Impact of Gas Flaring on Forced Vital Capacity, Body Mass Index and Biochemical Parameters: Evidence from a Nigerian Oil-Bearing Community

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DOI: https://doi.org/10.51584/IJRIAS.2025.1001037

Received: 23 January 2025; Accepted: 03 February 2025; Published: 20 February 2025

ABSTRACT

The Nigerian economy experienced a leap with oil exploitation as oil accounted for over 70% of the country's foreign exchange earnings. However, oil exploitation precipitated the problem of gas flaring. Consequently, this study seeks to evaluate the aftermath of gas flaring on the Forced Vital Capacity (FVC), Body Mass Index (BMI) and biochemical parameters of residents of Ibeno, an oil-bearing community in Akwa Ibom State, Nigeria. Afaha Udoe, another community in AkwaIbom State which is over 60km away from Ibeno, was used as control. Lung function was assessed using a spirometer while weight and height were measured with a weighing balance and a stadiometer. Determination of serum Aspartate Aminotransferase, Alanine Aminotransferase and Alkaline Phosphatase was done using Kinetic Ultraviolet Test Optimised International Federation of Clinical Chemistry and Laboratory Medicine (Kinetic UV Test Optimised IFCC) method while serum Bilirubin, Albumin and Total Protein was done using Jendrassik and Gróf, Bromocresol Green and Biuret methods respectively. Both groups are in the same BMI categorisation band, therefore gas flaring has no impact on people's BMI. There is no significant difference in baseline FVC; nevertheless, Control population presented a better FVC after stress (2.755L) compared to Test population (2.385L). The average aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, conjugate bilirubin, total bilirubin, albumin and total protein values were 6.420iu/L, 5.280 iu/L, 15.340 iu/L, 4.100 µmol/L, 7.500 µmol/L, 47.74 g/L, 74.040g/L for control subjects as against 14.500iu/L, 8.442iu/L, 21.096iu/L, 4.363 µmol/L, 8.790 µmol/L,42.314g/L, 69.712g/L for test subjects. All biochemical parameters tested were statistically significant against control at $p < 0.05$ except total protein. These results suggest imminent pathological situations in subjects exposed to gas flares, hence the call to end gas flaring.

Keywords: Oil exploitation, gas flaring, biochemical parameters, volatile organic compounds, petroleum products

INTRODUCTION

Upon the discovery of crude oil in Nigeria, agriculture suffered a setback. Oil exploration and exploitation began to account for over 70% of the country's foreign exchange earnings. Nigeria is furnished with more gas reserves than oil (Nigerian Upstream petroleum Regulatory Commission, 2024) but unfortunately, she lacks adequate infrastructure to harness the gas. Therefore, flaring is employed to burn off the associated gas. Gas flaring is the burning of natural gas that is associated with petroleum production while releasing hazardous compounds into the air (see figure 1). United States energy Information Administrative International energy statistics database (2023) reported that Nigeria is the 9th-highest natural gas flaring country with about 5.318 billion cubic meters of natural gas flared in the year 2022. Such compounds include alkanes, alkenes, volatile organic compounds (VOC), polycyclic aromatic hydrocarbons, styrene, naphthalene, fluoranthene, acetylene, anthracene, pyrene, xylene,

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue I January 2025

Figure 1: A typical picture of gas flaring

Source: https://www.istockphoto.com/photos/oil-and-gas-flare (2025)

ethylene, soot, greenhouse gases and carbon monoxide, (Mirrezaei and Orkomi, 2020; Ismail and Umukoro, 2012; Kindzierski, 2000). Also, heavy metals are not excluded (Ite *et al.*, 2013). In petroleum producing areas, flaring is employed to burn off the associated gas due to insufficient investment in infrastructure. The Niger Delta region, which comprises Akwa Ibom, Bayelsa, Cross Rivers, Delta, Edo and River States, covers over 20,000km^2 in the south. It is the centre of oil and gas production in Nigeria (Nwankpa, 2011).

Some works have been done on impact of gas flares on biochemical indices (Egwurugwu et al., 2013) and cardiopulmonary function of exposed humans (Enang et al., 2021; Aweto et al., 2019; Ovuakporaye, 2016), but no work has been simultaneously done using same samples to ascertain effects of gas flares on biochemical parameters, body mass index and cardiopulmonary functions for correlation of findings. This present study seeks to fill the gap.

Body Mass Index (BMI) is a person's weight (kilograms) divided by the square of height (meters). A high BMI can be an indicator of high body fatness. BMI is used to screen for weight categories that may lead to health problems.

Forced vital capacity measures the greatest volume of air that can be breathed out after a maximum inspiration (Sparling and Melo, 2022).

This study seeks to evaluate effect of gas flaring on the residents of Ibeno community in Akwa Ibom state, Nigeria, and to determine if there are any differences between the FVC, BMI and biochemical parameters of test and control subjects. Hence, bridge the gap created by the paucity of information on the impact of gas flaring on the health of these locals with a focus on Ibeno community of Akwa Ibom state, Nigeria.

MATERIALS AND METHODS

Description of Study Area

The study areas are Ibeno (Ibeno LGA) and Afaha Udoe (Itu LGA) both in Akwa Ibom State. Akwa Ibom State, the study site, is located within the south-south region of Nigeria. The coastal nature of the state makes it the natural deposit of marine, deltaic, estuarine, lagoonal and fluvio-lacustrine material (NACP.online). In Akwa Ibom State, crude oil production began in February 1970 from Idoho Field (Mobil Producing Nigeria Unlimited, 2011). More exploration in the state led to the discovery of oil and gas in commercial quantities in Ibeno, Itu, Etinan and Mbo local Government Areas (Akwa Ibom State Government, 2017). Oil exploration activity by Exxon Mobil has been on in Ibeno since the 1970's. The residents of Ibeno are therefore well exposed to gas flaring. This informed our choice of Ibeno as the test community

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Afaha Udoe is over 60 km away from Ibeno and the inhabitants are into farming as a major means of livelihood. The area has lush green vegetation. Ibeno and Afaha Udoe inhabitants have a lot in common, but there is active gas flaring by Exxon Mobil in Ibeno.

Sample Size Calculation

Minimum Sample size was calculated using the following formular:

$$n = 2* [Zci *\sqrt{2p_o (1-p_o)} + Z_{pwr} * \sqrt{p_1 (1-p_1) + p_2 (1-p_2)}]^2 / (p_1-p_2)^2$$ - (Feinstein, 2002)

Where:

p_1 and p_2 are the estimates of the proportions of abnormal haematological index in community exposed to gas flaring and community not exposed to gas flaring which is taken to be 60% and 22% respectively

Zci = standard normal deviate which is accepted confidence level of 95% (1.96) for this study;

Zpwr = accepted power of the test to detect a difference using the accepted estimates of the group proportions p1 and p2 set for this study at 80% (Adiembo and Nwafor, 2010).

Substituting these statistics in the formula,

$n = [1.96 \times \sqrt{(2 \times .82 \times 0.18)} + 0.84 \sqrt{(0.6 \times .4 + .22 \times .78)}]^2 / (0.38)^2$

$n = 1.96 * 0.543 + 0.84 \sqrt{(.412)} / 0.38$

$n = 1.064 + 0.539 / 0.144$

$n=1.603^2 /.144$

$n=2.57/.144$

$n=17.8$

A minimum sample size of 18 was determined for each of the 2 groups.

Selection of Subjects

The inhabitants were given an overview of the study. Apparently healthy-looking subjects of both sexes between the ages of 18 and 65 who have lived in the community consistently for not less than 5 years were selected. The questionnaire was administered by well-trained research assistants and a professional communicator who have a good grasp of the aim of study. Subjects who gave their informed consent by appending their signatures on the consent form after detailed explanation of the research and their contribution to it were recruited. A hundred and ninety participants took part in the study. Test group was 110, while control group was 80. Pregnant women and subjects with known cases of metabolic disease, cancer, cardiovascular disease, and inflammatory diseases like asthma were excluded.

Lung function and body mass index assessment

Subjects' lung function (baseline and stressed) was assessed using a spirometer. Then their weight and height were measured with a weighing balance and a stadiometer.

Collection and Analysis of Blood Samples

Each subject was given an identification number which was placed on their informed consent forms and the sterile plain bottles. Hands were dried after washing with soap and water and non-sterile gloves were put on. The subjects' arms were extended in order to inspect the forearm. A good vein was located and tourniquet

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applied correctly above the venepuncture site. The entry site was disinfected with alcohol swab and subjects were asked to form a fist to make the veins prominent. Five mL of blood was collected from the subjects, the tourniquet was released and needle withdrawn gently while slight pressure was applied to the site with a dry cotton-wool ball. Blood samples collected were put in sterile plain bottles. Labels on tubes and forms were checked for accuracy before dispatch. Then the tubes were placed in racks to avoid breakage during transportation. The samples were allowed to clot and retract properly and then centrifuged at 500rpm for 5 minutes. The supernatant – serum, was then used for biochemical analysis.

Liver Function test

Determination of Aspartate Aminotransferase (AST) using kinetic UV Test Optimised IFCC method

Principle

AST is an enzyme that can catalyse the reaction between alpha-amino acids and alpha-oxo acids. The oxaloacetate reacts with nicotinamide adenine dinucleotide (NADH) in the presence of maleate dehydrogenase enzyme (MDH) to form nicotinamide adenine dinucleotide (NAD). Rate of oxidation of NADH is a measure of AST activity.

Procedure

Test tubes were labelled blank, control, unknown and calibrator. Distilled water was used as blank. Into each test tube, 0.5 mL of AST substrate was put. This was done after warming the vials in 37°C heating bath for 4 minutes. Exactly 0.1 mL of sample was added to their respective tubes and mixed gently, and then they were returned to the water bath for 10 minutes. Then 0.5 mL AST colour reagent was added and mixed. This was then taken back to the bath for 10 minutes. This was followed by addition of 2 mL of 0.1N hydrochloric acid, and it was gently mixed. The spectrophotometer was then set at 530 nm wavelength and zeroed with the blank. After this, absorbance was taken and recorded within 1 hour. Absorbance reading of the calibrator and unknown were used to calculate AST using the formula below:

AST value = Absorbance of Unknown × concentration of calibrator (I /L) (Wrobleski and La Due, 1955; Wright *et al.*, 1972; Yakubu *et al.*, 2009; Onyeukwu, 2015).

Determination of Alanine Aminotransferase (ALT) using kinetic UV Test Optimised IFCC method

Principle

ALT catalyses the reaction between L-alanine and α-ketoglutarate to form pyruvate and L-glutamate. Pyruvate is further reduced to L-Lactate. The decrease in the absorbance is directly proportional to ALT activity.

Procedure

Vials were heated in water bath for at least 4 minutes. Test tubes were labelled blank, control, unknown and calibrator. Distilled water was used as blank. Exactly 0.5 mL of AST substrate was added into the test tubes. Then 0.1 mL of samples were added into appropriate tubes, mixed and returned to the bath. This was followed by addition of 0.5 mL of ALT colour reagent after 10 minutes; the tubes were gently mixed and returned to the bath immediately. After 10 minutes of returning to the bath, 2 mL of 0.1N hydrochloric acid was put and shaken slightly. Spectrophotometer was set at a wavelength of 530nm and instrument zeroed with the blank. Absorbance of all tubes was read within 60 minutes. Readings of the calibrator and unknown were used to calculate ALT using the formula below:

ALT value = Absorbance of Unknown × concentration of calibrator (I /L) (Wrobleski and La Due, 1955; Wright *et al.*, 1972; Yakubu *et al.*, 2009; Onyeukwu, 2015).

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Determination of Alkaline Phosphatase (ALP) using kinetic UV Test Optimised IFCC method

Principle

ALP converts p-Nitrophenyl phosphate to P-Nitrophenol and phosphate. The wavelength of absorption at 405nm is proportional to the concentration of ALP in the sample.

Procedure

Test tubes were labelled Blank, Calibrator, Control and Unknown and heated in 37°C water bath for 4 minutes. After this, 0.5 mL of ALP substrate was dispensed into the test tubes. About 0.1 mL of samples were dispensed into their respective tubes, mixed and returned to the water bath for 10 minutes. Distilled water was used as blank. ALP Colour reagent (0.5 mL) was added after 10 minutes, mixed and returned to the water bath with temperature maintained at 37°C for another 10 minutes after which 2 mL of 0.1N hydrochloric acid was put and mixed. Absorbance was read within 60 minutes at 500-550nm wavelength. Readings of calibrator and unknown were used to calculate ALP thus:

ALP value = Absorbance of Unknown × concentration of calibrator (I /L) (Wrobleski & La Due, 1955; Wright *et al*., 1972; Yakubu *et al*., 2009; Onyeukwu, 2015).

Determination of Bilirubin Using Jendrassik and Gróf Technique

Principle

Total bilirubin (TB) is measured by adding caffeine reagent (accelerator) and diazotized sulfanilic acid to the specimen. Both conjugated and the unconjugated bilirubin react with the diazo reagent to produce azobilirubin.

Procedure

Conjugate bilirubin (CB)

Hydrochloric acid (1.0 mL, Reagent No. 2) was added to two test tubes (labelled C for conjugated and the other B for blank). This was followed by addition of 2.0 mL caffeine benzoate reagent to test tube B only. Then 0.2 mL of specimen was added to each tube. To only test tube B, 0.5 mL sulphanilic acid solution (reagent No. 3) was added and mixed. Then 0.5 mL of diazotized sulfanilic acid solution (Reagent No. 5) was added to tube C and mixed. After 10 min, 0.1mL ascorbic acid solution (reagent No. 6) was added to test tube B and C, then 1.5 mL alkaline tartrate solution (Reagent No. 7) was put to test tubes B and C and mixed. Two mL of caffeine reagent (reagent No. 1) was added to tube C and mixed. The absorbance of test tube C was read at 600nm against that of test tube B set at zero absorbance. The calibration curve was then used to determine the concentration of CB in unknown.

Total bilirubin

About 2 mL of caffeine reagent (reagent No. 1) was added to a glass test tube labelled T (total). Then 0.2 mL of specimen was added to the test tube followed by addition and mixing of 0.5 mL of diazotized sulfanilic acid reagent (Reagent No. 5). This was followed after 10 min by the administration of ascorbic acid solution (0.1 mL), alkaline tartrate (1.5 mL), and hydrochloric acid (1.0 mL of 0.05 mol/L) (reagents No. 6, 7 and 8) in succession and mixed. The absorbance of the solution in tube T was read at 600nm against that of tube B set at zero absorbance. The calibration curve was then used to determine the concentration of total billirubin in each unknown.

TB or CB (mg/dl) = (Abs. of Test-Abs. of Serum Blank) x 20.2 (mg/dl) (Jendrassik and Gróf, 1938; Osigwe, Akah and Nworu, 2017).

Determination of serum albumin Using Bromocresol Green method

Principle

When albumin binds to Bromocresol Green (BCG), there is a change in the maximum absorbance of BCG which can be measured spectrophotometrically and used to determine albumin concentration.

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Procedure

The test tubes were labeled adequately. BCG (2.5 mL) was put into each tube. Then 10 µL of sample, calibrator or control was added into the appropriate tubes as the case may be but 10 µL of distilled water was put into the reagent blank tube. Absorbances of all tubes were read at 628 nm against the reagent blank after contents of the tubes were well mixed. Results were recorded.

Albumin concentration of each sample was calculated using the formula:

Albumin Concentration (g/dL) = (Absorbance x Dilution Factor) / (Extinction Coefficient x Path Length)

Where:

- Absorbance (A) is the measured absorbance of the sample

- Dilution Factor is the ratio of the sample volume to the total volume

- Extinction Coefficient (ε) is a constant specific to albumin (usually 0.021-0.023 mL/mg/cm for albumin at 630 nm)

- Path Length (l) is the distance light travels through the sample (usually 1 cm) (Tietz, 1987; Al Zunaidy, Al-Sowayan, and Mousa, 2015).

Determination of serum TP using biuret method

Principle

Blue-violet colour will form as cupric ions bind to the peptide bonds of protein molecules. This complex is determined photometrically and used to determine protein concentrations.

Procedure

NaOH (4.9 mL of 3%) was added into adequately labeled test tubes while 100 µL of distilled water was put into the reagent blank. Sample, control and standard (100 µL each) were added into appropriate test tubes. This was followed by addition of 1 mL biuret reagent into all tubes. They were mixed and incubated at 20-22°C room temperature for 20 minutes. The reaction mixtures were transferred into appropriate cuvette and absorbance of each tube measured at 520 nm using a spectrophotometer.

Protein Concentration (mg/mL) = (Absorbance x Dilution Factor) / (Extinction Coefficient x Path Length)

Where:

- Absorbance (A) is the measured absorbance of the sample

- Dilution Factor is the ratio of the sample volume to the total volume

- Extinction Coefficient (ε) is a constant specific to the protein or dye used

- Path Length (l) is the distance light travels through the sample (1 cm) **(**Doumas, et al., 1981).

RESULTS AND DISCUSSION

Average body mass index and forced vital capacity (baseline and stressed) of both groups are shown in Table 1. The differences seen are not statistically significant at $p < 0.05$.

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Table 1: Mean BMI, baseline FVC and FVC (stressed)

	Baseline FVC (L)	FVC (Stressed) (L)	BMI
Control	2.332 ± 0.133	2.755 ± 0.135	23.746 ± 0.707
Test	2.385 ± 0.118	2.385 ± 0.139	23.911 ± 0.572

n=149; values are presented as mean ± SEM

There is also no significant difference in baseline FVC. Control population presents a better FVC after stress (2.755) compared to test population (2.385). Ekwere (2016) also reported no significant difference in FVC between flare exposed subjects and control subjects. In contrast Aweto *et al.* (2019) reported a significant difference. Table 1 shows no correlation between BMI and FVC results. A possible explanation for the apparently normal FVC could be the effect of land and sea breezes from the Atlantic Ocean which has same boundary with Ibeno. This could disperse air pollutants.

Table 1 shows that there is no statistically significant difference between BMI of both groups. Both averages are in the same BMI categorisation band (WHO, 2010), therefore gas flaring obviously has no impact on people's BMI.

Obesity is a risk factor for several illnesses including pulmonary diseases. It was reported that adults aged 35–65 years who were obese (BMI ≥ 30) were twice as likely to die during the follow-up compared to adults who were at the lower normal (≥ 18.5 to < 20.75) BMI band (Yiengprugsawan *et al*., 2014). Moreover, many diseases such as cardiovascular diseases, diabetes, some cancers, breathing problems etc have been associated to obesity

Serum liver enzymes showed significant increases in test subjects relative to the control subjects. TB and CB were higher in test compared to control subjects. Albumin and total protein (TP) were reduced in test subjects but albumin alone showed a difference that was statistically significant at $p < 0.5$. Albumin and TP were reduced in test population (figure 2). Albumin is a water-soluble protein made by the liver and constitutes about 60% of the TP in the blood. It nourishes tissues, transports hormones, vitamins, drugs and other substances through the body and most importantly, prevents fluid from leaking out of the bloodstream into other tissues. Inflammation, malnourishment, kidney disease, shock or assault on the liver will result in reduction in serum Albumin level.

TPs were also found in the blood. Globulins, albumins and fibrinogens are major blood proteins. TP test measures quantity of all protein types in the blood. It gives information on kidney, liver and nutritional health. These health issues can cause TP to become abnormal. Egwurugwu *et al*., (2013) reported a statistically significant decrease in TP and Albumin of subjects exposed to gas flaring compared to control. Neghab et al (2015) and Moghadam et al (2020) got similar results in studies aimed at evaluating insidious liver and kidney dysfunction associated with occupational exposure to some pollutants in unleaded petrol and also differences in levels of parameters found in exposed and non-exposed subjects respectively. Serum TP and albumin were higher in test fish (*Clarias gariepinus)* exposed to aqueous extract of Nigerian Bonny light crude oil than control fish (Wegwu and & Omeodu, 2010). Wister albino rats fed crude oil contaminated diet had a significantly lower TP and albumin compared with the control (Achuba *et al*., 2016**)**. These variations may be due to oxidative stress associated with heavy metals found in crude oil (Owu *et al*., 2005; Andjelkovic *et al*., 2018). Andjelkovic *et al*. (2018) stated that exposure to heavy metal mixtures (which are also components of the gas flares) produces more unnoticed adverse effects than is apparent. Exposure to these components also leads to liver damage which would definitely cause increase in blood enzyme levels and reduced protein synthesis (Cobbina *et al*., 2015).

ALP is used to assess several organs in the body, especially the liver, bone or gall bladder. It has diagnostic role in detecting various diseases (Ray *et al*., 2017). It is indispensably involved in metabolism within the liver and development within the skeleton. Serum ALP was significantly increased in the test population when

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juxtaposed against the control (figure 3). This corroborates results of a study where ALP value for control was lower than that of petrol attendants (Ogunneye *et al*., 2014). Moreover, consumption of bonny light crude oil resulted in destruction of the renal reserve capacity with induction of severe pathologic changes in the kidney of male albino rats (Orisakwe *et al*., 2004). Ayalogu *et al*. (2001) reported that the elevation of ALP activity appears to reflect some inflammatory diseases or injuries to the liver or stress. It was found that there was an increase in lipid peroxidation and ALP activity in rat after peritoneal administration of petroleum products. In fact, a single dose of benzene caused an adverse effect that lasted up to 20 days (Rao and Pandya, 1978). This enzyme is found mainly in liver and bones. High serum level questions bone and liver integrity and very high levels may indicate acute hepatitis.

Alanine aminotransferase test estimates the ALT concentration in the blood. The level of this enzyme in the liver and kidney is usually high but low in the blood. But when there is an assault to the liver, there is a resultant release of ALT into the blood. It is one of the tests done along with other tests like AST (though ALT is more specific for the liver) to diagnose and monitor liver disease. Since ALT level in the test community was significantly ($P<0.05$) higher than that of the control population, there may be underlying liver disease. Other causes of increased ALT are obstruction of bile ducts, cirrhosis and hepatitis. Petrol attendants have shown a significant ($P<0.05$) increase in ALT levels compared to controls. Those that have been exposed to petrol for a longer time also showed significant ($P < 0.05$) increase in ALT levels compared with other petrol attendants that have spent lesser duration in filling stations (Ogunneye *et al*., 2014). A possible relationship between gas-flaring and hypertension (a leading cause of death in the world) (Maduka & Tobin-West, 2017) has been shown; and Rahman *et al*. (2020) have positively associated increased serum ALT with hypertension.

Aspartate aminotransferase test measures serum AST levels. This is one of the enzymes that can be used to diagnose liver, cardiovascular, kidney or pancreatic disease among others or monitor existing diseases. Its presence in the serum in above normal range could lead to an assault on any of these organs. From Figure 3, test population gave a significantly increased serum AST level (14.500 ± 0.658) compared to control (6.4200 ± 1.275). Several results show that serum AST concentration in the people exposed to gas flaring, petrol and petroleum products were significantly ($P < 0.05$) higher compared with the control where serum concentration increases as duration of exposure increases (Perez *et al*., 2006; Ogunneye *et al*., 2014; D'Andrea & Reddy, 2016). Most constituents of gasoline are also found in gas flares (Egwurugwu et al., 2013). Asefaw et al. (2020) reported duration of exposure-dependent increase in ALT and AST levels of gasoline exposed subjects compared to control. This has also been reported in prior studies (Nwanjo & Ojiako, 2007; Ogunneye et al., 2014; Egbuonu & Nkwazema, 2015; Bin-Mefrij & Alwakeel, 2017).

Animals were not exempted (Imo *et al*., 2015). Benzene, a constituent of flared gas (Ite & Semple, 2012), could be responsible for the high level of AST in test group compared to control, since D'Andrea and Reddy (2016) reported a significantly elevated AST in children exposed to benzene when juxtaposed against the unexposed children ($P= .001$). A motor mechanic was reported to have developed decompensated cirrhosis which was linked to exposure to gasoline via inadvertent ingestion due to occupational malpractice (Gunathilaka *et al*., 2017). Our result may be indicative of an impending liver, kidney or/and cardiovascular disease including muscle injury.

Bilirubin test is done to diagnose/monitor diseases of the liver and bile duct basically and also evaluate sickle cell disease patients and other anaemic patients. Bilirubin is basically produced by the breakdown of haem. The liver processes and ultimately eliminates bilirubin. Any health condition that interferes with this process or even increases red blood cell (RBC) breakdown will cause increase in bilirubin level. Bilirubin moves to the liver unconjugated but when sugars attach to them in the liver, they become conjugated hence conjugated bilirubin. From the liver, it moves to the small intestine, and then is eliminated in the faeces. Therefore, conjugated bilirubin is not expected to be in the blood though small levels can be ignored. TB gives a sum of all bilirubin types present in the blood. Figure 4 shows that total and conjugated bilirubins were found in both control and test samples but they were higher in test samples. This corroborates results of Ogunneye *et al*. (2014), Jabir et al. (2016) and Moghadam *et al*. (2020) in separate studies which among other parameters sought to compare serum bilirubin between petrol products attendants and control groups. Benzene (a component of flare gas) intoxication increased the activities of liver enzymes and bilirubin level (El-Shakour et al., 2014). Egbuonu and Nkwazema (2015) reported a significantly higher serum concentration of total and

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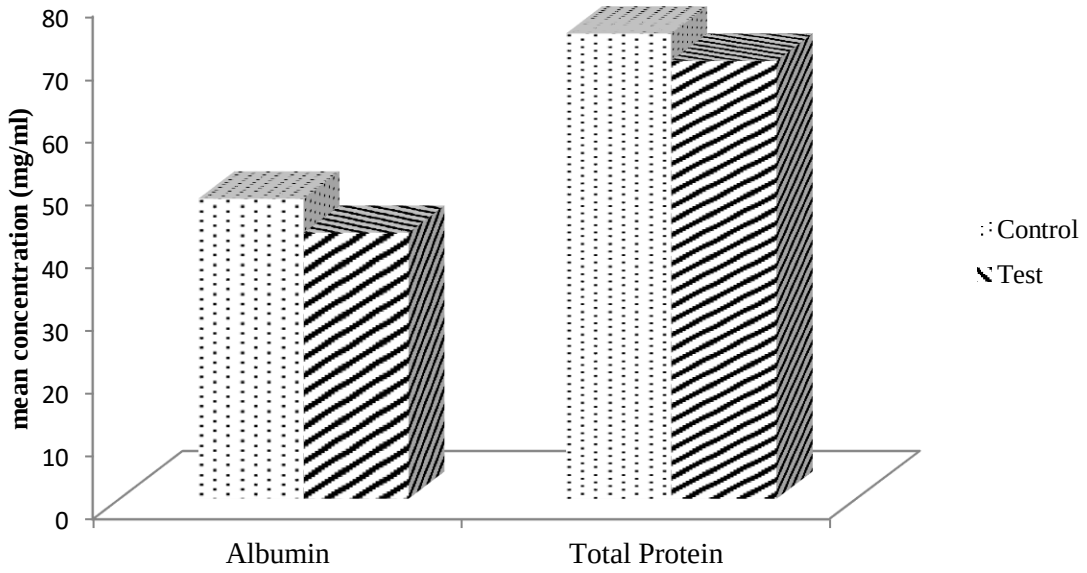
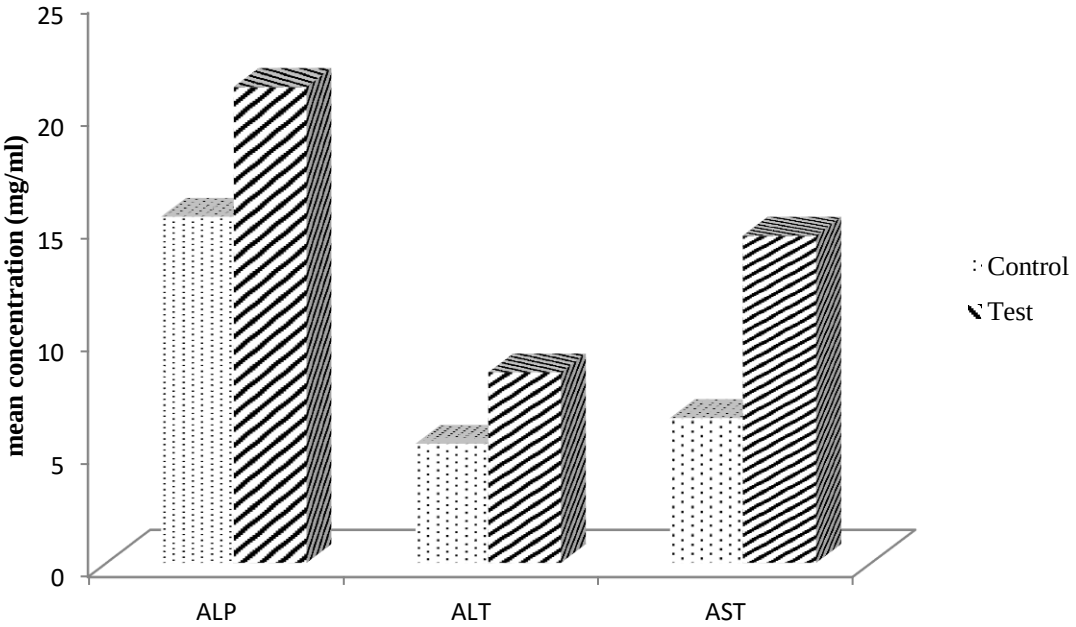
conjugated bilirubin in petrol depot workers than that of the control groups. Levels of unconjugated bilirubin increases with increase the rate of bilirubin formation (e.g., in haemolysis, dyserythropoiesis), or reduction in the rate of bilirubin conjugation (e.g., in Gilbert syndrome) (VanWagner & Green, 2015). Ramírez et al., (2022) reported the prevalence of the haematology disorders in men which was found to be dependent of the level of crude oil contamination while Gilbert syndrome worsened with prolonged exposure to perfluorocarbons (Fan et al., 2014) which may also be emitted during gas flaring.

Figure 2: Serum albumin and total protein of control and test population



n =149; Mean of albumin is statistically significant against control at $p<0.05$

Figure 3: Serum ALP, ALT and AST of control and test population



N=149; Mean is statistically significant against control at $p < 0.05$

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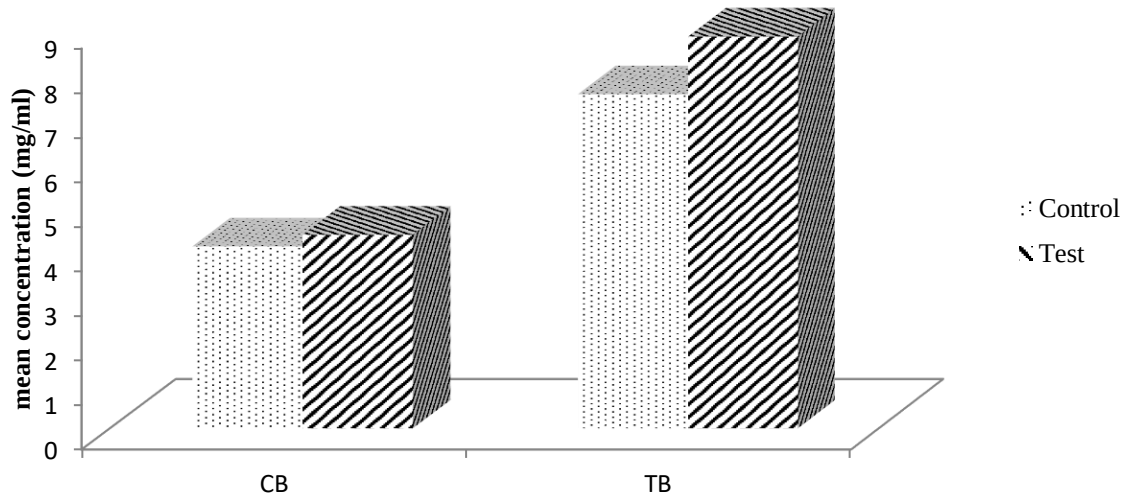
ALP – Alkaline Phosphatase; ALT – Alanine aminotransferase

AST – Aspartate aminotransferase

Figure 4: Serum CB and TB of control and test population



n=149; Mean of TB is statistically significant against control at $p<0.05$

CB – Conjugate Bilirubin, TB – Total Bilirubin

Kindzierski (2000) linked effect of gas flaring on humans to emissions that occur during incomplete combustion of the flared gases which they are exposed to, since most gas flare stacks are located close to residential areas (Edino *et al*., 2010). Among other components, gas flares have been reported to emit polycyclic aromatic hydrocarbons most importantly naphthalene, benzene, acetylene, styrene, flouoranthene, anthracene, pyrene, xylene and ethylene (Ismail and Umukoro, 2012; ATSDR, 2000b). Fluoranthene which is very harmful is made of naphthalene and benzene connected by a five-membered ring. Exposure to benzene and alkyl benzene is associated with kidney and liver injury (Brautbar et al., 2006; Henderson, 2001). Similarly, exposure to naphthalene can also result in kidney and liver dysfunction (Volney et al., 2018). Pyrene has also been associated with nephropathy (Deng et al., 2018).

CONCLUSION

The study compared the FVC, BMI and biochemical parameters of residents of Ibeno, an oil-bearing community, with those of residents of Afaha Udoe, as control group. Gas flaring had no impact on BMI. There was no significant difference in baseline FVC; nevertheless, Control population presented a better FVC after stress compared to Test population. It was also found out that average CB, TB, ALP, ALT, AST were higher while Alb and TP were lower than that of control subjects. This is probably indicative of imminent liver/kidney impairment among other disease conditions.

Limitations of the Study

If animal studies were included in this study, it could have given a better and more reliable result/conclusion since a lot of factors in animals can be controlled unlike in humans. This can become an area for future researchers to investigate further. Again, areas that have been exposed to gas flaring approximately for the same number of years or thereabouts could be compared, using two non-gas flaring areas as control. If the scope is also widened, it could affect the result and yield a better understanding of what is tested in this work. Future researchers can do a cross-country study involving residents of several or different regions of the world. Through this, it can be established if some genetic predispositions make the impact of flaring stronger in some regions than others, volume of gas flared notwithstanding.

Ethical considerations

Statement of Ethical approval

Ethical clearance for this research was obtained from the State Health Research Ethics Committee, Ministry of Health, Idongesit Nkanga secretariat, Uyo, Akwa Ibom State, Nigeria. The procedures used in this study adhere to the tenets of the declaration of Helsinki.

Conflict of Interest

The authors have no conflict of interest/competing interest to disclose

Data availability

Statement

The figures found in this paper are available in Figshare online data repository with DOI: 10.6084/m9.figshare.27215409

Statement of informed consent

Informed consent was obtained from all individual participants included in the study. This was gotten after an indigene who speaks the dialect of the locals and is well grounded on the purpose and process of the research gave a detailed explanation to the locals.

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ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue I January 2025

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