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Environmental Impacts of Artisanal Petroleum Refining and Products Quality in Rivers State, Nigeria.

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Abstract
This study was carried out to investigate the quality of petroleum products from artisanal petroleum refining which has become a regular feature in the landscape of the Niger Delta region of Nigeria including Rivers State. Environmental impacts of the operations and activities of these refineries and the use of their inferior quality products were also reviewed. Products samples - petrol, kerosene and diesel were analyzed in the laboratory according to the American Standards for Testing and Measurements (ASTM) standard operating procedures and international best practices to ascertain their quality. Results show that most of the analyzed parameters (specific gravity, flash point, pour point, fire point and viscosity) did not meet the industry standards indicating that the products are of poor quality. This signifies that the use of these products portends great danger not only to the machineries/equipment where they are used, but also to the environment and public health. This study traced poor products quality to ineffectual refining methods and equipment, product handling and transportation. Environmental concerns are compounded by the dumping of refinery residues direct into the ecosystems. Operations are unsafe resulting in explosions and fires with further environmental impacts.

Key words: *Artisanal refining, Petroleum products, Poor quality, Environmental challenges, Pollution, Ecosystem*

1. Introduction

Artisanal petroleum refining became prominent in the landscape of the Niger Delta, south-south geo-political zone of Nigeria, including Rivers State, a few decades back. This illegal petroleum refining and its associated activities do not only produce very poor-quality products, they have also led to severe environmental pollution and degradation in the Niger Delta ecosystem. The proliferation of illegal refineries in the region in the last couple of years has worsened environmental issues. Vegetation, soil, water resources (surface and groundwater), flora and fauna, as well as the rich biodiversity and atmospheric air have all been affected by pollution. Intensification of the greenhouse effect associated with global warming and climate change, acid rain, photochemical smog, reduced atmospheric visibility, dearth of forests, ozone layer depletion, soot/heavy metals deposition, poor water quality, surface water/groundwater contamination, soil contamination, disturbance of communities/flora/fauna, and destruction of ecosystems are some of the environmental impacts of the petroleum industry (E&P Forum, 1997; Speight, 2005; Mariano and La Rovere, 2007; Orszulik, 2008; Isa, 2012; Jafarinejad, 2015 & 2016).

Products of the illegal refineries are a far cry from the international standard for petroleum products. Laboratory analyses carried out for some of the products of the illegal refineries (Tables 1-6) indicate remarkable deviations from industry standards. This scenario portends very grave danger not only to the automobiles and machines where they are used, but also to the environment as poor combustion of the fuels usually throw up numerous environmental pollutants and contaminants including heavy metals, carcinogenic substances, greenhouse gases among others that are dangerous to living organisms.

2. Historical overview of artisanal petroleum refining in Nigeria

Illegal crude oil refining business in Nigeria started a couple of decades ago when aggrieved Niger Delta Youths started protesting for what they regarded as injustice being meted out to them and their communities by the International Oil Companies (IOCs) operating in the area. Paki (2015) aptly captured the feeling of the Niger Delta people when he posited that "local refining of crude oil is the effect of economic exclusion of relevant segments of the Niger Delta people from participating in the lucrative oil industry in Nigeria". The region argued that the IOCs and Nigeria's Federal Government through the state-owned oil giant, NNPC, deliberately marginalized them in employment opportunities and downstream operations and businesses in the oil sector. This was in addition to the environmental devastation and degradation their operations have, over the years, inflicted on their agrarian vegetation and aquatic ecosystem.

This double barrel affront on them, they further argued, took away their traditional sources of livelihood – farming and fishing, leaving them impoverished and wretched while the IOCs and their Nigerian government collaborators smiled to the banks. To make matters worse they believe the proceeds of the oil business in Nigeria are being used to develop other regions of the nation and neglecting the region from where the resources come from. They cite as examples the terrible state of infrastructure, including Federal roads and high ways in the area as compared to other regions of the country.

The youths, therefore, resorted to arms struggle to press home their demands for equity, fair play and justice in the distribution of the nation's resources. Oil workers were kidnapped for ransom. While some later regained their freedom, a few unfortunate ones lost their lives in their detention camps. The IOCs and the Nigerian government responded by deploying government security forces to the area to restore normalcy. Later, reports of human rights abuses in the area started emerging. Human Rights Watch Reports (2002) reported that "the oil companies are seen by the residents of the delta to be complicit in human rights abuses carried out by government security forces that are deployed to protect their facilities"

There arose a national outcry as crude oil production which remains Nigeria's main revenue earner nosedived. Attempts were made by the Nigerian government to engage the youths in dialogue to resolve the impasse. At a point some of them were invited to Abuja, the nation's capital, to meet and discuss with relevant government agencies and officials on the way forward. The talks were deadlocked as the massive infrastructural developments the agitating youths saw in the nation's capital as against what they are used to in their Niger Delta region further infuriated them and aggravated the situation. The struggle took a new twist as it developed into full blown militancy. The youths brazenly dared constituted authority (the government) and crude oil theft and sale in exchange for arms, kidnapping for ransom, sea piracy, cultism, street gangsterism, armed robbery and other anti-social behaviours and vices became the order of the day in the once peaceful region.

Later on, some of them started to refine part of the stolen crude oil and quickly disposing off their products at comparatively cheaper prices than the products market price. There are reports that some of these youths went into history books to recall how the defunct Biafra refined crude oil for domestic consumption during Nigeria's bloody civil war of 1967 – 1970. The basic refining techniques, first used in the Biafra war were resurrected and modernized by the militants to provide cash for insurgency (SDN Report, 2013). The recurring petroleum products scarcity in Nigeria provided ready market for their poor-quality products.

In 2009 peace was brokered between the aggrieved youths (militants) and the government through the amnesty deal. But when arms were dropped and surrendered to government, some of the repented militants did not drop their acquired knowledge of crude oil refining. They returned to the creeks and their communities to continue the illegal business which became lucrative and irresistible for them. And so the business continued even in greater dimension and with the active collaboration and connivance of some well-meaning Nigerians. The monstrous illegal crude oil refining business has come to be in one of the world's largest crude oil producing nation. However, the activities of the illegal crude oil refineries in Nigeria's Niger Delta are causing even more environmental degradation than what the youth agitators originally set out to fight against.

Fig. 1: Operators take a closer look as condensed petroleum liquids flow into products collection tanks in an illegal refinery. Source: Purefor (2010)

2.1. Illegal petroleum refining

Crude oil refining, although a complex process, is based on a simple scientific principle called distillation – boiling, vaporization, cooling and condensation. This is primarily aimed at separating mixtures into their pure components or, in the case of crude oil, into fractions based on their boiling temperature ranges. Complexity was imposed on a hitherto simple distillation or fractionation process by the need to eliminate impurities from both crude oil prior to refining and its products after refining. The other factors include the numerous auxiliary processes in the refineries that improve the octane rating of gasoline fractions, the cetane rating of diesel fractions as well as the ratio of lighter petroleum fractions to the heavier fractions in favour of the lighter ones. The above underline the fact that petroleum refining is not just a mere distillation process – a process of heating, boiling, vaporization and condensation to obtain usable products.

The operators of the illegal refineries do not have the technical expertise and financial capacity to be involved in these high technology processes and so confine themselves to just distillation - the boiling and vaporization of crude oil and recovering just a fraction of the vapours to get three products namely 'petrol', 'kerosene' and 'diesel'. They use crude and locally fabricated pieces of equipment- drums, plastic containers, hoses, pumps to set up refineries.

Heat energy required for the heating of the crude oil components to boiling points is provided by open fire set under the drums, a makeshift 'distillation column', using the residue of their refineries as source of fuel and paying little or no attention at all to safety of workforce and the protection of the ecosystem. Different pipes for different products are welded to the 'distillation drums' and connected to product storage facilities which are not more than large plastic containers or dug pits separated from the soil by thick cellophane materials. Africapractice (2012) admits that the entire illegal refining business (which involves oil theft and the actual refining) is risky and involves the heating of the stolen crude in drums at very high temperatures to produce fuel which is then connected in troughs via pipes connected to the drums.

Fig. 2: Scenes of severely polluted aquatic and land ecosystems at illegal refinery sites in the Niger Delta. Source: Taylor (2011)

These storage facilities are usually located not far away from the billowing balls of fire used in heating up the crude in the distillation drums, a dangerous act that sometimes leads to gasoline

explosions. The products are also exposed to the elements of the weather; sun that causes evaporation of products into the atmosphere leading to air pollution and rain that contaminates the products with water droplets that further degrade their quality. The products are put in plastic containers and shipped to their marketing outlets in the hinterland without any auxiliary treatment to upgrade or eliminate impurities as done in conventional refineries.

2.2. Quality of products of illegal refineries

Petroleum products are any petroleum-based products that can be obtained by refining and comprise refinery gas, ethane, liquefied petroleum gas (LPG), naphtha, gasoline, aviation fuel, marine fuel, kerosene, diesel fuel, distillate fuel oil, residual fuel oil, gas oil, lubricants, white oil, grease, wax, asphalt, as well as coke (Speight, 2014). The illegal refineries and their operators have neither the technical equipment nor the technical competence and manpower required to produce petroleum products that can meet international standards. They equally lack the scientific and technical expertise to carry out any form of laboratory analysis and quality assurance/control checks on their products to determine quality and compare same with stipulated regulatory standards.

Illegal refineries limit themselves to producing three basic petroleum products – *petrol (gasoline), kerosene and diesel (automotive gas oil)* without any attempt to improve their quality through reforming, alkylation, hydro-treating, blending and other post refining physical and chemical modification processes. This is unlike the conventional refineries that adopt a combination of the main fractionation process and the modification processes to produce top grade petroleum products that can guarantee high grade performance in automobile engines and ensure atmospheric air is not unduly polluted.

(a) (b)

Fig. 3: (a) Illegal Refineries storage pit exposed to weather. (b) Billowing fire for heating up crude oil not far away from product storage pit.

Another aspect of refinery operations that influence products' quality is the pre-refining operations for the removal/reduction of impurities. While some of these impurities occur naturally along with the crude oil, others find their ways into crude oils through anthropogenic activities during oil well drilling and production activities. There are numerous chemical additives used in drilling fluids, cementing operations, corrosion/scale/wax-asphaltenes inhibition operations, well stimulation and treatment as well as in improved oil recovery (chemical/gas flooding) and enhanced oil recovery (EOR) operations. These chemical additives find their ways into crude oil and natural gas and must be removed, or their concentrations drastically reduced to tolerable levels before refining.

When the impurities and natural contaminants in crude oils are not removed as is usually the case with all the illegal refineries, some of them also find their ways into the product streams and further degrade the product quality. Or the refining process can transform them into even more toxic substances that are detrimental to products, the environment, refinery processes and equipment.

3. Research methodology

3.1. Study area

Rivers State is located in the oil rich Niger Delta region, South-South geopolitical zone of Nigeria. It shares boundaries with the Atlantic Ocean in the south, Anambra, Imo and Abia states in the north, Akwa Ibom state in the east and Bayelsa/Delta states in the west. Rivers state has a flat topography and a network of rivers and tributaries which include among others Calabar, Orashi, Bonny, Sombreiro, Santa Babara, Andoni, Nun and Bartholomew.

Rivers state is a multi-ethnic, multilingual state, home to many indigenous groups such as Ikwerre, Ibani, Opobo, Eleme, Okrika, Kalabari, Etche, Ogoni, Engeni, Ogba, Ekpeye and others. The state is divided into the upland and riverine parts with the upland (about 61% land mass) consisting primarily of tropical rainforests while the riverine (39% land mass) is basically the typical Niger Delta environment featuring many creeks and mangrove swamps.

Fig. 4: Map of Rivers State showing 23 Local Government Areas.

3.2. Research materials and methods

The study carried out laboratory assessment of the quality of some products of artisanal petroleum refineries from various locations in parts of Rivers State in Nigeria's Niger Delta region. A total of 135 parameters of PMS, DPK and AGO were assessed. 27 parameters of samples of the same products from a conventional refinery were also analyzed. Standard operating procedures endorsed by the ASTM were adopted all through the study. Relevant safety precautionary measures were taken all through the work to ensure reliability and accuracy of the results. Results of analyses were compared with petroleum products standards obtained from literature.

3. Results

Results of the laboratory analyses of petroleum products of some illegal refineries operating in parts of Rivers State and obtained from some sale outlets are shown in Tables 1 to 6. Table 1 shows results obtained from analysis of samples of petroleum products from a conventional refinery while Tables 2 to 6 are results obtained from the analysis of samples of petroleum products from five different sale outlets of artisanal refineries operating in parts of Rivers State, Niger Delta region of Nigeria.

Table 1: Physicochemical properties of conventional refinery

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.87	0.82-0.87	ASTM D1298	0.83	0.800-0.825	ASTM D1298	0.74	0.72-0.74
API gravity	ASTM D1298	31	41 - 31	ASTM D1298	39	45 - 40	ASTM D1298	60	60
Flash point, ºC	ASTM D56	121	66	ASTM D56	88	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	-15	-30	ASTM D97	-9	-47	ASTM D97	-	N/A
Fire point, ºC	ASTM D56-97	149	76	ASTM D56-97	107	48	ASTM 56 - 97	-	N/A
Cloud point, ºC	ASTM D2500	-2	6	ASTM D2500	-10	N/A	ASTM D2500	-	N/A
Viscosity, cP	ASTM D88/D445	11	11	ASTM D88/D445	2	1.6	ASTM D88/D445	1	0.88
Water content, %v	ASTM D4007	0	0.05	ASTM D4007	0	0.05	ASTM D4007	0	0.05
Sediment, %w	ASTM D473	0	0.05	ASTM D473	0	0.05	ASTM D4007	0.5	0.05

Table 2: Physicochemical properties of illegally refined petroleum products from Location A (May 2018)

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.90	0.82-0.87	ASTM D1298	0.84	0.800-0.825	ASTM D1298	0.78	0.72-0.74
API gravity	ASTM D1298	26	41 - 31	ASTM D1298	37	45 - 40	ASTM D1298	50	60
Flash point, ºC	ASTM D56	141	66	ASTM D56	83	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	-10	-30	ASTM D97	-10	-47	ASTM D97	-6	N/A
Fire point, ºC	ASTM D56-97	132	76	ASTM D56-97	89	48	ASTM D56-97	-	N/A
Cloud point, ºC	ASTM D2500	4	6	ASTM D2500	10	N/A	ASTM D2500	1	N/A
Viscosity, cP	ASTM D88/D445	15	11	ASTM D88/D445	3	1.6	ASTM D88/D445	3	0.88
Water content, %v	ASTM D4007	0	0.05	ASTM D4007	0	0.05	ASTM D4007	0	0.05
Sediment, %w	ASTM D473	0	0.05	ASTM D473	0	0.05	ASTM D473	0	0.05

Table 3: Physicochemical properties of illegally refined petroleum products from Location B (May 2018)

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.92	0.820-0.87	ASTM D1298	0.79	0.800-0.825	ASTM D1298	0.77	0.72-0.74
API gravity	ASTM D1298	22	41 - 31	ASTM D1298	48	45 - 40	ASTM D1298	52	60
Flash point, ºC	ASTM D56	107	66	ASTM D56	68	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	1	-30	ASTM D97	-6	-47	ASTM D97	-6	N/A
Fire point, ºC	ASTM D56-97	110	76	ASTM D56-97	82	48	ASTM D56-97	-	N/A
Cloud point, ºC	ASTM D2500	13	6	ASTM D2500	10	N/A	ASTM D2500	10	N/A
Viscosity, cP	ASTM D88/D445	15	11	ASTM D88/D445	5	1.6	ASTM D88/D445	4	0.88
Water content, %v	ASTM D4007	0.13	0.05	ASTM D4007	0.23	0.05	ASTM D4007	1	0.05
Sediment, %w	ASTM D473	0	0.05	ASTM D473	0	0.05	ASTM D473	0.5	0.05

Table 4: Physicochemical properties of illegally refined petroleum products from Location C (May 2018)

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.90	0.82-0.87	ASTM D1298	0.81	0.800-0.825	ASTM D1298	0.78	0.72-0.74
API gravity	ASTM D1298	26	41 - 31	ASTM D1298	43	45 - 40	ASTM D1298	50	60
Flash point, ºC	ASTM D56	118	66	ASTM D56	77	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	-4	-30	ASTM D97	-9	-47	ASTM D97	-8	N/A
Fire point, ºC	ASTM D56-97	127	76	ASTM D56-97	79	48	ASTM D56-97	-	N/A
Cloud point, ºC	ASTM D2500	10	6	ASTM D2500	10	N/A	ASTM D2500	3	N/A
Viscosity, cP	ASTM D88/D445	10	11	ASTM D88/D445	3	1.6	ASTM D88/D445	4	0.88
Water content, %v	ASTM D4007	0.05	0.05	ASTM D4007	0	0.05	ASTM D4007	0	0.05
Sediment, %w	ASTM D473	0.05	0.05	ASTM D473	0	0.05	ASTM D473	0	0.05

Table 5: Physicochemical properties of illegally refined petroleum products from Location D (May 2018)

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.88	0.82-0.87	ASTM D1298	0.84	0.800-0.825	ASTM D1298	0.79	0.72-0.74
API gravity	ASTM D1298	29	41 - 31	ASTM D1298	37	45 - 40	ASTM D1298	47	60
Flash point, ºC	ASTM D56	104	66	ASTM D56	82	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	-3	-30	ASTM D97	-8	-47	ASTM D97	-8	N/A
Fire point, ºC	ASTM D56-97	129	76	ASTM D56-97	91	48	ASTM D56-97	-	N/A
Cloud point, ºC	ASTM D2500	13	6	ASTM D2500	10	N/A	ASTM D2500	5	N/A
Viscosity, cP	ASTM D88/D445	13	11	ASTM D88/D445	4	1.6	ASTM D88/D445	4	0.88
Water content, %v	ASTM D4007	1.7	0.05	ASTM D4007	0	0.05	ASTM D4007	0	0.05
Sediment, %w	ASTM D473	0	0.05	ASTM D473	0	0.05	ASTM D473	0	0.05

Table 6: Physicochemical properties of illegally refined petroleum products from Location E (May 2018)

Parameter/Unit	AGO			DPK			PMS		
	Method	Value	Standard	Method	Value	Standard	Method	Value	Standard
Specific gravity	ASTM D1298	0.86	0.82-0.87	ASTM D1298	0.83	0.800-0.825	ASTM D1298	0.78	0.72-0.74
API gravity	ASTM D1298	33	41 - 31	ASTM D1298	39	45 - 40	ASTM D1298	50	60
Flash point, ºC	ASTM D56	121	66	ASTM D56	84	45	ASTM D56	-	N/A
Pour point, ºC	ASTM D97	-10	-30	ASTM D97	-7	-47	ASTM D97	-9	N/A
Fire point, ºC	ASTM D56-97	135	76	ASTM D56-97	96	48	ASTM D56-97	-	N/A
Cloud point, ºC	ASTM D2500	4	6	ASTM D2500	6	N/A	ASTM D2500	5	N/A
Viscosity, cP	ASTM D88/D445	12	11	ASTM D88/D445	4	1.6	ASTM D88/D445	3	0.88
Water content, %v	ASTM D4007	0.1	0.05	ASTM D4007	0.13	0.05	ASTM D4007	0.11	0.05
Sediment, %w	ASTM D473	0	0.05	ASTM D473	0	0.05	ASTM D473	0	0.05

4. Discussion

A cursory look at the results shows deviations from standard specifications of the petroleum products of the illegal refineries (Tables 2 – 6), indicating poor quality. Results of the analyses of products of the conventional refinery captured in the study (Table 1) clearly indicate equality with or in very close proximity to standard specifications. For example, specific gravity/API gravity, viscosity, water content, and sediment all fall within range of the standard specifications except the sediment content of the PMS which deviated significantly from standard specification (0.5% as against 0.05% by mass). This could have resulted from handling, storage, distribution and transportation procedures by product marketers rather than from processing methods or lack of adherence to standard refining practice.

In Tables 2 – 5, the specific gravity (API gravity) of AGO all fall outside the range of standard specifications for the product. This indicates the presence of substances that are not expected within the product; probably higher range of hydrocarbon compounds. This is also reflected in the flash points and viscosities of the petroleum product samples which also showed higher values than standard specifications. These observations are also true for the DPK and PMS samples, except DPK sample in Table 3 where the specific gravity is lower than standard specifications. Again, this points to the fact that the product probably contains lighter grades of hydrocarbon compounds than the normal range.

In Table 6, the specific gravity of the AGO is within range but with higher viscosity than normal. This indicates another abnormality and inconsistency in the product which is simply a failure of the production and handling process of the refinery operators.

Worthy of note also is the level of water contamination of some of the product samples. In Table 3, the water content across the three samples of AGO, DPK and PMS are higher than standard specifications (0.13%, 0.23% and 0.1% as against 0.05%, 0.05% and 0.05%) respectively. Similarly, Table 6 shows high water content in the three samples of AGO, DPK and PMS. In Table 5, AGO sample has very high water content (1.7%) against 0.05 standard specification.

Undoubtedly, the poor quality as indicated in the results is basically as a result of: (a) Poor and crude processing/refining methods with equally poor equipment; (b) Lack of pre and post refining purification and modification processes of crude oil and refined products; and (c) Poor product handling, storage and transportation to end users by artisanal refiners. Conventional refineries adopt standard and international best practice of subjecting all products to laboratory analyses to ascertain compliance to standard specifications before sending them out to the market. But artisanal refineries do not have the capacity to undertake such analyses.

Refineries all over the world are major sources of environmental pollutants and contaminants. This is basically the reason why their operations are highly regulated by stringent environmental laws related to air, land and water. Sadly, these illegal refineries have no semblance of rules that guide their operations. Product quality standards and specifications are not adhered to, neither are the basic health and safety rules and regulations for the highly sensitive and volatile petroleum industry operations obeyed.

Pre-crude distillation processes such as dewatering, desalination, desulphurization among others to eliminate impurities are never carried out by the operators. In the same vein, post distillation physical and chemical modification processes to further eliminate impurities and undesirable substances and improve product quality are equally not embarked upon. Some of these processes include isomerization, cracking, polymerization, hydro-treating, desulphurization among others. It becomes clear, therefore, why products of illegal refineries are substandard and why the environment becomes highly compromised by their operations.

Poor quality petroleum products not only perform poorly in engines, they equally lead to incomplete combustions and emission of such poisonous gases like carbon monoxide, hydrogen sulphide, sulphur dioxide and oxides of nitrogen into the atmosphere. Conventional refineries subject all their products to purification processes to eliminate or reduce the concentration of certain impurities such as sulphur compounds (H_2S, SO_2), mercaptans "R"SH (a series of complex organic compounds having as many as six carbon atoms in the hydrocarbon radical "R" and nitrogen compounds. The sulphur and nitrogen compounds are acidic gases that are harmful to the environment (acid rain); they are also technically undesirable and produce foul odours.

Presence of water in petroleum products not only reduce technical performance of the product, it encourages poor combustion and corrosion of storage facilities including automobile fuel tanks. Poor combustion results in emission of obnoxious gases that compromise air quality.

As a result of environmental concerns and regulations, most countries of the world now restrict sulphur contents in petroleum products. According

to EPA report, US EPA began regulating diesel fuel sulphur levels in 1993. Before then, diesel contained as much as 5,000 ppm of sulphur. Again prior to 2016, the world and in particular the US were content with 500 ppm low sulphur diesel (LSD) as the maximum allowable sulphur concentration in diesel fuels. In 2006, however, EPA rolled out more stringent laws on sulphur concentrations of automobile fuels because of greater environmental concerns and awareness of the impact of sulphur on air quality. The sulphur content of fuels has steadily gone down from 5,000 ppm to 500 ppm for low sulphur diesel (LSD) and to 15 ppm for ultra-low sulphur (ULSD) (Natekar, 2009).

In the European Union and the United States, diesel fuel is now generally restricted to maximum sulphur levels of 10 to 15 ppm (Waddams et al., 2018). All these stringent rules are geared towards alleviating the level of environmental pollution and thus improving air quality standards. Due to environmental concerns, it became incumbent on the petroleum refining industry in the 1990s to invest massively in the modification of refined petroleum products in order to minimize environmental emissions and their associated environmental and health hazards. Illegal refineries operating in the Niger Delta have neither the technical and infrastructural capability nor the financial and manpower capacity to embark on these product modification processes.

5. Conclusions

In this study, laboratory analyses of samples of products of artisanal refineries in parts of Rivers State were carried out to determine their quality. Results showed that these products deviated from industry standards indicating that they do not meet the standards required for their use. A review of the operations and activities of the artisanal refineries carried out also revealed a lot of negative environmental impacts. This study, therefore, concludes that artisanal refineries operating in Nigeria are producing very poor quality petroleum products (fuels) that are not only a threat to the automobile and power generator engines, but also to the environment through air, land and water pollution. Their operations are far from international best practice; and the environment, our economy, health and wellbeing have become major casualties.

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