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Gaseous Emission from the Combustion of AGO from the KRPC in Nigeria

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Abstract

Refined petroleum products from Kaduna refinery and petroleum company serves as a source of energy to the nation but gaseous emission from the combustion of these refined products can be harmful to the ecosystem. Gaseous emission from the combustion of AGO of different volumes from Kaduna Refinery was characterized for gaseous air pollutants using the E8500 combustion analyzer. The concentrations for the gaseous emission from the combustion of AGO were 45.84 mg/m^3 HC, 16.33 mg/m^3 CO, 206.33 mg/m^3 NO_x for 10 mL. 76.39 mg/m^3 HC, 44.33 mg/m^3 CO, 689.33 mg/m^3 NO_x for 20 mL 102.59 mg/m^3 HC, 0 mg/m^3 CO, 692.67 mg/m^3 NO_x for 30 ml. 154.97 mg/m^3 HC, 0 mg/m^3 CO, 1459 mg/m^3 NO_x for 40 ml. 141.88 mg/m^3 HC, 0 mg/m^3 CO, 1516.33 mg/m^3 NO_x, for 50 ml. This study shows that CO and HC exceeded the acceptable limit for stationary sources while NO_x and SO_2 were below the acceptable limit. Hence, there is a need for rapid response and urgent attention from government and regulatory bodies to put in place policies that will help minimize the effect of these emissions.

Keywords: *Emissions; Combustion; Refinery; Petroleum; Concentration.*

1. Introduction

Combustion of refined products in all aspects of life have brought about great industrialization in the country but at a discouraging price. Air pollution is a major threat to the ambient air quality of both developing and developed nations resulting in an increase in health and environmental hazard [1]. Increasing world population and energy generation has extremely contributed to an alarming increase in air pollution. Urban centres in major parts of the world especially the less developed countries are exposed to emissions derived from the combustion of refined products among others that have adversely affected air quality and human health and as such, exposure to these emissions is now considered detrimental to the urban life and the world at large [2].

Combustion of refined petroleum products is primarily engaged in waste management, energy generation and vehicular transport. The products of these processes include criteria air emissions such as oxides of nitrogen (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM_{10}). These criteria pollutants, in turn, leads to air pollution which is very detrimental not only to humans but also to the environment. Air pollution is defined as the introduction of biological materials or chemicals into the surrounding air which can be harmful to humans, plants and structures. Air pollution is classified into anthropogenic and non-anthropogenic origins. Indoor and outdoor air pollution have been a major concern in both developed and less developed nations. Any substance that contaminates air quality is termed air pollutant. Air pollution is basically the presence of air pollutants such as sulphur dioxide (SO_2), particle substances (PM), nitrogen oxides (NO_x) and ozone (O_3) in the air that when ingested at levels, brings about adverse effects on human health and the environment [3-4] highlighted important criteria air pollutants that contribute to ambient air pollution which may include sulphur dioxide (SO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), ozone (O_3), total suspended particulate matter (TSP) and lead (Pb). These pollutants increasingly pose both direct and indirect risks to human health, structures of the society and atmospheric visibility in the environment. Maintaining standard air quality limits has become a significant task for policymakers as well as for non-governmental organizations.

Transport is the main culprit behind urban air pollution. Combustion of (fossil) fuels releases emission in the forms of solid particles, liquid droplets, or gases and pollution separated in primary and secondary pollutants. Due to the dependence on refined petroleum products, inroad transportation has immensely contributed to the emissions of criteria air pollutants with consequential effects on humans, structures and plants [5-6]. Emission from vehicular traffic contains a wide range of pollutants which are carbon monoxide (CO), oxides of nitrogen (NO_x), particulate matter (PM) and volatile organic compounds (VOCs) which has a long term impact on air quality [7-8].

Although, in-vehicle transport technology, the type and quality of refined petroleum products used, environmental conditions, meteorological factors (ambient temperature and atmospheric pressure) and driving and maintenance culture determine the type of criteria air pollutants released [9-10], stated that vehicular pollution arises mainly from incomplete combustion of fossil fuels. Incomplete combustion of these fuels has the potential to release large amounts of oxides of nitrogen (NOx), oxides of sulphur (SOx) and carbon monoxide (CO) into the outdoor ambient air. Today, mobile source emissions have tended to be the largest contributor to urban emission inventories in many locations and they contribute to air pollution with deleterious impact on plants, human health and climate [11].

2. Materials and methods

The materials and equipment used during the combustion of AGO refined petroleum product include fuel samples – gasoline, kerosene and diesel; measuring cylinder; a conical flask; a combustion chamber; an air compressor; a combustion analyzer. The study area is shown in Figure 1.

Fig. 1. Kaduna Refining and Petroleum Company

2.1. Combustion apparatus, fuel and experimental procedure

The E8500 plus combustion analyzer was used for gaseous emission characterization. It is a complete, portable tool for EPA compliance–level emissions monitoring of boilers, engines, and other combustion equipment. It has up to nine gas sensors with a weight of 5 kg and a dimension of 26 x 15 x 24 cm.

It is an analyzer equipped with inbuilt thermoelectric chiller which efficiently and quickly removes water vapor from gas samples to prevent gases from bubbling into the condensate drain gas velocity measurement capability which makes the instrument scientifically efficient. Gaseous emissions from the combustion of refined petroleum products were measured using the E8500 plus portable industrial gas and emissions analyser.

The combustion analyser is capable of measuring gaseous emissions including; oxygen (O_2), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen NO_x (NO, NO_2), sulphur dioxide (SO_2), and hydrogen sulfide (H_2S). Its CO detection range is 0 -

2000 ppm with 1 ppm resolution while its NO and NO_2 detection range is 0 - 400 ppm with 1 ppm resolution. The detection range of its H_2S is 0 - 500 ppm with 1 ppm resolution. In addition, the temperature of the flue gas and the ambient air in its area of operation can also be measured with the analyzer at the range of 0 – 1000°C. It also measures pressure/draft excess air of combustion, gas velocity, and the efficiency of combustion.

The air compressor used is a 50-litre air receiver which has a 3 HP, 230 V, 1 HP motor with electrical overload protection. This 66 kg robust air compressor of 930 x 420 x 800 mm dimensions features a heavy-duty cast iron pump, designed to appeal to commercial, agricultural, and consumer users. It delivers a more-than-adequate volume & pressure of compressed air. It has also a maximum working pressure of 10.3 bar (148.5 psi) controlled by a fully automatic pressure switch. It has a cast-iron `V` type twin cylinder air compressor pump with 15cfm displacement. The air compressor is powered by a petrol-fuelled engine which is placed far away from the combustion chamber and analyzer so that it does not influence the emissions being read by the analyzer. It is capable of providing a more than adequate volume and pressure of compressed air to power professional spray-guns and many of the frequently used air tools.

Without the gas sampling probe connected to the instrument, the combustion analyzer is turned on. Baseline calibration is required to zero out any sensors that may have drifted far of zero. After the required baseline calibration and there were no errors, the gas sampling probe is connected to the instrument. The electronic analyzer is now ready for use to monitor any gaseous emission for which the appropriate sensor is installed. Gaseous emissions including; hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO, NO_2, NO_x), sulphur dioxide (SO_2), and hydrogen sulfide (H_2S) were measured with the use of the combustion analyzer. All emissions were measured in mg/m^3 with the exception of HC and CO which was measured in ppm and % respectively.

Fuel samples were stored in air-tight plastic containers to avoid contamination and maintain sample quality. The fuel containers were leak-proof to prevent the escape of gases including hydrocarbon. The fuel samples stored includes AGO from KRPC. The volume of AGO was varied between 10 ml and 50 ml. This was done to determine the time taken for each volume to be combusted and characterization of the air pollutants. Also, to determine the emission rate of the gaseous pollutant which is the unit mass of gaseous emissions per time taken for characterization of the air pollutants from the combustion of AGO refined petroleum product. For each experimental run, a varied volume of the refined product was measured with a measuring cylinder.

2.2. Sampling and measurement techniques

Air was passed into the combustion chamber with the aid of a Clarke air CE compressor to provide sufficient air for the combustion process. The air supplied was at a constant flowrate which was achieved at the maximum working pressure condition of the compressor, 10.3 bar (148.5 psi). The air compressor was powered by a petrol-fuelled engine which was placed far away from the combustion chamber and analyzer so that the compressor emissions do not interfere with the emissions being read by the analyzer.

For each experimental run, the measured volume sample of each AGO sample was transferred into the combustion chamber, air from the compressor was passed into the chamber and ignition was done via the ignition hole using a lightning gun. The lid was placed firmly on it as combustion commences. During the combustion process, gaseous emissions including; hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO, NO_2, NO_x), sulphur dioxide (SO_2), and hydrogen sulfide (H_2S) were emitted into the atmosphere from the combustion chamber stack and into the atmosphere. The combustion analyzer gas probe was inserted into the combustion zone through the stack of the chamber in order to measure the accurate air pollutants coming directly from the combustion zone in the chamber as opposed the ambient zone when measured from the top of the combustion chamber.

Readings were taken and recorded with the use of the combustion analyzer as the concentration values of air pollutants changed during the period of combustion. At the end of combustion, the combustion analyzer was calibrated back to zero in order to zero out the sensors that may have drifted far of zero. Three experimental runs were carried out for each volume of refined product that was varied.

3. Results and discussion

For the varied volume of AGO experiment carried out in the laboratory, the average measured gaseous emissions and time taken during combustion of AGO are summarized in Table 1.

Table 1. Emission characterization of combustion of varying volumes of AGO

Vol. of PMS (mL)	Time (s)	HC (mg/m^3)	CO (mg/m^3)	NO$_x$ (mg/m^3)	CO$_2$ (mg/m^3)	SO$_2$ (mg/m^3)
10	295	45.836	16.333	206.333	0	0
20	512.67	76.394	44.333	689.333	0	0
30	742	102.586	0	692.667	0	0
40	1222.67	154.971	0	1459	0	0
50	1644.67	141.875	0	1516.33	0	0

The statistical descriptions of the emissions from the AGO combustion can be seen in Figure 2.

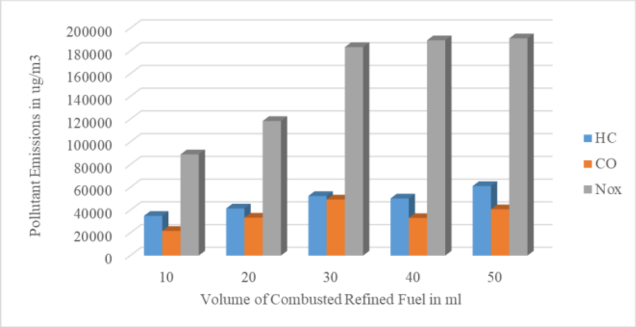

Figure 2. Descriptive statistic of gaseous emissions from the combustion of varying volumes of AGO

The measured average concentrations for the combustion of 10 mL of AGO were 45.836 mg/m^3 of HC, 16.333 mg/m^3 of CO, 206.333 mg/m^3 of NO$_x$ and zero values were recorded for CO$_2$ and SO$_2$.

For 20 mL of AGO, the measured average concentrations were 76.394 mg/m^3 of HC, 44.333 mg/m^3 of CO, 689.333 mg/m^3 of NO$_x$ and zero values were recorded for CO$_2$ and SO$_2$.

For 30 mL of AGO, the measured average concentrations were 102.586 mg/m^3 of HC, 692.667 mg/m^3 of NO$_x$ and zero values were recorded for CO, CO$_2$ and SO$_2$. For 40 ml of AGO, the measured average concentrations were 154.971 mg/m^3 of HC, 1459 mg/m^3 of NO$_x$, and zero values were recorded for CO, CO$_2$ and SO$_2$. For 50 ml of AGO, the measured average concentrations were 141.875 mg/m^3 of HC, 1516.33 mg/m^3 of NO$_x$, and zero values were recorded for CO, CO$_2$ and SO$_2$.

The measured concentration of gaseous pollutants for 10 mL of AGO for the three (3) experimental runs were in the range of 52.385 – 45.836 mg/m^3 for HC, 16 – 17 mg/m^3 for CO, 186–42 mg/m^3 for NO$_x$, 0 mg/m^{3}for SO$_2$ and 0 mg/m^3 for CO$_2$, the mean and standard deviation were 45.836 ± 8.167, 16.333 ± 0.5, 203.333 ± 56.9 for HC, CO and NO$_x$ respectively.

The measured concentration of gaseous pollutants for 20 mL of AGO for the three (3) experimental runs were in the range of 39.288 – 91.673 mg/m^3 for HC, 30 – 53 mg/m^3 for CO, 403–845 mg/m^3 for NO$_x$, 0 mg/m^3 for SO$_2$ and 0 mg/m^3 for CO$_2$, the mean and standard deviation were 76.394 ± 326.323, 44.333 ± 10.2, 689.333 ± 202.7 for HC, CO and NO$_x$ respectively.

The measured concentration of gaseous pollutants for 30 mL of AGO for the three (3) experimental runs were in the range of 98.221 – 104.769 mg/m^3 for HC, 684 – 774 mg/m^3 for NO$_x$, 0 mg/m^3 for CO, SO$_2$ and CO$_2$ respectively, the mean and standard deviation were 102.586 ± 3.087, 692.667 ± 63.2 for HC and NO$_x$ respectively.

The measured concentration of gaseous pollutants for 40 mL of AGO for the three (3) experimental runs were in the range of 157.153 – 163.701 mg/m^3 for HC, 1164 – 1781 mg/m^3

for NO_x and 0 mg/m^3 for CO and SO_2 respectively, the mean and standard deviation were 154.971 ± 8.167, 1459 ± 252.6, for HC and NO_x, respectively.

The measured concentration of gaseous pollutants for 50 mL of AGO for the three (3) experimental runs were in the range of 137.509 – 144.057 mg/m^3 for HC, 1410 – 1597 mg/m^3 for NO_x, 0 mg/m^3 for SO_2, CO andCO_2 respectively, the mean and standard deviation were 141.875 ± 3.087, 1516.333 ± 78.5, for HC and NO_x respectively.

3.1. Ambient air quality implication

The air pollutants (HC, CO, SO_2 and NO_x) were identified from the combustion of AGO.

In this study, the emission of CO from combustion of refined petroleum products might result from low combustion temperature, insufficient oxygen, poor mixing of fuel with the compressed air and/or too short a resident time combustion gas in the combustion zone [12-14].

When the emissions of AGO combustion from varying volume (10 mL – 50 mL) (Table 1) are compared with [15] limits for gaseous emissions from stationary sources in Table 2.

Table 2. Emission limits for specific pollutants from stationary source

Pollutant	Limits (mg/m^3)
Carbon monoxide	10
Hydrocarbon	50
Oxides of nitrogen	350 – 1000
Sulphur dioxide	30 – 3000

Source [15]

HC emitted from AGO combustion breached the permitted emission limit for stationary sources except for 10 ml, while the average emissions of HC breached the permitted limit. CO emitted from AGO combustion breached the permitted emission limit for stationary sources. For NO_x (NO and NO_2), it was observed that its emission from AGO combustion was below the permitted limits for stationary sources except for 40 ml and 50 ml, while the average emissions of NOx were below the permitted limit. Also, it was observed that SO_2 emissions had zero values. Deduced from the comparison, emissions concentration from AGO combustion were below the set standards permitted for stationary source. Hence AGO from KRPC could serve as a source of energy with un-sustainable environmental effects. Measures would have to be taken to ensure a better quality blend of AGO being produced at the refinery.

4. Conclusions

This study identifies air pollutants associated with the combustion of AGO refined petroleum product. Automotive gasoline oil (AGO) was combusted in an experimental chamber. Hydrocarbons (HCs), carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide (SO_2) and carbon dioxide (CO_2) were characterised with the use of a combustion gas analyzer and these pollutants are harmful to the ecosystem and can affect the air quality of the study area.

The gaseous emissions of CO and HC exceeded the permissible limit while that of NO_x and SO_2 are below the acceptable limit. This results in poor air quality of this area. Therefore, there is a need for rapid response and urgent attention from government and regulatory bodies (FEPA) to put in place policies that will help minimize the effect of these emissions.

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