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Abstract

Purpose: This study examined the effects of gas flare exposure on haematological indices and cytokines levels of residents of Ibeno, an oil-bearing community in Akwa Ibom State, Nigeria.

Materials and Methods: Haematological parameters were assessed on whole blood samples using electrical impedance method, while the serum was used for cytokine analysis using enzyme-linked immunosorbent assay (ELISA). Statistical analysis was done using SPSS (version 21 for windows, SPSS Inc., Chicago, USA). Student t-test (independent-samples) was employed to ascertain the statistical significance of the difference between means.

Findings: Blood analysis results showed reduced RBC, haemoglobin and platelet but increased white blood cells in test group (TG) compared to control group (CG). Interleukin-4 (IL-4) levels in test subjects significantly increased relative to control subjects, but the reverse was the case with transforming growth factor-beta (TGF-β) and interleukin-10 (IL-10). The haematological parameters and cytokine levels are suggestive of imminent dangerous health conditions. Exposure to flare gas pollutants has endangered the health of residents of Ibeno.

Unique Contribution to Theory, Practice and Policy: Empirical studies on the impact of gas flaring on humans have not been adequately documented. There is need for more research and documentation of research findings on gas flaring. There is also a dearth of data on possible effects of gas flaring on cytokines, and by extension, the immune system. All these underscored the crying need for this research. It is therefore recommended that the Federal Government of Nigeria should strengthen the capacity of regulatory agencies such as the National Oil Spill Detection and Response Agency (NOSDRA) to enforce adequate sanctions that can check environmental pollution by oil companies. Government should set a realistic date for ending gas flaring since the 2020 deadline was not met.

Keywords: *Gas Flaring, Haematology, Cytokine, ELISA, Ibeno*

JEL Code: Q53, 118, and Q8

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INTRODUCTION

In the process of refining crude, a resultant associate gas is formed. This by-product is burnt off in a process called gas flaring or released into the atmosphere without burning through venting (Figure 1) (Buzcu-Guven and Harriss, 2012; Kearns et al., 2000). More than 120 flaring locations are found in Nigeria's Niger Delta region (Egwurugwu, 2013), with vast deposits of crude oil. The gas released into a flare system is usually a mixture of constituents ranging from hydrogen to hydrocarbons.

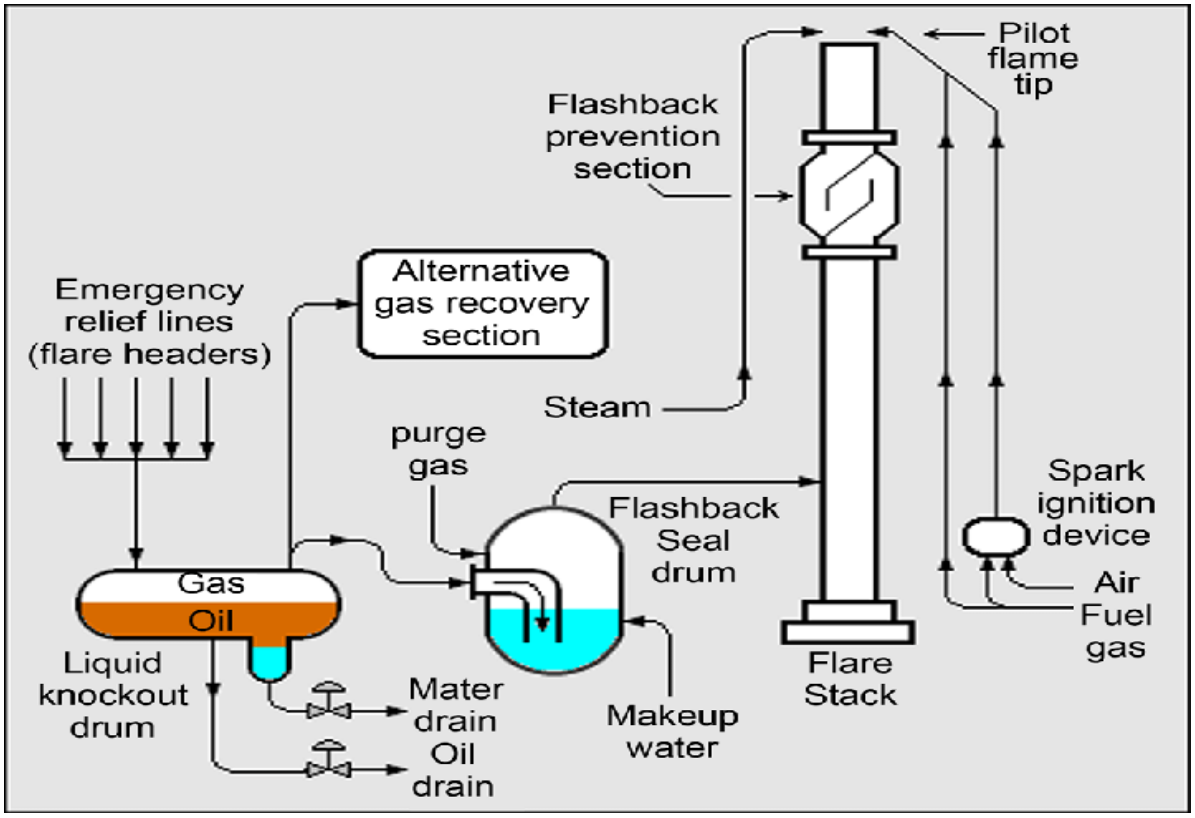

Figure 1: Schematic Flow Diagrams of a Flare Stack System

Source: Research Gate; https://en.wikipedia.org/wiki/Gas_flare (2018)

Nigeria has one of the worst gas flaring rates globally (Ismail and Umukoro, 2012), thus the impact of gas flaring is of great concern. Gas flaring releases hazardous compounds into the air. Such compounds include alkanes, alkenes, volatile organic compounds (VOC), polycyclic aromatic hydrocarbons, carbon monoxide, (Kindzierski, 2000; Strosher, 1996; Nwokedi, 1992), and heavy metals (Ite et al., 2013) etc. Polycyclic aromatic hydrocarbons from gas flares are benzene, flouoranthene, styrene, acetylene, anthracene, naphthalene, xylene, ethylene and pyrene (Strosher, 1996). Volatile organic compounds contain carbon, hydrogen, oxygen, halogens, sulphur and / or nitrogen (Toxtown, 2017).

Kindzierski (2000) linked effect of gas flaring on human to emissions from incomplete combustion of flared gases which they are exposed to, since most gas flare stacks are located close to residential areas. People have reported headache, watery eyes, respiratory problems (Oboetim, 2017; Okon, 2017; Edino et al., 2010) etc. Adiembo and Nwafor (2010) reported an increase in the morphological abnormality of erythrocytes, white blood cell count and a decrease in packed cell volume (PCV), haemoglobin (HGB), and red blood cell (RBC) count in people living in gas flaring environment relative to control. Emelike et al. (2015) and Okoro

et al. (2006) reported a decrease in PCV, HGB, and RBC count among petrol station attendants. Other studies have also found a decrease in RBC, HGB, MCV, MCHC, PLT, total protein and albumin compared with the control (Onwuka et al., 2025; Eqwurugwu et al., 2013a; Okoro, et al., 2006) among others.

Egwurugwu et al. (2013b)'s study on humans from where he reported abnormal haematology profiles was a build-up on a previous study of nestling herring gulls fed Prudhoe crude oil (Leighton, 1986). Results showed reduced red blood cell count, hein body formation and dyserythropoiesis on prolonged exposure to gas flaring (Otitoloju and Dan-Patrick, 2010).

While prior studies have examined the impact of gas flaring on haematological parameters (Adiembo and Nwafor, 2010; Egwurugwu et al., 2013; Onyije et al., 2024; Jato et al., 2024) and biochemical indices of residents of gas flare impacted communities in Nigeria's Niger Delta region (Egwurugwu et al., 2013; Njoku-Tony et al., 2017; Odinga et al., 2020; Onwuka et al., 2025), there is a noticeable dearth of studies on how exposure to gas flaring impacts on the cytokine levels of humans. Cytokines are small proteins that strongly regulate immune cells; therefore, they have a regulatory influence on several processes including inflammation, immune response, hematopoiesis, angiogenesis, tumorigenesis and viral pathogenesis (Deverman et al., 2009). Cytokines are involved in virtually every process of the human system since they regulate cell growth, development, division and differentiation (Kulbe et al., 2012). Alteration in cytokine production influences pathophysiology of autoimmune and inflammatory diseases, infections and cancer, etc (Burska et al., 2014). Therefore, cytokine levels are useful tools for diagnosing and assessing disease progression. It is therefore important to pay empirical attention to the cytokine levels of residents of gas flare-impacted communities since gas flaring has been identified as dangerous to humans and their environment. A study of this nature can influence government policies targeted at environmental preservation and protection, especially in the area of ending gas flaring and meting out adequate sanctions on harmful environmental practices.

MATERIALS AND METHODS

Description of Study Area

The study areas are Ibeno and Afaha Udoe (Itu LGA) both in Akwa Ibom State, Nigeria. Ibeno is located at the south end of Akwa Ibom State, Nigeria (Figure 2). Ibeno has the largest Atlantic coastline that measures over 129km in Akwa Ibom State. An oil exploration activity by Exxon Mobil has been on in the area since the 1970's. The residents of Ibeno are therefore well exposed to gas flaring; hence Ibeno is the test community while Afaha Udoe is the control community.

Afaha Udoe is over 60km away from Ibeno and the inhabitants are into farming as a major 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.

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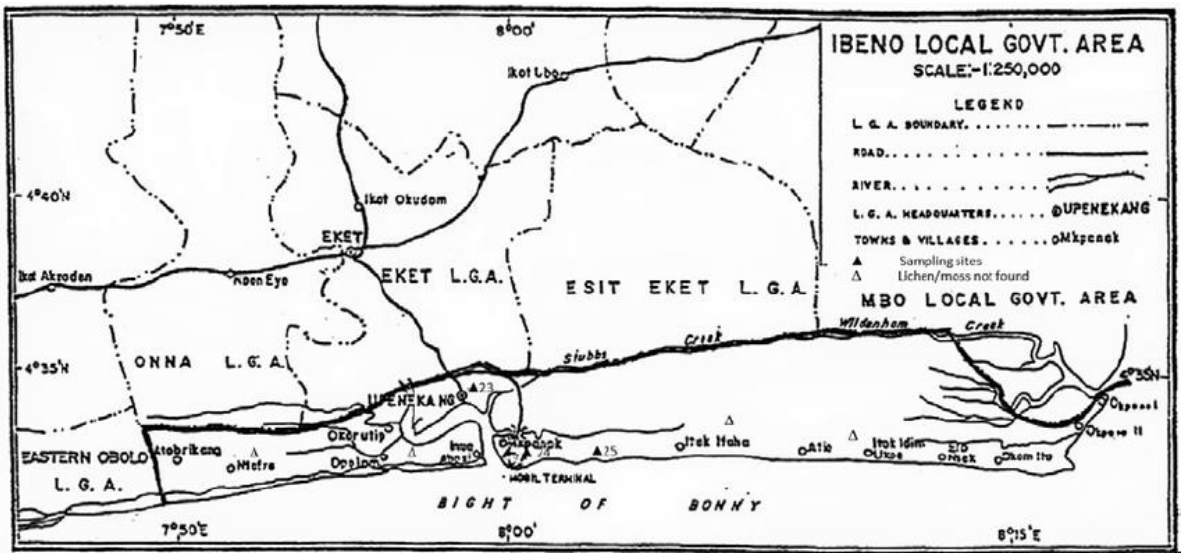

Figure 2: Map of Ibeno Local Government Area

Source: Ministry of Environment and Mineral Resources, Akwa Ibom State, Nigeria (2017)

Selection of Subjects

To arrive at the sample size, the formula below was used. Details are shown in Appendix 1.

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

A sample size of 18 participants was determined for each of the two groups.

The participants were given an overview of the study. Apparently healthy-looking subjects 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 has 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. One hundred and ninety participants of both genders took part in this 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 such as asthma, etc. were excluded.

Collection and Analysis of Blood Samples

Five milliliters (5 mL) of venous blood were drawn from a peripheral vein of subjects. Two mills was put into a sterile EDTA anticoagulant bottle for haematological tests; three mills was put in sterile plain bottles, allowed to clot, retracted properly and then centrifuged at 500rpm for 5 minutes. The supernatant, serum, was used for cytokine analysis.

Haematological Analysis Using Electrical Impedance Method

Two mills of blood sample was put into a sterile EDTA anticoagulant bottle and gently inverted to mix properly. An auto haematology analyser was used for this analysis. The machine was turned on, and the parameters displayed on the screen. The sample containing EDTA bottle was placed under the tube mechanism (Probe) to introduce the sample into the machine for analysis by the help of the aspirator. The auto analyser dispensed the sample into the various counting chamber compartments. E-Z cleanser, cell lyse, and diluents were introduced into each chamber. These reagents were mixed with the aspirated sample at the counting chamber

for proper dilution of samples. The counting was done automatically and values displayed and printed (Scoffin, 2014).

Determination of Cytokines Using Enzyme-Linked Immunosorbent Assay (ELISA)

One hundred microlitres of standard /sample was added to each well and incubated for 90 minutes. The liquid was removed and 100 µL of biotinylated detection antibody was added. This was incubated for 1 hour at 37°C, aspirated and washed three times. A hundred microlitre of HPR conjugate was added and incubated for 30 minutes at 37°C. The above was aspirated and washed 5 times. Ninety microliter of substrate reagent was then added and also incubated for 15 minutes at 37°C. Thereafter, fifty microlitre of stop solution was added and the optical density (OD) value determined at 450nm immediately. The results were then calculated (Chiswick et al., 2012).

Statistical analysis was done using SPSS (version 21 for windows, SPSS Inc., Chicago, USA) was used to analyse the data

Safety and Ethical Considerations

This research was approved by the Honourable Commissioner for Health, based on the recommendation of the State Health Research Ethics Committee, Akwa Ibom State, Nigeria. Guidelines governing sample collection from humans and general approved research protocols were adhered to.

FINDINGS

Haematological Measurements

The mean haematological biomarkers for control and test communities are given in Table 1. Details of the differentials are also given. The test group showed higher levels of MPV/PCT, PDW/PLT and MPV/PLT compared to the control group.

Table 1: Haematology Analysis Results

Haematology Parameter	Control ± SEM	Test ± SEM
White blood cell ($\times10^9$/l)	4.369 ± 0.610	6.969 ± 0.259*
Lymphocyte ($\times10^3$/µL)	2.1120±0.14416	3.2727 ± 0.10532*
Monocyte ($\times10^3$/µL)	0.5280 ± 0.01537	0.3631 ± 0.2675*
Basophil ($\times10^3$/µL)	0.0200 ± 0.00392	0.0386 ± 0.00780
Neutrophils ($\times10^3$/µL)	1.8900 ± 0.09931	2.8063 ± 0.16750
Eosinophils ($\times10^3$/µL)	0.500 ± 0.1036	0.5929 ± 0.08797
Haemoglobin (g/L)	129.097 ± 6.244	125.080 ± 2.339
Red blood cell(10^{12}/L)	4.752 ± 0.290	4.584 ± 0.068
RDW-SD (µm^3)	41.60 ± 1.37441	46.1440 ± 0.52875*
MCH (pg)	29.8400 ± 0.96156	27.3280 ± 0.3700*
MCHC (g/L)	34.099 ± 0.3337	31.7940 ± 0.1509*
MCV (µm^3)	85.5800 ± 2.44242	85.8560 ± 0.96465
HCT/PCV (%)	0.4046 ± 0.01819	0.3930 ± 0.00679
Platelet(10^9/L)	221.667 ± 7.434	204.255 ± 8.445*
PCT (ng/ml)	1.9486 ± 0.5553	1.9928 ± 0.09281
MPV (fL)	8.9310 ± 0.11306	9.3200 ± 0.11599
PDW (%)	16.0024 ± 0.06177	16.1520 ± 0.06089
MPV/PCT	4.7944 ± 0.2045	5.2360 ± 0.2945
MPV/PLT	0.0433 ± 0.0023	0.0493 ± 0.0030
PDW/PLT	0.0770 ± 0.0036	0.0851 ± 0.0051

n=190; values are presented as mean ± SEM. * = means that are statistically significant against control at $p < 0.05$

Cytokines Analysis

The Blood test samples had mean interleukin 4 higher for test samples while IL 10 and TGF B were higher for control samples.

Details of this result can be seen in Figures 3 and 4.

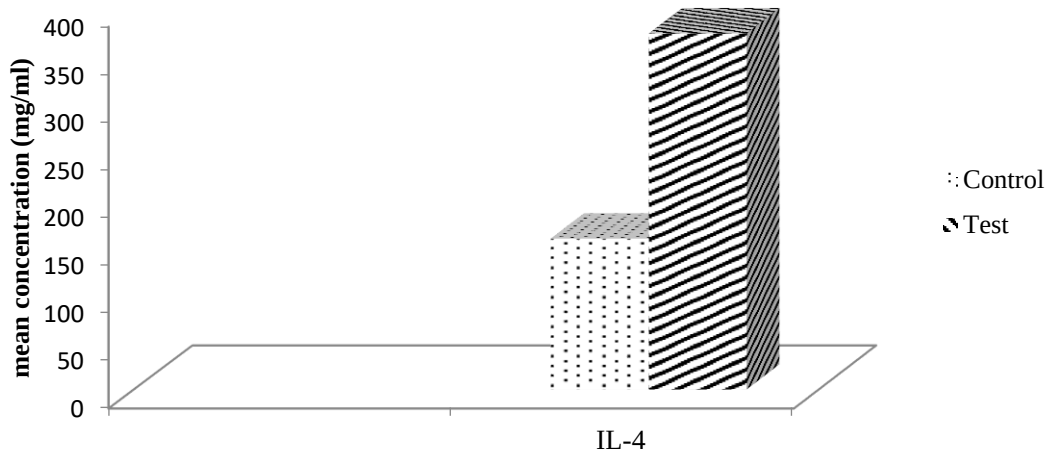

Figure 3: Cytokine (Interleukin 4 i.e. IL-4) Levels in Blood of Control and Test Population

N = 85, mean of IL-4 is statistically significant against control at $p < 0.05$

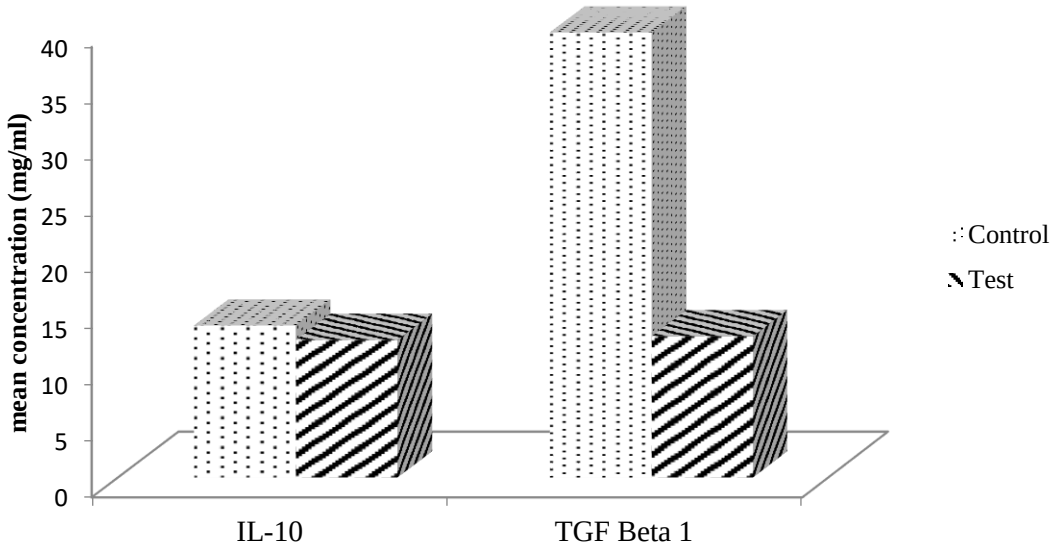

Figure 4: Cytokine (IL-10, TGF Beta 1) Levels in Blood of Control and Test Population

IL-10 = Interleukin 10, TGF = Tumour Growth Factor, n=85

Discussion of Findings

Red blood cell (RBC), platelet (PLT), haemoglobin (HGB) and white blood cell (WBC) of test/control blood samples were 4.58/4.75 ($\times 10^9$/L), 204.26/221.67 ($\times 10^9$/L), 125.08/129.10 (g/L) and 6.969/4.369 ($\times 10^9$/L) respectively (Table 1). These cells are produced from the hematopoietic stem cells in the bone marrow. Haemoglobin is the oxygen transport protein found in the red blood cells. The primary function of red blood cells is to transport oxygen from the lungs to the tissues and carbon dioxide from tissues to lungs (to be exhaled) and also for maintenance of systemic acid/base equilibria. Platelets function to prevent bleeding. Similar studies reported a statistically significant decrease in platelet; RBC and haemoglobin concentration of blood samples got from subjects exposed to gas flaring compared with control subjects and an increase in white blood cell (Holland et al., 1988; Owu et al., 2005; Adiembo and Nwafor, 2010; Egwurugwu et al., 2013b).

Mean RBC in control group was 4.752 (10^{12}/L) while it was 4.584 (10^{12}/L) in test group. Alterations in red cell indices can lead to weakness and shortness of breath

Studies have linked many cardiovascular and cerebrovascular incidences to alterations of RDW levels (Arkew et al., 2022; Li *et al*., 2017). RDW value is used to assess the severity and progression of CVDs (Li et al., 2017) and to confirm the presence of anaemia as well as to decipher the underlying cause (Sharma et al., 2016). Researchers found, in 2010, that a high RDW might have a connection with poor outcomes in heart failure patients and in fact can serve as a reliable predictor of mortality in adults above 45 years (Perlstein et al., 2009; Li et al., 2017;). Elevated RDW correlates well with marked anisocytosis, severe preeclampsia (Gopal, 2016) and increased risk of renal cell carcinoma (Wang et al., 2014). RDW is also a prognostic indicator in paediatric heart disease and after surgery (Polat et al., 2014).

There is reduced ability of the blood to clot with reduced platelet count. Low haemoglobin may be a symptom of anaemia. Decreased platelet count and red blood cell was reported in rabbits exposed chronically to Nigerian crude oil (Ovuru and Ekweozor, 2004). Reduced haemoglobin and platelet counts are also reported of subjects that have worked for up to 20 years in oil stations (Hameed et al., 2009). Benzene causes bone marrow depression (Gillis et al., 2005) and since hematopoietic stem cells reside in the bone marrow, haematopoiesis is impaired. Arsenic and Lead cause malfunction of the kidney and liver (WHO, 1995; Centeno et al., 2005) and since the kidney is involved in red blood cell production, it is expected that blood production will be hampered. With respect to hospital paediatric patients, Golwala et al. (2016) found a significantly higher platelet count in survivors compared to non-survivors.

Mean PCT, MPV and PDW of test subjects were higher than those of control subjects. Procalcitonin (PCT) is a biomarker which is employed in differentiating bacterial from non-bacterial infections (Yap and Aw, 2014). High levels of PCT indicate ongoing bacterial infection. Its clinical usefulness is found in diagnosing sepsis; monitoring infection severity; and in guiding and reviewing antibiotic therapy (Yap and Aw, 2014; Samsudin and Vasikaran, 2017; Covington et al., 2018). Mean platelet volume (MPV) gives the average size of platelets. Increased MPV has been linked to cardiovascular incidents, (Slavka et al., 2011; Korniluk et al., 2019) respiratory diseases, chronic renal failure, rheumatoid diseases, diabetes (Korniluk et al., 2019), tuberculosis (Unsal et al., 2005; Feng et al., 2011), Crohn's disease (Liu et al., 2012), increased risk of diabetes and worse outcome (Rollini et al., 2013) and cancer (Carlioglu et al., 2014; Li et al., 2017; Yin et al., 2018) etc. Platelet distribution width (PDW) helps in monitoring platelet function. Elevated PDW can be linked to peripheral artery disease, vascular diseases and deep vein thrombosis (Song et al., 2019). It is a risk factor for postoperative

pneumonia in certain patients (Xie et al., 2022). A more severe clinical profile is connected to elevated PDW values on admission to the medical ward (Tzur et al., 2019).

Higher values of MPV/PCT, PDW/PLT and MPV/PLT were seen in test group compared to control group. A high MPV/PCT indicates increased production of larger platelets, which could be associated with inflammation, cancer, sepsis, diabetes mellitus, myocardial infarction etc. (Pogorzelska et al., 2020). A raised MPV/PCT is a risk factor for mortality on admission to hospital (Golwala et al., 2016; Rani and Balasundaram, 2021). MPV/PLT is linked to bone marrow or bleeding disorders, cardiovascular disease, sepsis etc (Ates et al., 2015) while PDW/PLT is used to access platelet function (Vagdatli et al., 2010).

WBC in TG (6.969 $\times 10^9$/l) deviated significantly from CG (4.369 $\times 10^9$/l). White blood cells, also called leukocytes, are primarily for host defence. High white blood cell count may be indicative of several disease conditions, including infections and autoimmune diseases. Elevated WBC count was connected to mortality due to coronary heart disease (Kabat. 2017). Lymphocytosis is suggestive of an active infection, autoimmune disorders such as lupus, rheumatoid arthritis and multiple sclerosis or blood cancers like leukaemia (Devi et al., 2022; Jabbour, 2024). Basophilia is found in association with myxedema, colitis, polycythemia vera, allergic sensitization and myeloid leukaemia (Shelley et al., 1965). Neutrophilia is usually linked to the presence of an infection or inflammation. It plays a major role in the immune system (Malech et al., 2014; Shafqat et al., 2023). Allergic reactions, (hay fever, eczema), vasculitides, drug reactions, parasitic infections and some cancers (Weaver et al., 2024), pulmonary diseases (Singhet al., 2020; Wechsler et al., 2021; Park et al., 2021) and certain fungal infections (Figueiredo and Neves, 2018) can cause eosinophilia. Otitoloju and Dan-Patrick (2010) reported eosinophilia in gas flare exposed mice (for 8weeks under laboratory conditions).

PAH found in flare gas have toxic effects on blood cells. Oral administration of a polycyclic aromatic hydrocarbon, benzo (a) pyrene, to non-responsive mice led to pancytopenia, aplastic anaemia, severe peripheral leukopenia, bone marrow depression among others (Anselstetter et al., 1986). Likewise, long term administration of benzene may cause damage to the immune system and DNA (Askoy, 1985; WHO, 1993). In fact, oil spill resulting from the blow-out of a Texaco Funiwa–F offshore station in 1980 where about 400,000 barrels of oil was involved resulted in the death of 180 people (Manby, 1999). The anomaly seen in the result of RBC, PLT, HGB and WBC (Table 1) of test subjects compared to control group may be sequel to the harmful effects of the toxic pollutants associated with gas flares.

It was reported that inhalation of petroleum fumes raised the odds/odds ratio that a subject would become anaemic progressively from less than 1 in the control to greater than 1, an indication that petroleum fumes disrupt haematological indices (Okoro et al., 2006). It becomes necessary that employers of such labour subject their staff to blood tests occasionally to decipher when their blood metal concentrations have passed the permissible exposure limit and grant them some leave if need be.

Human Interleukin-4 and Interleukin-10 was 158.790 ± 65.667 and 13.494 ± 4.343 in the control group respectively while in the test group, it was 373.142 ±68.759 and 12.217 ± 7.153 respectively all in (pg./ml) (Figures 3 and 4). These differences were statistically significant. Interleukins are among the cytokines that regulate inflammatory response. They are involved in the communication between WBC, Chemokines and Interferons. Cytokines promote chemotaxis while interferons have antiviral effects. Cytokines are very much involved in the development of diseases that are linked to chronic inflammation, tumorigenesis and

autoimmunity (Kleiner et al., 2013); hence, they are used as biomarkers of several disease processes.

High levels of IL-4 can ensue when the immune system is aggressively reacting to assaults, e.g., in allergies, asthma and autoimmune diseases. IL-4 is highly implicated in development of allergic inflammation (Steinke and Borish, 2001). One of the ways through which IL-4 enhances Ig E mediated immune responses is by up regulating Ig E receptors on the cell surface (Dabbagh et al., 1999). Asthmatic patients who received IL-4 into their airway by nebulisation showed increased airway hyper responsiveness (Shi et al., 1998). High levels of IL-4 were reported in a child with idiopathic hypereosinophilic syndrome compared with controls (Takamizawa et al., 1994). Diminution of IL-4 production resulted in inhibition of excessive mucus production. Thus IL-4 production is believed to be greatly involved in respiratory diseases/ allergic disorders. These results correlate well with the findings of Gobo et al., (2009) that respiratory diseases are more prevalent in gas flaring communities than in non-gas flaring communities.

IL-10 is an anti-inflammatory cytokine involved in immunoregulation and inflammation hence reduced IL-10 levels may be linked to compromised immunity. Lack of interleukin-10 has been linked to cardiac and vascular endothelial dysfunctions in mice (Sikka et al., 2013). This could be why there is prevalence of reports of cardiovascular diseases in gas flare-exposed communities than areas free of such. A test on multiple sclerosis and systemic lupus erythematosus patients shows that they have lower levels of IL-10 than healthy subjects (Salmaggi et al., 1996; Mado et al., 2024). Interleukin-10 producing bacteria caused improvement in patients with Crohn disease (Braat et al., 2006). High levels of IL-10 correlated well with decrease in inducible nitric oxide synthase expression and cell death (Chen et al., 2010). Due to its well-known anti-inflammatory functions, IL-10 has a role in tissue fibrosis and is being considered for antifibrotic therapies (Steen et al., 2020). It also facilitates resolution of inflammatory cascades to avoid secondary brain damage (Garcia et al., 2017).

TGF β is involved in the maintenance of tissue homeostasis. It is an immunoregulator. TGF-β effectively inhibits proliferation of normal colon epithelial cells and acts as a tumour suppressor. TGF- β controls cell growth, proliferation, differentiation, and apoptosis (Vaughn et al., 2000). It also has immunoregulatory function. The role of TGF- β is complicated (Eliot and Blobe, 2005), and in fact, self-contradictory given that in normal tissues, tumour suppressor activities dominate (Pietenpol et al., 1990) whereas during tumorigenesis, oncogenesis is favoured (De Caestecker et al., 2000). Control community had 39.530 ± 20.104 pg/mL of TGF-β but test community had 12.542 ± 5.697 pg/mL (figure 4). With reduced TGF- β, tumour suppressor activities in normal tissues will be inhibited. TGF- β is reported to have played an anti-inflammatory role in injured adult brain (Shull et al., 1992; Makwana et al., 2007) and in promoting repair mechanisms (Shull et al., 1992). It has displayed a protective role following cerebral ischemia in animals (Gross et al., 1993; Henrich-Noack et al., 1996). More studies are ongoing to fully elucidate the import of TGF- β in different organs of the body but for now, it is known that suppression of TGF- β predisposes subjects to cancers. This validates the assumption that gas flaring causes cancer in exposed subjects.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study was done to investigate the effects of gas flare exposure on haematological indices and cytokines. Blood analysis results showed reduced RBC, haemoglobin and platelet but increased white blood cells in test group (TG) compared to control group (CG). IL-4 levels in

test subjects significantly increased relative to control subjects but the reverse is the case with TGF- β and IL-10. The haematological parameters and cytokine levels is suggestive of imminent dangerous health conditions. Exposure to flare gas pollutants has endangered the health of residents of Ibeno community in Akwa Ibom State, Nigeria.

Recommendations

It is therefore recommended that the Federal Government of Nigeria should strengthen the capacity of regulatory agencies such as the National Oil Spill Detection and Response Agengy (NOSDRA) to enforce adequate sanctions that can check environmental pollution by oil companies. Secondly, government should set a realistic date for ending gas flaring since the 2020 deadline was not met.

There should be periodic medical screening for people living around or working in industries where gas is flared. Affected persons should be granted financial support to receive medical attention promptly. Furthermore, environmental clean-up of gas flare-impacted communities is recommended to restore the environment.

Acknowledgement

The authors express sincere appreciation to the excellent reviewers of the study. Their incisive comments helped to improve the overall quality of our study.

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.

Consent to Participate

Informed consent was obtained from all individuals who participated in this study. This was got 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.

Consent to Publish

The authors affirm that participants of this research provided informed consent for publication of the article.

Competing Interest

No potential conflict of interest was reported by the authors.

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Appendix 1

$n = 2^* [Zci *\sqrt{2p_o (1-p_o)} + Z_{pwr} * \sqrt{p_1 (1-p_1) + p_2 (1-p_2)}]^2 / (p_1-p_2)^2$ - (Feinstein A R. Principle of Medical statistics Boca Raton, fla CRC, 2002: 503)

Where:

$P1$ 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 corresponding to an accepted confidence level of 95% (1.96) for this study;

Zpwr = standard normal deviate corresponding to 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,

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

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

$n = 1.064 + 0.539 / 0.144$

$n=1.603^2 /.144$

$n=2.57/.144$

$n=17.8$

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