomic considerations. Technical and logistical aspects exert a more substantial influence compared to socioeconomic factors, encompassing increasing population rates, urbanisation, and income disparities. These factors have significant implications not only for transportation methods but also for the resulting environmental consequences on land (Albert et al., 2018a). In a study conducted by Atoufi & Lampert (2020), in order to effectively address environmental issues associated with the transportation of petroleum products, it is crucial to acquire a comprehensive understanding of the socioeconomic dynamics, as emphasised by (Alam et al., 2003; Albert et al., 2018b; de Oliveira et al., 2020). The socioeconomic factor of the increasing global population influences the transportation of petroleum products, and the exponential population growth in Nigeria has led to an escalation in both the energy demand and the consumption of petroleum-derived products within the country, leading to a corresponding surge in transportation needs, thereby exerting additional strain on the pre-existing infrastructure and the logistical aspects of petroleum product distribution. Insufficient infrastructure to accommodate the growing demand can result in congestion, delays, and an elevated risk of accidents. Consequently, this can have detrimental effects on soil pollution and environmental degradation.

According to (Labena et al., 2023), urbanisation is a notable socioeconomic factor that influences the transportation of petroleum products. Nigeria is currently undergoing a significant process of urbanisation, characterised by a noteworthy migration of a considerable proportion of its population towards urban areas and other regions with urban characteristics. Due to the heightened energy demands, urban areas necessitate the implementation of extensive transport systems to facilitate the efficient dissemination of petroleum commodities. The urbanisation process, coupled with the concurrent escalation in vehicular activity, can lead to exacerbated traffic congestion and heightened emissions, thereby exacerbating the issue of air pollution and potentially impacting soil quality. Income inequality is a significant factor that influences the transportation of petroleum products and the subsequent environmental consequences. Nigeria exhibits a substantial economic disparity, with a considerable proportion of its populace residing below the officially designated poverty threshold. However, Baldwin & Cederberg (2015) posits differences in the accessibility of energy resources can result in variations in the availability and pricing of petroleum products. The outcome manifests as distribution networks characterised by inefficiency and informality, wherein the utilisation of vehicles failing to adhere to transportation industry standards is prevalent. Informal networks of this nature possess the capacity to give rise to incidents such as spills, leaks, and other hazardous occurrences that can potentially exert adverse effects on the soil and ecosystems within the proximate vicinity.

More so, Schnepf (2013) opined the transportation of petroleum products has significant socioeconomic implications, leading to a diverse array of environmental degradation that affects soil quality. The expansion of the human population and the proliferation of urban

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areas exert pressure on the natural environment, which can accelerate the pollution and deterioration of soil quality. The increasing demand for petroleum products has the potential to lead to an escalation in operations related to their extraction, refining, and transportation. Consequently, this raises concerns regarding the potential for environmental harm resulting from leaks, spills, and pollution. Furthermore, disparities in income have the potential to exacerbate the environmental risks. In situations where cost effective and ecologically sustainable energy resources are scarce, individuals may turn to the utilisation of substandard fuels or engage in adulteration practices. These actions can potentially exert detrimental effects on soil health. Informal transportation networks may lack adequate safety measures, thereby potentially heightening the likelihood of accidents and causing environmental harm (Popescu & Gabor, 2021). It is necessary to take a comprehensive approach to address the socioeconomic variables as well as the environmental repercussions through investing in the development of infrastructure, such as road networks and storage facilities, which can lead to improvements in the effectiveness and dependability of the transportation of petroleum products. This will aid in the alleviation of congestion, lower the risks of spills and leaks, and minimise the effects on the environment. Reducing reliance on petroleum products and mitigating the environmental concerns associated with this dependency can be accomplished through the promotion of alternative energy options, such as renewable energy. Also, it is essential to educate the general population about the adverse effects that the transportation of petroleum products has on the environment, as well as to encourage responsible consumption and transportation practices. Education programmes can help raise awareness about the significance of conserving soil and making environmentally responsible decisions about modes of transportation (Khaustov et al., 2019).

Promoting equitable socioeconomic conditions and fostering economic growth are additional factors that can contribute to the advancement of sustainable transportation practises. According to Usman (2017), in reference to petroleum policies and laws in Nigeria, enhancing economic opportunities and improving individuals' living standards are key factors that can mitigate the dependence on informal transportation methods, known for their associated risks. Nigeria has the potential to transition towards a more sustainable and environmentally conscious approach by acknowledging and resolving the socioeconomic challenges that impact the transportation of petroleum products. This approach would lead to a decrease in the environmental consequences arising from the transportation of petroleum products in Nigeria, which has resulted in significant environmental impacts, particularly in relation to soil degradation. However, the subsequent enumeration presents a compilation of distinct environmental consequences arising from the transportation of petroleum products to the terrestrial environment in Nigeria (Sui et al., 2021). Therefore, focuses on the issue at hand pertains to the contamination of agricultural land and fisheries. A crucial aspect of this environmental concern is the potential harm that petroleum product spills could cause to fishing and farming areas, as well as the ensuing soil contamination and significant degradation due to oil spills that occur as a result of accidental tanker incidents (Speight & El-Gendy, 2017).

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Finally, the presence of oil contaminants in the soil leads to inhibited plant growth and contamination of the groundwater and runoff pollution has a negative impact on the ecosystem. However, it is worth noting that a considerable proportion of the incidents involving the transportation of petroleum products via road in Nigeria have been associated with detrimental outcomes for both human well-being and the natural environment. In consideration of the studies by Muazu & Tasmin (2019) provided an analysis of the amplified consequences of oil exploration and extraction in Nigeria, emphasising the environmental degradation that accompanies these activities. The author employs the Niger Delta as a case study to effectively illustrate the impacts and examines the environmental consequences of oil exploration and exploitation in Nigeria, using the Niger Delta as a focal point for analysis. The discussion centres on the various factors that contribute to these repercussions. The ecosystem experiences a range of adverse impacts, including deforestation, soil degradation, and a decline in biodiversity. The environmental consequences associated with the transportation of petroleum products on land in Nigeria have significant implications for the country's economy and the welfare of its population.

2.13 Trends in Petroleum Products Transportation and its Implications

The transportation of petroleum products in Nigeria has been linked to a number of environmental repercussions, most notably those affecting the soil. Trends and environmental repercussions caused by the transportation of petroleum products in Nigeria there has been a consistent increase in the number of road tanker vehicles in Nigeria, which accounts for approximately eighty per cent of all petroleum transportation in the country (Elshaboury et al., 2022). It has been proposed as a solution to combat the artificial scarcity of refined petroleum products, improve the welfare of Nigerians, and guarantee a virile economy by putting an end to the importation of refined petroleum products at exorbitant costs to satisfy domestic utilisation. Deregulation of the downstream petroleum industry would accomplish these goals by bringing an end to the importation of refined petroleum products at excessive prices. According to (George et al., 2023), environmental consequences resulting from the transportation and distribution of petroleum products in Nigeria, a great deal of environmental damage has been caused, which in turn has had repercussions on both society and the natural environment. The soil in Nigeria has suffered tremendous devastation as a result of oil that has leaked from pipelines and tankers.

However, a preview of petroleum products transportation trends in Nigeria between 2010 and 2022, as depicted in Table 1.0, underscores the significant role of the petroleum industry in the country's economy. However, it also sheds light on the various challenges that accompany this sector, such as disruptions to the supply of electricity and petroleum products, environmental risks, and limitations in road haulage capabilities. The observed trends also indicate the necessity for governmental and industry authorities to undertake measures in order to tackle these challenges and guarantee the industry's adherence to environmental sustainability.

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Table 1: Showing Trends in Transportation of Petroleum Products from 2010-2022

S/N	Author/Year	Trends	Environmental Effects
1	Obasanjo et al., (2014)	In the year 2010, Approximately 80% of petroleum transportation operations were carried out via road, exhibiting a consistent increase in the quantity of road tanker vehicles utilised.	The limitations associated with road transportation have resulted in the occurrence of environmental pollution, specifically heavy metal pollution.
2	Playfoot, (2015)	In the year 2011, Nigeria ranked as the foremost oil producer in Africa, following Libya, Algeria, and Angola.	‘’
3	Liu et al. (2021)	In the year 2019, The oil and gas industry constituted approximately 5.8% of Nigeria's actual gross domestic product (GDP) and played a significant role in generating 95% of Nigeria's foreign exchange earnings and 80% of its budgetary revenues.	‘’
4	Abu-Khasan & Makarov, (2021)	In the year 2021, The transportation sector was identified as the primary consumer, responsible for 88% of the overall consumption of oil products.	Transportation and distribution of petroleum products have given rise to various environmental hazards, encompassing the contamination of soil and water, the depletion of biodiversity, and the emergence of health risks for both humans and animals.
5	Akujor et al., (2022)	In the year 2022, There was a reported rise in production costs attributed to the disruptions in the supply of electricity and petroleum products.	The transportation industry is the primary consumer of fossil fuels, thereby making it the leading contributor to carbon emissions. The sector relies exclusively on fossil fuels for fulfilling its energy needs and obligations, thereby constituting a substantial source of environmental pollution.
6	George et al., (2023)	In the year 2023, There was a reported drop in production and a surge to the cost of PMS, AGO.	Transportation and distribution of petroleum products have given rise to various environmental hazards, encompassing the contamination of soil and water, the depletion of biodiversity, and the emergence of health risks for both humans and animals which is mainly anthropogenic.

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The Nigerian economy is confronted with various challenges, encompassing issues such as interruptions in the provision of electricity and petroleum products, environmental risks, and limitations in road transport. The observed trends underscore the imperative for governmental and industry stakeholders to proactively tackle these challenges and establish measures that promote the industry's adherence to environmental sustainability. Road transportation of petroleum products has been found to have significant environmental consequences, encompassing the pollution of heavy metals, soil, and water, the depletion of biodiversity, as well as posing health hazards to both humans and animals. Transportation of petroleum products in Nigeria has significant environmental consequences, specifically with regard to the nation's soil. Governmental entities and business leaders must act in order to mitigate these consequences and guarantee the industry operates in an environmentally sustainable manner.

3.0 POLICY RECOMMENDATIONS

Policy suggestions for the transportation of petroleum products and the environmental repercussions that it will have on the land in Nigeria are essential issues that have to be carefully evaluated. This critical review seeks to assess policy submissions and their potential efficacy in addressing the environmental challenges associated with the transportation of petroleum products. One of the most crucial policy recommendations entails strengthening regulatory frameworks and enhancing enforcement measures. While the presence of stringent legislation is vital, the effectiveness of such regulations heavily relies on the government's ability to allocate adequate resources and establish comprehensive monitoring and inspection protocols to ensure adherence. Furthermore, the implementation of substantial penalties for failure to comply can serve as a deterrent and incentivize businesses to embrace responsible transportation practices (Dietsche, 2018; Okudo, 2013; H. Zhang et al., 2021). The effectiveness of these measures will depend on the regulatory authorities' commitment and capacity to consistently and impartially enforce the regulations.

An additional potential avenue for public policy that exhibits potential is the expansion of educational and awareness-raising initiatives. The establishment of a culture characterised by responsible and sustainable practises has the potential to be achieved through the education of stakeholders, carriers, and the general public regarding the environmental impacts associated with the transportation of petroleum products. Campaigns aimed at increasing awareness may prioritise the importance of appropriately managing, storing and disposing of petroleum products to mitigate the probability of incidents such as spills, leaks, and soil contamination. However, the efficacy of these programmes relies on both their breadth and their ability to induce changes in behaviour effectively. Consequently, it is imperative to thoroughly plan and implement these educational programmes, considering the demographic characteristics of the target audience, the cultural sensitivities involved, and the level of accessibility, as noted (Coker

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& Sotudeh-Gharebagh, 2022). Provision and upkeep of infrastructure investments are crucial policy recommendations for mitigating the adverse impacts of environmental consequences. Enhancing various components of the transportation infrastructure, including pipelines, storage facilities, and tanker trucks, has the potential to substantially mitigate the occurrence of leaks, spills, and soil contamination. Additionally, the implementation of advanced technologies, such as improved storage tanks and leak detection systems, has the potential to enhance the efficiency and safety of petroleum product transportation. However, the successful implementation of these infrastructure projects necessitates a substantial allocation of financial resources and a long-term commitment.

Finally, the presence of sufficient financial resources, transparent procurement procedures, and efficient project management are crucial factors that facilitate the successful execution and sustainability of a project. Policy recommendations pertaining to the transportation of petroleum products and the resulting environmental consequences on Nigerian soil provide a framework for addressing the challenges associated with this sector. According to (Ukhurebor et al., 2021), the mitigation of environmental hazards necessitates the implementation of several crucial measures, such as enhancing legal structures, promoting education and consciousness, and allocating resources towards the advancement of infrastructure. Furthermore, the successful execution, enforcement, and continuous surveillance of these policy recommendations are of utmost significance in guaranteeing their efficacy in safeguarding Nigeria's soil resources, preserving the environment, and attaining sustainable development within the petroleum sector. These objectives can only be achieved through dedicated and persistent efforts.

4.0 CONCLUSION

The degradation of petroleum pollutants in soil is a complicated process that is dependent on the quantity, status, and characteristics of the petroleum pollutants as well as the environmental conditions of the ground. Petroleum pollution discharge accounts for soil environmental capacity and self-purification. This discharge needs to emphasise the fundamental reduction of its direct impacts on the environment, increase the treatment of oil-containing pollutants, shorten the retention time of petroleum pollutants in the environment, and predictably lower environmental pollution from different viewpoints, including comprehensive environmental, behavioural research, soil pollutant treatment, and Technological development. To prevent spills and leaks, transportation infrastructure, including pipelines and storage facilities, must be maintained and updated. Routine inspections, repairs, and advanced monitoring systems can identify and fix system flaws. Safety laws must also be followed. In minimising accidents and reducing pollution, tanker truck safety measures, driver training, and vehicle inspections must be implemented. Encourage eco-friendly transportation as well. Petroleum operations are vital to Nigeria's economy, yet their distribution has severe environmental impacts. Oil spills, soil pollution, and accidents threaten environmental sustainability. To mitigate these environmental impacts and ensure a sustainable petroleum industry in Nigeria, the government, industry

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stakeholders, and regulatory bodies must prioritise environmentally responsible practises, invest in infrastructure upgrades, enforce safety regulations, and promote cleaner and more sustainable transportation options. Resolving these difficulties will improve the efficacy, safety, and dependability of road transportation of petroleum products, which will help the petroleum sector run smoothly and satisfy the energy needs of Nigeria's growing population.

Authors Contributions

Conceptualization: I.I. George; **Methodology**: I.I. George; **Formal analysis**: I.I. George and M.G.M. Nawawi; **Investigation**: I.I. George; **Resources**: M.Z. Jafaar and M.G.M. Nawawi; **Data curation**: I.I. George, A. Agi, and M.Z. Jafaar; **Writing-original draft preparation:** I.I. George, U A. Abubakar, and A. Agi; **Writing-review and editing:** I.I. George U.A. Abubakar and A. Agi; **Funding acquisition:** Bayero S Farah, M.Z. Jafaar, and M.G.M. Nawawi.

Declaration of Competing Interests

The authors (Ikenna Ignatius George, Mohd Ghazali Mohd Nawawi, Zaidi Jafaar Mohd, Bayero Salih Farah, Umar Alfa Abubakar and Agi Augustine) affirm that they have no known conflicts of interest and agree with the publishing of this work.

Data availability

No data was used for the research described in the article.

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Declaration of interests

- The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
- The authors declare the following financial interests/personal relationships, which may be considered as potential competing interests

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