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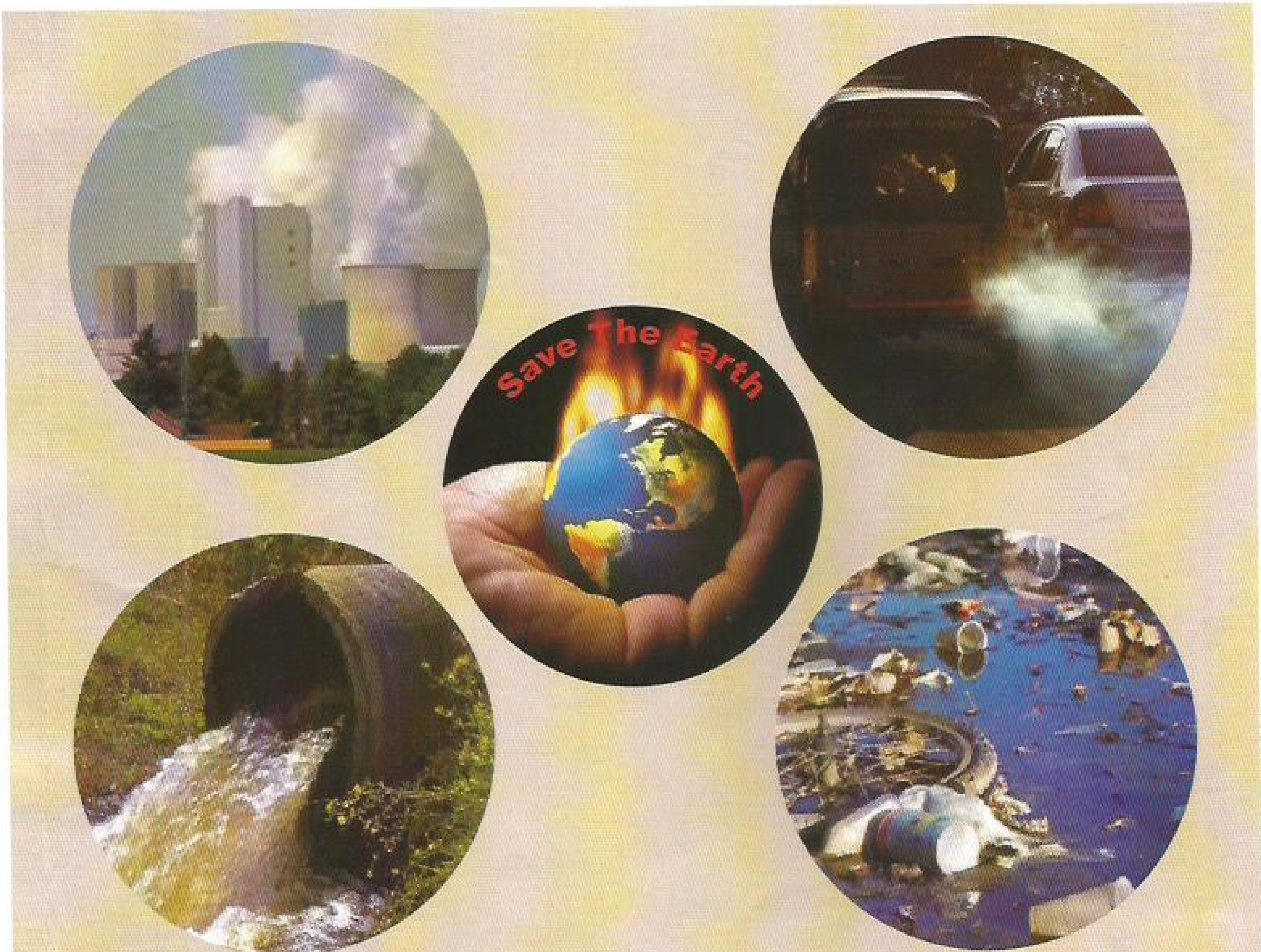

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Issue on Air and Noise Pollution and Its Control

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Impacts Analysis of Emissions From Biodiesel and Washing Water

Ayoola A. Ayodeji, Hymore F. Kofi, Omonhinmin A. Conrad, Efeovbokhan E. Vincent, Ayeni O. Augustine and Olafadehan A. Olaosebikan

Covenant University, Chemical Engineering Department, Ota, Nigeria

Producing quality biodiesel with favourable environmental implications is of great importance in order to achieve sustainable energy management. This research is focused on the impact analysis of emissions from biodiesel produced through alkaline catalysed transesterification of waste groundnut oil (WGO), waste soyabean oil (WSO) and crudepalm kernel oil (CPKO), using SIMAPRO 7.33. In this research, the comparative analysis of the emissions from 1 kg biodiesel produced was carried out. Waste groundnut oil biodiesel emissions had the most pronounced impact on human health : Waste groundnut oil biodiesel had 2.94×10^{-10} kg emissions, waste soyabean oil biodiesel released 2.40×10^{-10} kg non-environmentally friendly substances, while crudepalm kernel oil biodiesel had 1.85×10^{-10} kg emissions. On damage to ecosystem quality, emissions from waste groundnut oil biodiesel biodiesel was 1.25×10^{-3} kg, 9.95×10^{-4} kg emissions from waste soyabean oil biodiesel and 4.39×10^{-4} kg emissions from crudepalm kernel oil biodiesel. The result of damage to climate change showed that waste soyabean oil biodiesel contributed the most with 1.54×10^{-6} kg CO_2, followed by waste groundnut oil biodiesel with 1.32×10^{-6} kg CO_2 and crudepalm kernel oil biodiesel with 1.18×10^{-6} kg CO_2. Single score result showed that the increasing order of damage on the 3 categories considered is human health, climate change and then ecosystem quality.

KEYWORD

Biodiesel, Impact analysis, Transesterification.

INTRODUCTION

The world economy depends on sustainable energy generation. In the nearest future, the economic consequences of inadequate energy in the world as a result of the predominant dependency on fossil fuels could be severe (Zahira *et al.*, 2014; Liuqing *et al.*, 2014; Liang *et al.*, 2013). In addition, ecosystem and life quality degradation associated with the use of fossil fuels have become a lingering global challenge (Kumar *et al.*, 2013; Parag, 2013; Ayoola *et al.*, 2012). These have prompted world leaders, organisations, industries and educational institutions to look for alternative or complimentary energy sources that are sustainable, with less negative environmental impact. Energy production from biomass, such as crop oils, woody and waste materials has a great advantage over fossil fuels (Zahira *et al.*, 2014; Debalina and Ralph, 2013; Kumar *et al.*, 2013; Lee and Shah, 2013; Cvengros, 2004). Biodiesel, generic term for alkyl esters of fatty acids, is a renewable biomass energy source.It is produced through transesterification process in which triglycerides of edible or non-edible plant oils (such as palm oil, sunflower, jatropha) react with alcohol, in the presence of an acidic or alkaline catalyst, glycerol is produced as byproduct (Ali and Tay, 2013; Evangelos, 2013; Pinzi *et al.*, 2011; Varanda *et al.*, 2011; Marulanda *et al.*, 2010; Kian *et al.*, 2009; Myint and El. Halwagi, 2009; Dzida and Prusakiewiez, 2008).

As energy source, biodiesel exhibits similar performance in diesel engine as petroleum diesel. Emissions from biodiesel produced from different feedstocks have been reviewed by many researchers.The common emissions from biodiesel are carbon monoxide (CO), hydrocarbons (HCs), nitrogen oxides (NO_x) and particulate matter (PM) (Debalina and Ralph, 2013; Kumar *et al.,* 2013; Varanda *et al.,* 2011; Kian *et al.* 2009). Emissions from biodiesel are lesser compare to emissions from petroleum diesel (Chauhan *et al.* 2012; Oner and Altun, 2009; William, 2006). Kumar *et al.* (2013) and Canakci (2007) reported a reduction of 18.4 % in carbon monoxide emission, Oner and Altun (2009) reported 14.5% reduction in carbon monoxide emission while the result of the work of Nabi *et al.* (2006) showed 4 % reduction in carbon monoxide emission. This is due to the fact that biodiesel has higher percentage of oxygen in its molecules that allow complete combustion of the fuel and make possible the total conversion of carbon monoxide to carbon dioxide (Kumar *et al.,* 2013; Nabi *et al.,* 2009). Emissions from biodiesel contribute to global warming. Global warming, as a phenomenon, results from the release of greenhouse gases (GHGs) into the atmosphere and greenhouse gases resilient permanence in the atmosphere leads to the entrapment of heat on the earth's surface. The most significant examples of greenhouse gases are CH_4, H_2O, CO_2, NO_2 and fluorinated compounds (Kian *et al.,* 2009; Lopez *et al.,* 2009).

The focus of this study is to identify, quantify and compare emissions from both the biodiesel obtained and washing water used during the transesterification of waste groundnut oil (WGO), waste soyabean oil (WSO) and crude palm kernel oil (CPKO); to analyse the environmental impacts of such emissions and to suggest the most environmentally-friendly biodiesel feedstocks among the 3 feedstocks. The impacts analysis can be achieved by considering the life cycle assessment (LCA) of the biodiesel produced. Life cycle assessment of biodiesel will aid in the deci-sion making process by incorporating green design objectives into engineering-related projects and thus provides opportunities for environmental improvement (Gabi, 2013). Governments, consultants, academicians and industries can use life cycle assessment to help identify environmental impacts associated with 'cradle-to-grave' activities of biodiesel and even the processes involved (Debalina and Ralph, 2013; Gabi, 2013; William, 2006).

In this research, the potential impacts of laboratory scale biodiesel produced from waste groundnut oil (WGO), waste soyabean oil (WSO) and crude palm kernel oil (CPKO) are assessed and compared through life cycle assessment. Life cycle assessment as a tool, comprises of 4 distinct but interrelated phases: Goal and scope phase, inventory phase, impact assessment phase and interpretation phase (Debalina and Ralph, 2013;Gabi, 2013; Goedkoop *et al.,* 2010; Requena *et al.,* 2010; Gnansounou *et al.,* 2009; Bernesson and Hansson, 2006; Goedkoop and Spriensma, 2000).

It is important to note that the life cycle assessment study of this work covers 'gate to gravel' of biodiesel production, that is only the assessment of the emissions during biodiesel production is considered. Emissions during the production of raw materials, emissions while transporting and emissions during biodiesel usage are not considered. In characterising the non-environmentally-friendly substances identified, 7 midpoint categories are considered. These categories are carcinogens, non-carcinogens, respiratory inorganics, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification and global warming. And their impacts on human health, ecosystem quality and climate change are quantified. With the aid of single score, biodiesel emissions from the 3 different oils were compared and the significance of each kind of emission is accounted for.

MATERIAL AND METHOD

Oil treatment

Impurities present in waste groundnut oil, waste soyabean oil and crude palm kernel oil were first removed through filtration using industrial sieve with pore diameter 70 µm. To prevent soap formation during transesterification process, the removal of free fatty acid (FFA) was carried out through saponification process by reacting 10 mL of 0.125M NaOH

Table 1. *Properties of the raw waste oil*

Oil	Flash point, °C	Viscosity, mm^2/s @ 40°C	Density, g/cm^3	Acid value, mg KOH/g	Sap. value, mg KOH/g	Water content, %
WGO	243	32.64	0.9090	1.561	220.0	0.63
WSO	232	31.67	0.9110	1.843	240.1	0.67
CPKO	230	36.72	0.9100	1.106	203.7	0.56

Table 2. *Triglyceride composition of WGO, WSO and CPKO*

Fatty acid			Weight percentage, %		
			WGO	WSO	CPKO
$C_{18}H_{32}O_2$	Linoleic acid,	C18:2	0.42	34.86	-
$C_{18}H_{34}O_2$	Oleic acid,	C18:1	90.21	39.14	9.29
$C_{12}H_{24}O_2$	Lauric acid	C12:0	-	10.39	42.58
$C_{14}H_{28}O_2$	Myristic acid	C14:0	-	-	10.64
$C_{16}H_{32}O_2$	Palmitic acid	C16:0	-	-	28.34

Table 3. *Properties of biodiesel obtained*

Property	ASTM mtd	CPKO biodiesel	WSO biodiesel	WGO biodiesel
Density @ 25°C, g/cm^3	ASTM D4052	0.8760	0.8820	0.8903
Pour point, °C	ASTM D97	-6	-6	-9
Flash point, °C	ASTM D93	208	204	180
Water content, %		0.004	0.006	0.005
Viscosity @ 40°C, mm^2/s	ASTM D445	4.70-5.00	4.55-4.85	4.30-4.70
Cetane number		51.7-53.2	50.6-52.8	49.4-51.0

solution with free fatty acid present in every 100 g of waste oil; the mixture was continuously stirred at a temperature of 40 °C for 15 min. After 30 min of gravitational settling, 2 distinct layers were formed: The upper layer was less viscous waste oil free of free fatty acid and lower layer was an emulsion of soap. Properties and triglycerides compositions of waste groundnut oil, waste soyabean oil and crudepaln kernel oil considered are shown in tables 1 and 2, respectively. Biodiesel properties obtained from the transesterification process of the 3 kinds of oil considered are as shown on table 3.

Transesterification

In the transesterification of waste groundnut oi, waste soyabean oil and crudepaln kernel oil, the oil triglycerides reacted with methanol in the presence of KOH catalyst to produce methyl ester (biodiesel) and glycerol. Catalyst was first dissolved completely in the required amount of methanol as specified in the experimental design to form a clear solution of potassium methoxide. The solution was transferred to 100 g pretreated oil heated to 50 °C. The mixture was tightly enclosed, maintained at 60°C and continu-ously stirred at 400 rpm on a 7.25" x 7.25" Cimarec digital magnetic stirring hotplate (USA) for 60 min reaction time. Biodiesel and glycerol obtained were transferred to separating funnel and allowed to separate into 2 distinct layers (in 24 hr); a light yellow biodiesel (top layer) and a reddish brown glycerol (bottom layer).

Table 4. *Substances obtained from biodiesel and washing water analysis, in mg/L*

Substance	CPKO biodiesel	WGO biodiesel	WSO biodiesel	CPKO washing H_2O	WGO washing H_2O	WSO washing H_2O
Aluminium (λ=396.1 nm)	0.015	0.021	0.016	0.009	0.011	0.015
Arsenic (λ=193.7 nm)	0.002	0.003	0.001	0.014	0.039	0.042
Beryllium (λ=234.9 nm)	0.009	0.011	0.007	-	-	-
Cadmium (λ=228.8 nm)	0.010	0.031	0.051	0.025	0.031	0.028
Calcium	-	-	-	0.860	0.760	0.550
Carbonate, μg/L	-	-	-	430	500	530
Chloride	-	-	-	1.460	1.710	0.990
Chromium (λ=357.9 nm)	0.003	0.007	0.004	0.001	0.003	0.002
Cobalt (λ=240.7 nm)	0.002	0.004	0.003	-	-	-
Copper (λ=324.7 nm), μg/L	3	7	11	17	23	15
Hydroxide	-	-	-	0.680	0.810	0.750
Lead (λ= 283.3 nm)	0.020	0.013	0.014	0.004	0.006	0.010
Nickel (λ=232.0 nm)	0.038	0.056	0.028	0.005	0.009	0.007
Nitrate	-	-	-	0.520	0.480	0.420
Phosphate	-	-	-	0.190	0.280	0.270
Sulphate	-	-	-	0.640	0.650	0.700
Zinc (λ=213.9 nm)	0.013	0.078	0.042	0.138	0.141	0.093
Water turbidity, NTU				207	210	207
Colour of water , PCU	-	-	-	307	307	307

– means not determined; λ is the working condition wavelength considered during AAS analysis

Slit width used during AAS analysis: 0.1 nm (Be), 0.2 nm (Cr and Ni), 1.0 nm (Zn) and 0.5 nm (other metals)

NTU – Nephelometric turbidity unit, PCU – Platinum cobalt unit (pure water has zero values of NTU and PCU)

Biodiesel obtained was cleansed of impurities (unconverted methanol, catalyst, soap and traces of glycerol) by washing with several charges of warm distilled water and dried afterward at 120 °C in an oven for 30 min to eliminate residual moisture.

Analysis of the emission

Emons to the environment from biodiesel produced and washing water obtained were identified, quantified and then aggregated based on the unit system considered (1 kg of biodiesel produced). Elemental analysis of the emissions from the washing water and biodiesel was carried out using atomic absorption spectroscopy (AAS, AAnalyst 200 Perkin Elmer precisely, USA). The determination of SO_4^{2-}, PO_3^-, NO_3^- in washing water was carried out using DR 1900 portable hach spectrophotometer (USA) and C99 multi-parameter bench photometer (HANNA, USA) and standard methods were followed. In addition, Cl^-, CO_3^-, OH^- and Ca^{2+} present in the washing water were also analysed through titration method.The results of the emissions analysis obtained are shown in table 4.

Elemental analysis : Atomic absorption spectroscopy (AAS, AAnalyst 200 Perkin Elmer precisely, USA) and AOAC methods were employed for the elemental analysis of the emissions. Atomic absorption spectroscopy consists of a high efficiency burner system with a high sensitivity nebulizer and an atomic absorption spectrometer. The burner system provides the thermal energy necessary to dissociate the chemical compounds, providing free analyte atoms so that atomic absorption can occur. The spectrometer measured the amount of light absorbed at a specific wavelength using a hollow cathode lamp as the primary light source, a monochromator and a detector. A deuterium arc lamp corrects for background absorbance caused by non-atomic species in the atom cloud. Each digested sample was aspirated into nebulizer compact. In nebulizer compact, air, acetylene and the sample were mixed together to form a mixture.Flame burned and atomised the sample from ground state to the excited state. At excited state, absorption occurs and monochromator select the wavelength in agreement with the atom, that is coming in, based on the source of light. The source of light is hollow cathode lamp. The detector detects the atom and transfers the concentration reading to reader.

Determination of SO_4^{2-}, PO_3^-, NO_3^- in washing water : Hach spectrophotometer and C99 multi-parameter bench photometer (HANNA, USA) were used for the analysis. In each case, 10 mL of washing water was put into a vial bottle and standard reagent powder was added and then shaken to allow complete reaction for 5 min, resulting into a change in colour of the sample. Another bottle containing the blank water sample was then inserted into the holder to obtain zero reading being displayed by the timer. Then the sample to analyse was then inserted into the compartment/holder and a specific anion method was selected on the equipment (based on the anion to determine); the read button displayed the concentration of the anion in mg/L. For SO_4^{2-} determination, SulfaVer 4 method (method 8051) and Hach spectrophotometer were used. For PO_3^- and NO_3^- determination, HI 93713-0 reagent powder and HI 93728-0 reagent powder were used, respectively in C99 multiparameter bench photometer.

Cl^-, CO_3^-, OH^- and Ca^{2+}determination through titration : The following were analysed in washing water through titration method :

Determination of Cl^- in washing water: 20 mL of the sample of washing water was taken into a conical flask, 2 drops of potassium dichromate was added and a yellow colouration was observed. The solution was titrated with 0.1M silver nitrate until a pink colour end point was reached. Cl^- concentration was calculated thus

$$\text{Chloride ion (mg/L)} = \frac{\text{Volume of } AgNO_3 \text{ used } \times 0.1M \times 35.5 \times 1000}{\text{20 mL of the sample}}$$

Determination of CO_3^- and OH^- in washing water: In each case, 20 mL of the sample of washing water was put into a conical flask and 2 drops of methyl orange was added and a yellow colouration was observed. The solution was carefully titrated with 0.01M hydrochloric acid until a redcolour end point was observed.The concentration of the anion present in washing water (in each case) was calculated using the equation below :

$$\text{Anion present (mg/L)} = \frac{\text{Volume of HCl used } \times 0.01M \times \text{MW of Anion} \times 1000}{\text{20 mL of the sample}}$$

Determination of Ca^{2+} in washing water : 20 mL of the water sample was put into a conical flask, ammonia buffer was added, then 2 drops of erichrome black T indicator was added. The water solution was titrated with 0.01M EDTA and a sharp blue point was observed. Ca^{2+} was obtained using :

$$Ca^{2+} \text{ (mg/L)} = \frac{\text{Volume of EDTA used } \times 0.01M \times 1000}{\text{20 mL of the sample}}$$

Impact assessment

Impact assessment of the emissions on both man and environment was carried out using SIMAPRO 7.33 software, after the transesterification of the 3 kinds of oils. And modification of impact 2000+ method used was carried out to suit the geographical location

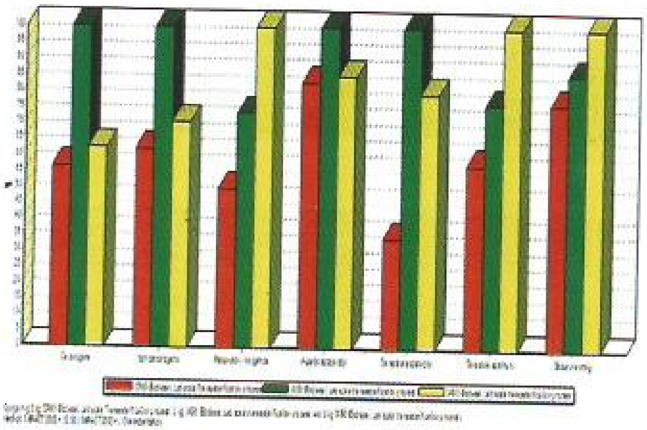

Figure 1. *Characterisation of emissions from washing water and biodiesel produced*

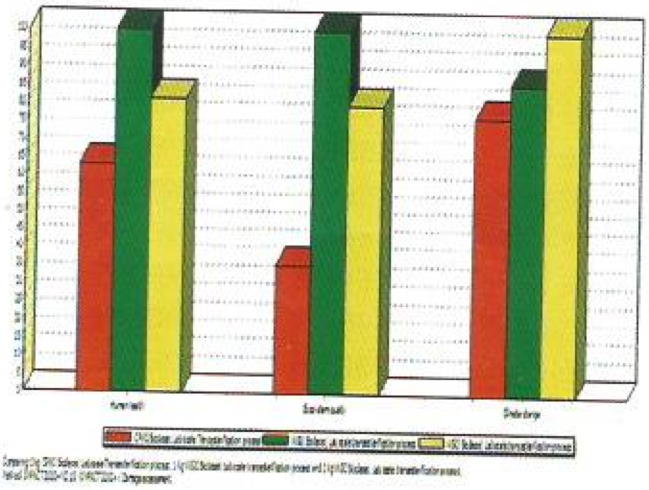

Figure 2. *Damage assessment of emission from washing water and biodiesel obtained*

(Nigeria) of interest. Results obtained were discussed in section 3. And data obtained were expressed in international system of units (systeme international d'unites).

RESULT AND DISCUSSION

Characterisation

With the aid of SIMAPRO 7.33, the results obtained during the characterisation of the emissions from washing water and biodiesel are as shown figure 1 and table 5. In each category, the highest cumulative quantity of non environmentally friendly substances from each biodiesel feedstock was assigned 100%. Considering carcinogens, crudepalm kernel oil biodiesel released 3.21×10^{-6} kg (56%) non-environmentally friendly substances, waste groundnut oil biodiesel had 5.69×10^{-6} kg (100 %) non-environmentally friendly substances released, while 3.55×10^{-6} kg (62% of the substances released from waste groundnut oil biodiesel) were released from waste soyabean oil biodiesel production.

Damage assessment

The impacts of the non environmentally friendly substances released are assessed by grouping them into 3 categories: Damage to human health, damage to ecosystem quality and damage to climatechange. The results are shown in figure 2 and table 6.

Damage to human health

The results obtained from the damage assessment on human health comprising of carcinogens, non-carcinogens and respiratory inorganics. These substances are expressed in DALY (disability adjusted life year). According to WHO (2014), one DALY is one year lost due to ill-health, disability or early death.

Non-environmentally friendly substances from waste groundnut oil biodiesel was 2.94×10^{-10} kg (100 %), waste soyabean oil biodiesel released 2.40×10^{-10} kg (80 %), while crudepalm kernel oil biodiesel released 1.85×10^{-10} kg (60 %). These results indicated that emission from waste groundnut oil biodiesel had the most pronounced adverse effects on human health. Potential non-environmentally friendly sub-stances released into the atmospheric air are more than that released into the environment through biodiesel washing water. Also, non-carcinogens (such as beryllium, lead, zinc) accounted for (80-90) % of the total emission released in this category. Hence, the incor-poration of any process that will effectively remove these 3 key substances during biodiesel production will amount to production of 'healthier' biodiesel. In man, lead result into kidney damage, miscarriages, malfunctioning of nervous systems, brain damage, diminished learning abilities of children and even death both in animals and humans. It also affects plant chlorophyll synthesis (Sabine and

Table 5. *Characterisation of substance into 7 categories*

Substance	Compartment	CPKO biodiesel	WGO biodiesel	WSO biodiesel
Carcinogens				
Arsenic, kg/C_2H_3Cl eq.	Air	2.49E-06	3.73E-06	1.24E-06
Cadmium, kg/C_2H_3Cl eq.	Air	3.56E-07	1.10E-06	1.82E-06
Chromium VI, kg/C_2H_3Cl eq.	Air	3.65E-07	8.52E-07	4.87E-07
Total		3.21E-06	5.69E-06	3.55E-06
Non carcinogens				
Aluminium, kg/C_2H_3Cl eq.	Air	7.29E-09	1.02E-08	7.78E-08
Aluminium, kg/C_2H_3Cl eq.	Water	1.85E-08	2.26E-08	3.08E-08
Beryllium, kg/C_2H_3Cl eq.	Air	2.50E-05	3.75E-05	1.25E-05
Cobalt,kg/C_2H_3Cl eq.	Air	5.48E-06	1.70E-05	2.80E-05
Chromium III, kg/C_2H_3Cl eq.	Air	5.39E-08	1.26E-07	7.18E-08
Chromium III, kg/C_2H_3Cl eq.	Water	4.51E-09	1.35E-08	9.02E-09
Copper, kg/C_2H_3Cl eq.	Air	6.13E-09	1.43E-08	2.25E-08
Lead, kg/C_2H_3Cl eq.	Air	5.21E-08	3.38E-08	3.64E-08
Lead, kg/C_2H_3Cl eq.	Water	4.30E-08	6.45E-08	1.07E-07
Nickel, kg/C_2H_3Cl eq.	Air	3.37E-07	4.97E-07	2.48E-07
Zinc, kg/C_2H_3Cl eq.	Air	1.21E-06	7.23E-06	3.90E-06
Zinc, kg/C_2H_3Cl eq.	Water	1.84E-05	1.88E-05	1.24E-05
Total		5.06E-05	8.13E-05	5.74E-05
Respiratory inorganics				
Nitrogen dioxide, kg/$PM_{2.5}$ eq.	Air	3.69E-08	4.60E-08	5.86E-08
Sulphur dioxide, kg/$PM_{2.5}$ eq.	Air	1.25E-08	2.65E-08	4.06E-08
Total		4.94E-08	7.25E-08	9.92E-08
Aquatic ecotoxicity				
Aluminium, kg TEG water	Air	7.40E-03	1.04E-02	7.89E-03
Aluminium, kg TEG water	Water	3.24E-02	3.96E-02	5.39E-02
Arsenic, kg TEG water	Air	1.10E-04	1.65E-04	5.48E-05
Cadmium, kg TEG water	Air	4.28E-03	1.33E-02	2.18E-02
Chromium, kg TEG water	Air	2.01E-04	4.69E-04	2.68E-04
Chromium, kg TEG water	Water	4.53E-04	1.36E-03	9.06E-04
Copper, kg TEG water	Air	8.82E-03	2.06E-02	3.23E-02
Lead, kg TEG water	Air	8.01E-04	5.21E-04	2.64E-03
Lead, kg TEG water	Water	1.05E-03	1.58E-03	2.64E-03
Nickel, kg TEG water	Air	6.79E-03	1.00E-02	5.00E-03
Zinc,kg TEG water	Air	2.65E-03	1.59E-02	8.57E-03

Continued...

Substance	Compartment	CPKO biodiesel	WGO biodiesel	WSO biodiesel
Zinc, kg TEG water	Water	1.94E-01	1.98E-01	1.30E-01
Total		2.59E-01	3.12E-01	2.66E-01
Terrestrial ecotoxicity				
Aluminium, kg TEG soil	Air	1.90E-03	2.66E-03	2.02E-03
Aluminium, kg TEG soil	Water	2.04E-16	2.50E-16	3.40E-16
Arsenic, kg TEG soil	Air	8.37E-04	1.26E-03	4.19E-04
Cadmium, kg TEG soil	Air	9.12E-03	2.83E-02	4.65E-02
Chromium, kg TEG soil	Air	1.15E-03	2.67E-03	1.53E-03
Copper, kg TEG soil	Air	3.55E-03	8.29E-03	1.30E-02
Lead, kg TEG soil	Air	2.61E-03	1.70E-03	1.83E-03
Nickel, kg TEG soil	Air	2.14E-02	3.15E-02	1.58E-02
Zinc, kg TEG soil	Air	1.32E-02	7.89E-02	4.25E-02
Total		5.38E-02	1.55E-01	1.24E-01
Terrestrial acidification/nutr.				
Nitrogen dioxide, kg SO_2 eq.	Air	1.59E-06	1.98E-06	2.52E-06
Sulphur dioxide, kg SO_2 eq.	Air	1.60E-07	3.40E-07	5.20E-07
Total		1.75E-06	2.32E-06	3.04E-06
Global warming				
Carbon dioxide, kg CO_2 eq.	Water	1.18E-06	1.32E-06	1.54E-06
Total		1.18E-06	1.32E-06	1.54E-06

kg $PM_{2.5}$ eq. - Kilogram of particulate matter with diameter equivalent to 2.5 micrometer or less
kg TEG soil - Kilogram of tri-ethylene glycol in soil

Wendy, 2009). High concentration of zinc in the bodies of both man and animals results in skin irritations, vomiting, anemia, damaged pancreas and disturbed protein metabolism. Only a limited number of plants can survive on zinc-rich soils and it retards the metabolic activities of micro-organisms and earthworms (Muradov and Veziroglu, 2013).

Damage to ecosystem quality : Damage to ecosystem quality refers to the degradation in quality of water, soil and air, which may impose varied degrees of threat to species found in the ecosystem. The harmful substances released are expressed in PDF* m^2*yr (PDF = Potentially disappeared fraction of species). Considering ecosystem quality in Figure YY, waste groundnut oil biodiesel showed greatest potential damage with 1.25 x 10^{-3} kg (100 %) emission, waste soyabean oil biodiesel with 9.95x10^{-4} kg (75 %) emission and crudepalm kernel oil biodiesel with 4.39 x 10^{-4} kg (30 %)non- environmentally friendly emissions. This could be traced to the percentage of double of fatty acids that make up the bonds of biodiesel produced. Crudepalm kernel oil had the lowest percentage of unsaturated fatty acids (49.29 %), waste soyabean oil contains 74 % unsaturated fatty acids while waste groundnut contains 90.63 % unsaturated fatty acids. That is the higher the double bond the

Table 6. *Damage assessment*

Substance	Compartment	CPKO biodiesel	WGO biodiesel	WSO biodiesel
Human health				
Aluminium, DALY	Air	2.04E-14	2.86E-14	2.18E-14
Aluminium, DALY	Water	5.17E-14	6.32E-14	8.61E-14
Arsenic, DALY	Air	7.69E-11	1.15E-10	3.84E-11
Cadmium, DALY	Air	1.63E-11	5.07E-11	8.34E-11
Chromium, DALY	Air	1.17E-12	2.74E-12	1.56E-12
Chromium, DALY	Water	1.26E-14	3.79E-14	2.53E-14
Copper, DALY	Air	1.72E-14	4.00E-14	6.29E-14
Lead, DALY	Air	1.46E-13	9.48E-14	1.02E-13
Lead, DALY	Water	1.20E-13	1.80E-13	3.01E-13
Nickel, DALY	Air	9.44E-13	1.39E-12	6.96E-13
Nitrogen dioxide, DALY	Air	2.58E-11	3.22E-11	4.10E-11
Sulphur dioxide, DALY	Air	8.74E-12	1.86E-11	2.84E-11
Zinc, DALY	Air	3.38E-12	2.03E-11	1.09E-11
Zinc, DALY	Water	5.15E-11	5.27E-11	3.47E-11
Total		1.85E-10	2.94E-10	2.40E-10
Ecosystem quality				
Aluminium, PDF*m²*yr	Air	1.54E-05	2.15E-05	1.64E-05
Aluminium, PDF*m²*yr	Water	1.62E-06	1.99E-06	2.71E-06
Arsenic, PDF*m²*yr	Air	6.63E-06	9.94E-06	3.31E-06
Cadmium, PDF*m²*yr	Air	7.23E-05	2.24E-04	3.69E-04
Chromium, PDF*m²*yr	Air	9.07E-06	2.12E-05	1.21E-05
Chromium, PDF*m²*yr	Water	2.27E-08	6.82E-08	4.55E-08
Copper, PDF*m²*yr	Air	2.85E-05	6.66E-05	1.05E-04
Lead, PDF*m²*yr	Air	2.07E-05	1.35E-05	1.45E-05
Lead, PDF*m²*yr	Water	5.30E-08	7.94E-08	1.32E-07
Nickel, PDF*m²*yr	Air	1.69E-04	2.50E-04	1.25E-04
Nitrogen dioxide, PDF*m²*yr	Air	1.66E-06	2.06E-06	2.63E-06
Sulphur dioxide, PDF*m²*yr	Air	1.66E-07	3.54E-07	5.41E-07
Zinc, PDF*m²*yr	Air	1.04E-04	6.25E-04	3.37E-04
Zinc, PDF*m²*yr	Water	9.72E-06	9.93E-06	6.55E-06
Total		4.39E-04	1.25E-03	9.95E-04
Climate change				
Carbon dioxide, kg CO_2 eq	Water	1.18E-06	1.32E-06	1.54E-06
Total		1.18E-06	1.32E-06	1.54E-06

DALY - Disability adjusted life year, PDF - Potentially disappeared fraction of species

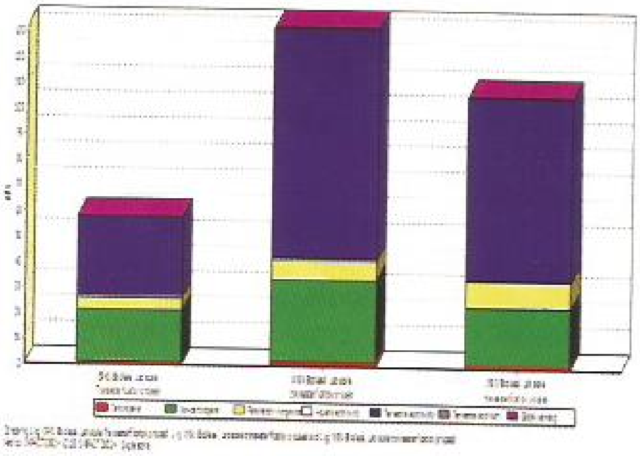

Figure 3. *Single score of crudepalm kernel oil, waste groundnut oil and waste soyabean oil biodiesel*

higher the emission from the biodiesel (Requena *et al.*, 2010; Choe and Min, 2007).

Successful removal of nickel, zinc and cadmium (which account for 80-88% of the total emission) during the processes of biodiesel production would make ecosystem quality to be infinitesimally altered. In man, cadmium causes the damage of the immune system, DNA and central nervous system in animals; it is also carcinogenic in nature. Cadmium poisoning can result from animals feeding on plants grow on cadmium-enriched soils (Muradov and Veziroglu, 2013). Nickel poisoning in animals results in respiratory failure, birth defects, asthma, chronic bronchitis, heart disorder and allergic reactions, such as skin rashes. High nickel concentration on sandy soils can damage plants and can also retard the growth rates of aquatic animals (Walton, 2009).

Damage to climate change : Climate change is due to global warming. The global warming potential (GWP) measures how much a mass of greenhouse gas GHG (in CO_2 equivalent) can contribute to climate change. In the present analysis, the amount of CO_2 released from crudepalm kernel oil, waste groundnut oil and waste soyabean oil biodiesel are expressed in kilogram (Table 6) and in percentage (Figure YY). Potentially, waste soyabean oil biodiesel contributes more to climate change with 1.54×10^{-6} kg (100 %) CO_2 release; followed by waste groundnut oil biodiesel with 1.32×10^{-6} kg (80 %) and crudepalm kernel oil biodiesel with 1.18×10^{-6} kg (70 %) emission of CO_2. The globe experiences acid rain as a result of the release of CO_2 that eventually react with certain substances in the atmosphere (Walton, 2009). It is important to note that biodiesel production contributes to the reduction of greenhouse gases emissions, for CO_2 utilised during the photosynthesis of oil-bearing of plants is far greater than CO_2 released into

Table 7. *Single scores, in Pt*

	Impact category	CPKO biodiesel	WGO biodiesel	WSO biodiesel
Human Health	Carcinogenics	1.27E-09	2.25E-09	1.40E-09
	Non carcinogenics	2.00E-08	3.21E-08	2.26E-08
	Respiratory inorganics	4.88E-09	7.15E-09	9.78E-09
	Total	2.62E-08	4.15E-08	3.38E-08
Ecosystem Quality	Aquatic ecotoxicity	9.47E-10	1.14E-09	9.69E-10
	Terrestial ecotoxicity	3.10E-08	8.96E-08	7.13E-08
	Terrestial acid/nutr.	1.33E-10	1.76E-10	2.31E-10
	Total	3.21E-08	9.09E-08	7.25E-08
Climate Change	Global warming	1.19E-10	1.33E-10	1.56E-10
	Total	1.19E-10	1.33E-10	1.56E-10

*Pt = Point

the atmosphere due to biodiesel production and/or utilization (Kian *et al.*, 2009; Nabi *et al.*, 2009).

Single score of waste groundnut oil, waste soyabean oil and crudepalm kernel oil biodiesel

Single score view each product or process as a unit by making comparative analysis of the categories involved in the production of a product. By extension, it allows comparative analysis of products (waste groundnut oil, waste soyabean oil and crudepalm kernel oil biodiesel) to be easily carried out. Figure 3 and table 7 give the single score of biodiesels, based on midpoint categories. The nano point scale suggests how small the values of the harmful substances are. Comparing the 7 midpoint categories, the most pronounced effect is terrestrial ecotoxicity.

From figures 1-3, crudepalm kernel oil biodiesel utilisation generated the least potential damage to man and the environment. This may be due to the level of saturation of carbon chains of the oils. Most of the carbon atoms in crudepalm kernel oil are saturated. However, carbon atoms in waste groundnut oil and waste soyabean oil biodiesel are mostly unsaturated (Table 2). Due to more reactive nature of unsaturated carbons, compounds, such as phospholipid are formed from waste groundnut oil or waste soyabean oil and materials in contact with during cooking (frying). These compounds pose a threat to the sanity of the environment when eventually released into the environment (Choe and Min, 2007; Chung *et al.*, 2004). In addition, the repeated usage of waste groundnut oil and waste soyabean oil for cooking (frying) at high temperatures may cause higher levels of harmful substances released by waste groundnut oil and waste soyabean oil biodiesels. At such high temperatures, weaker double bonds of fatty acid units of waste soyabean oil waste groundnut oil and are easily broken, resulting in formation of environmentally sensitive substances (Chen *et al.*, 2009).

CONCLUSION

Based on emissions released, present study shows that the order of preference of usage of the 3 kinds of biodiesel for diesel engine is crudepalm kernel oil biodiesel, waste soyabean oil biodiesel and crudepalm kernel oil biodiesel. The lower the degree of unsaturation of the carbon bonds of the feedstocks, the better the performance of the biodiesel as diesel engine oil and the lesser the release of non-environmentally friendly substances into the environment (Evangelos, 2013). Also, human health experiences the least damage, follow by climate change and then ecosystem quality.

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