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Exposure to Gas Flaring Among Residents of Oil-Producing Communities in Bayelsa State, Niger Delta Region of Nigeria: A Cross-Sectional Study of Haematological Indices

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Abstract: Air pollution contributes significantly to morbidity and mortality globally. The Niger Delta Region of Nigeria flares the second largest amount of natural gas in the world, with residents of oil-producing communities bearing the burden of outdoor pollution that may have adverse effects on their health and well-being. Our study aimed to investigate the haematological indices of residents of a selected gas-flaring site. We conducted a cross-sectional study, wherein a total of eighty adults aged 24 to 73 years were recruited from communities located within a radius of approximately 5 to 10 km from the gas-flaring facility. Blood specimens were collected from consenting participants and analysed for various haematological parameters, including Red Blood Cell (RBC) count, Packed Cell Volume (PCV), Haemoglobin (HB), Mean Cell Haemoglobin (MCH), platelet count (PLT), White Blood Cell (WBC) count, neutrophil (NEU), lymphocytes (LYMs), and Monocyte + Basophil + Eosinophil (MXD). The analysis was performed using an automated Sysmex KX21N haematological analyser. Overall, there was a significant decrease in RBC counts ($p < 0.001$) and a significant elevation in WBCs ($p < 0.001$) among people residing within a 5 km radius compared to those residing within a 10 km radius. About 42.5% of males residing within a 5 Km radius exhibited low RBC counts in contrast to only 15% of males residing within a 10 km radius. The WBC levels were found to be significantly higher ($p < 0.001$) than the reference range among both males and females residing within a 5 km radius compared to those residing at a distance of 10 km. In the female population, 15% of individuals residing within a 5 km and 10 Km radius exhibited RBC levels below the reference category, while 7.5% showed RBC levels above the reference range. Exposure to gas flaring may alter haematological indices. It is, therefore, recommended that a comprehensive longitudinal study be conducted among residents of oil-producing communities and workers at gas-flaring facilities in the Niger Delta region of Nigeria to assess the potential environmental and health implications of their exposure to chemical pollutants.

Keywords: gas flaring; haematological indices; malignancy; air pollution; Niger Delta region; Nigeria

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1. Introduction

Gas flaring is the process of expelling neutral gas through rapid oxidation, which is commonly linked with the extraction of crude oil [1]. Gas flaring contributes to outdoor pollution, leading to morbidity and mortality globally, with over 350 million tonnes of carbon dioxide (CO_2) released in 2021 [2,3]. According to the World Health Organization, more than 4.2 million deaths were attributed to ambient air pollution in 2016, marking it as

a global public health emergency. In 2019, 99% of the global population resided in areas where air quality exceeded WHO limitations [4]. Seven nations are responsible for 66% of worldwide gas flaring, with Nigeria listed as one of the seven with over 170 gas-flaring sites, all located in the Niger Delta region [5,6]. Numerous carcinogenic substances, such as polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM), carbon monoxide (CO), CO_2, sulphur dioxide (SO_2), and volatile organic chemicals (VOCs) like formaldehyde, benzene, xylene, toluene, and others, emanate from it. These substances significantly contribute to outdoor air pollution [1,7]. Air pollution has been linked to different types of cancers. The International Agency for Research on Cancer (IARC/WHO) has classified PAHs, PM, formaldehyde, and benzene in Group 1, signifying their carcinogenicity to humans, and these substances have been associated with various types of cancer, including lung cancer and leukaemia [8,9]. McKenzie and co-authors, in a study conducted in Colorado, USA, reported that children aged 5–24 years old living in highly polluted environments with oil and gas were at risk of leukaemia four-fold [10]. Also, Andrea and Reddy [11] reported significant alterations in haematological and liver markers among non-smoking residents in the UK exposed to benzene from prolonged gas flaring.

Haematological examinations provide valuable information for the diagnosis of infections and anaemia and can also serve as potential biomarkers for specific types of cancer [12]. The precise mechanisms by which air pollution causes toxic effects at the cellular level remain unclear, although several hypotheses have been proposed. Studies have been conducted to assess the blood parameters of individuals exposed to gas flaring in a few Nigerian states. Abia et al. [13] reported low haematological parameters in both Red Blood Cells (RBCs) and White Blood Cells (WBCs) among individuals residing in gas-flaring communities. Similarly, Egwurugwu et al. [14] reported low RBCs but increased WBC indices in the same locality, with Adienbo and Nwafor [15] also noting similarities and comparable findings. However, some of the findings have been inconclusive. The lack of consistency in some results highlights the need for further research to better understand the potential health risks associated with gas-flaring exposures.

Thus, the aim of this research was to assess the haematological parameters of individuals residing at distances of 5 and 10 km (Km) from gas-flaring locations in Bayelsa State, located in the Niger Delta Region of Nigeria.

2. Materials and Methods

2.1. Study Population and Design

We conducted a cross-sectional study, wherein a total of 80 participants (40 males and 40 females) aged 24 to 73 years were recruited in 2018 from communities located within a radius of 5 to 10 km from the gas-flaring facility at Gbarain–Ekpetiama in Bayelsa State in the Niger Delta Region of Nigeria. The residents of these communities are predominantly engaged in farming and fishing. In total, 40 of the participants resided in the Gbarain–Ekpetiama communities within a 5 km radius of the gas-flaring facility, while the remaining 40 participants resided in Yenagoa, approximately 10 km away from the gas-flaring facility.

2.2. Blood Cell Count and Measurements

Blood was collected from consenting participants via venipuncture and involved the extraction of 2 mL of venous blood into a vial that had been pre-coated with Ethylenediaminetetraacetic acid (EDTA), which functions to chelate calcium and prevent the blood from coagulating. The venous blood specimens were then subjected to analysis for various haematological parameters, including Red Blood Cell (RBC) count, Packed Cell Volume (PCV), Haemoglobin (HB), Mean Cell Haemoglobin (MCH), platelet count (PLT), White Blood Cell (WBC) count, neutrophil (NEU), lymphocytes (LYMs), and Monocyte + Basophil + Eosinophil (MXD). The analysis was performed using an automated Sysmex KX-21N haematological analyser. Sysmex KX-21N is a highly suitable haematology analyser for research testing owing to its simplified operation. It provides a

high level of accuracy through the use of automatic floating discriminators built on reliable Sysmex technology [16].

2.3. Statistical Analysis

Using standard blood measurement values for male and female Nigerians [17], we categorised our data into the following three groups: low, reference, and high haematological indices. This approach allowed us to assess any changes in the index, whether they were elevated or reduced. The statistical analysis performed comprised descriptive and inferential statistics, including a t-test, Analysis of Variance, and Chi-Square test of independence. Based on our hypotheses, we assumed no prior expectation about the direction of the effect, and thus, all statistical tests were subjected to a two-tailed test. A probability value of 0.05 was used as the minimum threshold for declaring statistical significance. Data management and statistical analyses were conducted using SAS 9.4 version software (SAS Institute, Cary, NC, USA).

2.4. Human Subject Protection

The study protocol and materials were reviewed and approved (#13/1179) on 5 August 2018 by the Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. All participants were informed of the purpose of the study and the fact that participation in the study was anonymous, consensual, and voluntary. Informed consent was obtained from all who agreed to participate in the study prior to blood sample collection. The study was conducted in accordance with the Declaration of Helsinki.

3. Results

The graphical representation in Figure 1 illustrates the distribution of enrolled participants categorised by age and sex. The age range of the participants varied from 24 to 73 years, with an average age of 40.33 ± 11.95 years.

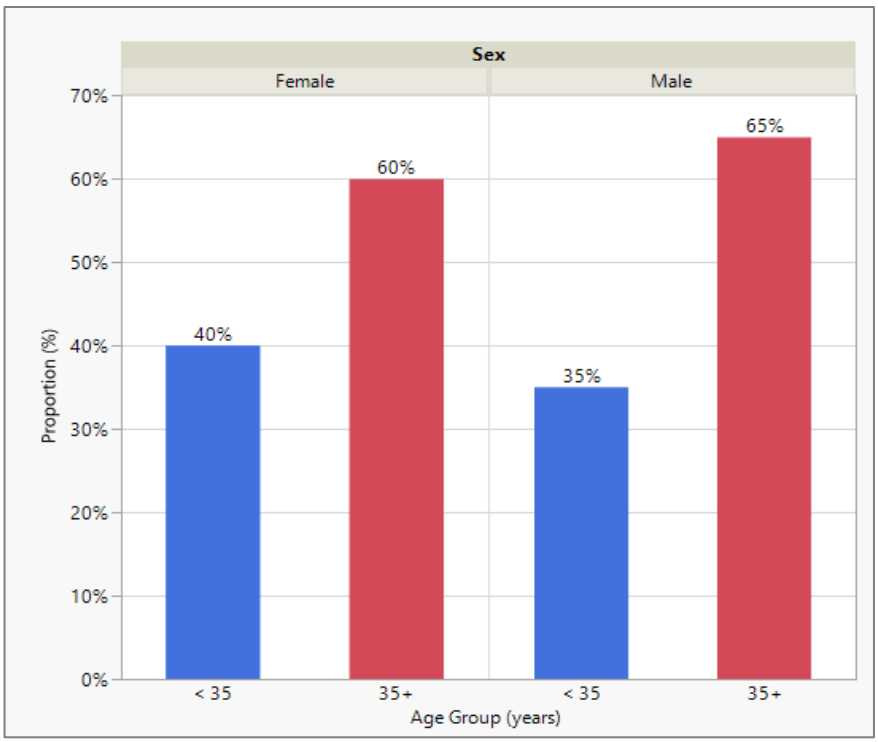

Figure 1. Characteristics of study participants by sex and age group.

Table 1 shows the haematological indices of participants who had been exposed to gas flaring, categorised by their proximity to the source within a radius of 5 and 10 Km.

The mean age of participants residing within a 5 km radius of the gas-flare point was determined to be 46.23 ± 1.82 years, while those residing within a 10 km radius had a mean age of 34.43 ± 1.47 years. A significant decrease was observed in the levels of RBCs, PCV, and MCH ($p < 0.001$), as well as in neutrophil ($p < 0.020$) and lymphocyte ($p < 0.037$) counts among participants residing within a 5 km radius compared to those residing within a 10 km radius. A statistically significant increase of 89.9% in the WBC count was observed among participants living within a 5 km radius ($p < 0.001$). The relationships between WBCs, RBCs, and the age of our study population by distance from the gas-flaring site are displayed in Figure 2. We noted a significant decreasing trend ($p = 0.0031$, $R^2 = 0.208$) in RBCs with increasing age for participants who resided within a 10 km radius. In contrast, the WBC count significantly ($p = 0.0085$, $R^2 = 0.169$) increased with increasing age among participants who resided at a distance of 10 km. However, these relationships were not statistically significant ($p > 0.05$) for both WBCs and RBCs among the participants who lived within a 5 km radius of the gas flaring sites. Similarly, MXD (18.9%, $p = 0.039$) and PLT (168.3%, $p < 0.001$) increased compared to those residing within a 10 km radius.

Table 1. Haematological indices of residents exposed to gas flaring by distance from gas-flaring sites.

		Distance $^{\beta}$		Test Statistics	
Parameter	**Overall (N = 80) Mean ± SEM**	**5 Km (n = 40) Mean ± SEM**	**10 Km (n = 40) Mean ± SEM**	**t-Ratio**	**Prob > |t|**
Age (Years)	40.33 ± 1.34	46.23 ± 1.82	34.43 ± 1.47	5.054	<0.001 ***
RBCs ($\times 10^{12}$/L)	5.44 ± 0.16	4.74 ± 0.09	6.13 ± 0.26	4.965	<0.001 ***
PCV (%)	37.56 ± 0.45	35.75 ± 0.50	39.40 ± 0.64	4.524	<0.001 ***
MCH (%)	29.06 ± 0.36	27.13 ± 0.43	30.99 ± 0.39	6.649	<0.001 ***
WBCs ($\times 10^{9}$/L)	6.62 ± 0.28	8.68 ± 0.30	4.57 ± 0.08	−13.115	<0.001 ***
Neutrophil (%)	42.98 ± 1.17	40.28 ± 1.60	45.68 ± 1.62	2.370	0.020 *
Lymphocytes (%)	46.88 ± 1.06	44.98 ± 1.17	48.78 ± 1.75	1.810	0.037 *
MXD (%)	7.25 ± 0.30	7.88 ± 0.38	6.63 ± 0.46	−2.094	0.039 *
PLT ($\times 10^{9}$/L)	165.62 ± 10.19	241.33 ± 11.15	89.92 ± 1.53	−13.449	<0.001 ***

Abbreviations: SEM: standard error of the mean; PCV: Packed Cell Volume; WBC: White Blood Cell count; RBC: Red Blood Cell count; PLT: platelet count; MCH: Mean Cell Haemoglobin; NEU: neutrophil; LYM: lymphocytes; MXD: Monocyte + Basophil + Eosinophil. $^{\beta}$ Distance from gas-flaring sites; significance level: * = $p < 0.05$; *** = $p < 0.001$.

Table 2 shows the haematological indices of participants who were exposed to gas flaring, categorised by sex and proximity. No significant alterations were observed in RBC, MCH, WBC, neutrophil, and lymphocyte counts ($p > 0.05$) in relation to sex and proximity to the gas-flaring location. A significant decrease ($p < 0.001$) in PCV was observed among both male and female subjects residing within a 5 km radius compared to a 10 Km radius. However, a significant increase ($p < 0.001$) in MXD was observed among females residing within a 5 km radius compared to those residing within a 10 km radius.

Table 3 shows trichotomized haematological indices for both male and female participants who were exposed to gas flaring, categorised by distance. Among the male participants residing within a 5 km radius of the exposure source, 42.5% exhibited low RBC counts below the reference category, while only 2.5% exceeded the reference category. For those residing within a 10 km radius, 15% had RBC counts below the reference category, with 27.5% exceeding the reference category. This study revealed that the PCV values of male individuals residing within a 5 km radius of the source of exposure were significantly lower (42.5%) compared to those residing 10 km away (2.5%). Also, 50% of the male population residing within the 5 km radius had lower HB levels than the reference category, while those residing 10 km away had 47% lower HB levels. Furthermore, it was observed that 27.5% of participants residing within a 5 km radius had MCH values that fell within the reference category, whereas only 45% of those residing within a 10 km radius exhibited higher MCH values.

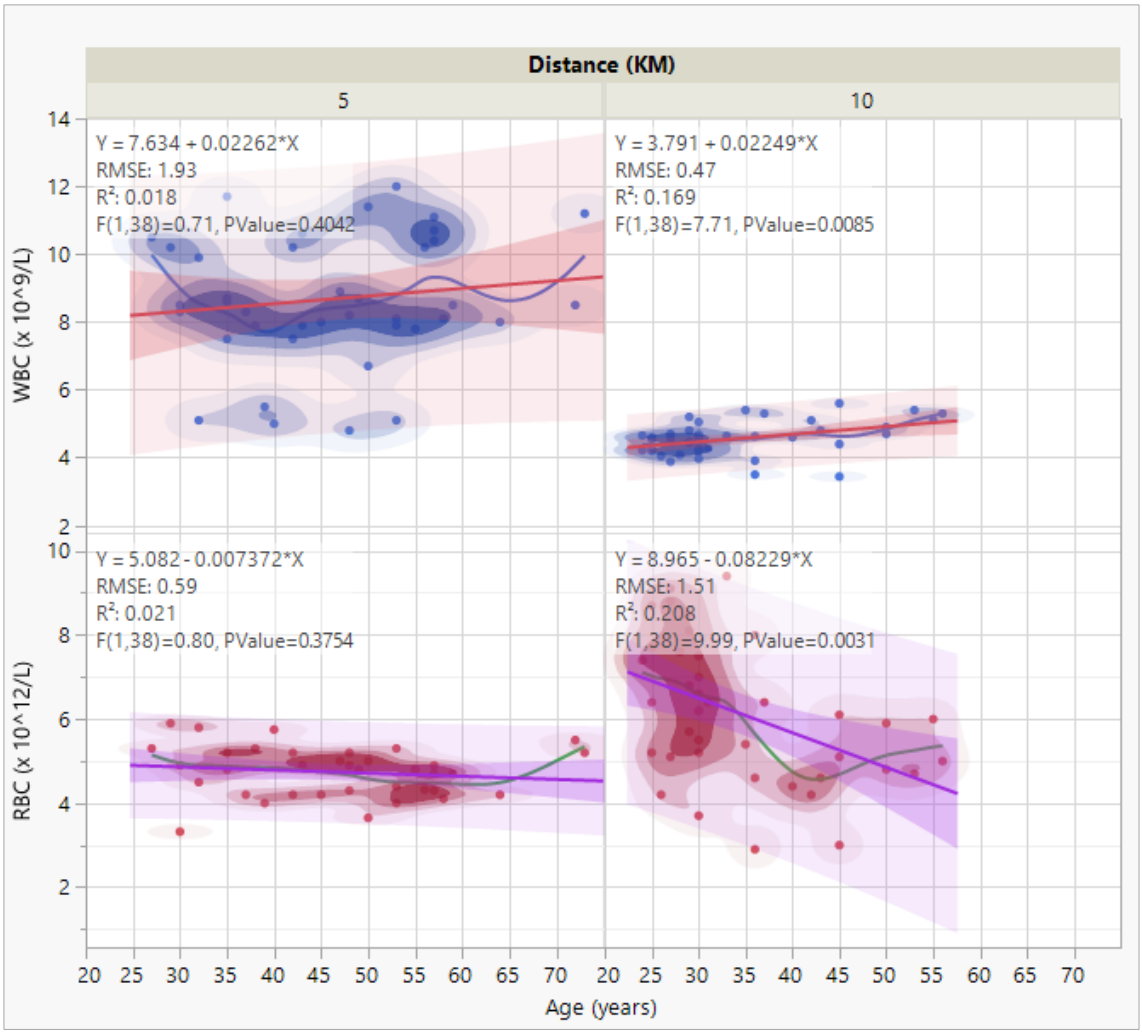

Figure 2. Relationships between WBC, RBC, and age of participants by distance from gas-flaring sites. The color bands indicate data point density within a specific area of the plot, highlighting where data clusters are most concentrated. Darker colors represent higher density, while lighter colors indicate lower density. The bands display the confidence intervals around fitted lines or model predictions.

Table 2. Haematological indices of residents exposed to gas flaring by sex and distance.

Parameter	5 Km		10 Km		Test Statistics	
	Female Mean ± SEM	Male Mean ± SEM	Female Mean ± SEM	Male Mean ± SEM	F-Ratio	*p*-Value
RBC ($\times 10^{12}$/L)	4.84 ± 0.15	4.64 ± 0.10	6.26 ± 0.38	6.01 ± 0.38	0.0113	0.915 ^{ns}
PCV (%)	34.20 ± 0.65 ^{a}	37.25 ± 0.59 ^{b}	36.40 ± 0.73 ^{b}	42.40 ± 0.46 ^{c}	5.7358	<0.001 ***
MCH (%)	27.58 ± 0.71	26.68 ± 0.47	31.15 ± 0.61	30.83 ± 0.51	0.2521	0.617 ^{ns}
WBC ($\times 10^{9}$/L)	8.92 ± 0.43	8.44 ± 0.43	4.38 ± 0.13	4.75 ± 0.08	1.8428	0.178 ^{ns}
Neutrophil (%)	46.35 ± 1.62	34.20 ± 2.01	48.55 ± 2.37	42.80 ± 2.07	2.4738	0.119 ^{ns}
Lymphocytes (%)	43.10 ± 1.89	46.85 ± 1.28	45.75 ± 2.13	51.80 ± 2.65	0.3156	0.575 ^{ns}
MXD (%)	9.35 ± 0.39 ^{a}	6.40 ± 0.47 ^{b}	5.85 ± 0.63 ^{b}	7.40 ± 0.63 ^{ab}	17.3038	<0.001 ***
PLT ($\times 10^{9}$/L)	272.55 ± 16.86 ^{a}	210.10 ± 11.13 ^{b}	88.42 ± 2.93 ^{c}	91.41 ± 0.86 ^{c}	10.2578	0.002 **

Abbreviations: SEM: standard error of the mean; PCV: Packed Cell Volume; WBC: White Blood Cell count; RBC: Red Blood Cell count; PLT: platelet count; MCH: Mean Cell Haemoglobin; NEU: Neutrophil; LYM: lymphocytes; MXD: Monocyte + Basophil + Eosinophil; Within parameters, mean ± SEM with different superscripts is significantly different. Significance level: ** = $p < 0.01$; *** = $p < 0.001$; ns = not significant ($p > 0.05$).

Table 3. Trichotomized haematological–haematological indices for males and females exposed to gas flaring by distance.

			Females				Males		
Parameter	**Trichotomized Measure**	***N* (%)**	**5 Km *n* (%)**	**10 Km *n* (%)**	**χ^2 Value (*p*-Value)**	**Trichotomized Measure**	**5 Km *n* (%)**	**10 Km *n* (%)**	**χ^2 Value (*p*-Value)**
RBCs ($\times 10^{12}$/L)	Low (<4.5)	32 (40.0)	6 (15.0)	3 (7.5)		Low (<5.1)	17 (42.50)	6 (15.0)	
	Reference (4.5–5.3)	19 (23.8)	11 (27.5)	3 (7.5)	12.689	Reference (5.1–5.3)	2 (5.0)	3 (7.5)	13.794
	High (>5.3)	29 (36.3)	3 (7.5)	14 (35.0)	(0.0018) **	High (>5.3)	1 (2.5)	11 (27.5)	(0.0010) ***
PCV (%)	Low (<36)	42 (52.5)	15 (37.5)	9 (22.5)	3.75	Low (<40)	17 (42.5)	1 (2.5)	25.859
	Reference (36–46)	38 (47.5)	5 (12.5)	11 (27.5)	(0.0528) *	Reference (40–50)	3 (7.5)	19 (47.5)	(<0.0001) ****
	High (>46)	0 (0.0)	0 (0.0)	0 (0.0)		High (>46)	0 (0.0)	0 (0.0)	
HB (g/dl)	Low (<12.4)	73 (91.3)	20 (50.0)	16 (40.0)		Low (<14.0)	20 (50.0)	17 (42.5)	
	Reference (12.4–13.1)	7 (8.8)	0 (0.0)	4 (10.0)	^{f} (0.1060) ^{ns}	Reference (14.0–14.4)	0 (0.00)	3 (7.5)	^{f} (0.2308) ^{ns}
	High (>13.1)	0 (0.0)	0 (0.0)	0 (0.0)		High (>14.4)	0 (0.00)	0 (0.00)	
MCH (%)	Low (<27.1)	21 (26.3)	9 (22.5)	0 (0.0)		Low (<27.2)	11 (27.5)	1 (2.5)	
	Reference (27.1–28.9)	12 (15.0)	2 (5.0)	5 (12.5)	11.786	Reference (27.2–28.1)	4 (10.0)	1 (2.5)	17.481
	High (>28.9)	47 (58.8)	9 (22.5)	15 (37.5)	(0.0028) **	High (>28.1)	5 (12.5)	18 (45.0)	(0.0002) ***
WBCs ($\times 10^{9}$/L)	Low (<4.4)	14 (17.5)	0 (0.0)	11 (27.5)		Low (<4.3)	0 (0.0)	3 (7.5)	
	Reference (4.4–4.8)	12 (15.0)	0 (0.0)	5 (12.5)	26.667	Reference (4.3–4.6)	0 (0.0)	7 (17.5)	13.333
	High (>4.8)	54 (67.5)	20 (50.0)	4 (10.0)	(<0.001) ***	High (>4.6)	20 (50.0)	10 (25.0)	(0.0013) ***
NEU (%)	Low <49.1	59 (73.8)	16 (40.0)	8 (20.0)		Low (<52.6)	19 (47.5)	16 (40.0)	
	Reference (49.1–52.3)	8 (10.00)	1 (2.5)	4 (10.0)	6.739	Reference (52.6–55.2)	0 (0.0)	3 (7.5)	3.257
	High >52.3	13 (16.25)	3 (7.5)	8 (20.0)	(0.0344) *	High (>55.2)	1 (2.5)	1 (2.5)	(0.1962) ^{ns}
LYMPHs (%)	Low (<39.0)	8 (10.0)	5 (12.5)	2 (5.0)		Low (<37.4)	0 (0.0)	1 (2.5)	
	Reference (39.0–42.1)	12 (15.0)	1 (2.5)	7 (17.5)	6.146	Reference (37.4–40.2)	2 (5.0)	2 (5.0)	1.029
	High (>42.1)	60 (75.0)	14 (35.0)	11 (27.5)	(0.0463) *	High (>40.2)	18 (45.0)	17 (42.5)	(0.5979) ^{ns}
PLT ($\times 10^{9}$/L)	Low (>251.2)	51 (63.8)	5 (12.5)	20 (50.0)		Low (<206.8)	6 (15.0)	20 (50.0)	
	Reference (229.3–251.2)	8 (10.0)	4 (10.0)	0 (0.0)	24.000	Reference (206.8–226.8)	4 (10.0)	0 (0.0)	21.538
	High (<229.3)	21 (26.3)	11 (27.5)	0 (0.0)	(<0.0001) ****	High (>226.8)	10 (25.0)	0 (0.0)	(<0.0001) ****

Abbreviations: PCV: Packed Cell Volume; WBC: White Blood Cell count; RBC: Red Blood Cell count; PLT: platelet count; MCH: Mean Cell Haemoglobin; NEU: neutrophil; LYM: lymphocytes; MXD: Monocyte + Basophil + Eosinophil. Significance level: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; **** = $p < 0.0001$; ns = not significant ($p > 0.05$).

The white blood cell levels of males (50%) residing within a 5 km radius were found to be significantly higher (p = 0.001) than those residing 10 km away (25%). Similarly, male residents within a 5 km radius exhibited a higher percentage of lymphocytes (45%) compared to those residing within a 10 km radius (42%). On the other hand, neutrophil count was higher in males residing at a distance of 5 km (47.5%) compared to those residing within a distance of 10 km (40%). The platelet levels of males residing within a 5 km radius were found to be 15% lower than those residing within a 10 km radius.

Among females, 15% of those residing within a 5 km radius exhibited RBC counts below the reference category, with only 7.5% exceeding the reference value. For those residing within a 10 km radius, 7.5% of the participants had RBC counts below the reference value, while 35% recorded values above it. More than half of females (52.5%) exhibited PCV levels lower than the reference category compared to 37.5% for those residing within a 10 km radius. Also, 50% of females residing within a 5 km radius exhibited HB levels below the reference category, but these levels were slightly lower (40%) for those residing within a 10 km radius.

There were increased WBC counts for female individuals residing within a 5 km radius, which was found to be 50% (p = 0.001), whereas only 10% of those residing within a 10 km radius exhibited increased WBC counts compared to the reference category. Likewise, there was an increase in lymphocyte count (35%) among female individuals inhabiting the 5 Km radius compared to those residing in the 10 Km radius (27.5%) (p = 0.046). On the contrary, neutrophils were found to be lower than the reference category, with 40% and 20% lower values observed for those residing at the 5 Km and 10 Km distances, respectively. Approximately 50% of both males and females who resided at a distance of 10 Km ($p < 0.0001$) exhibited significantly low platelet counts compared to individuals who resided at a distance of 5 Km.

4. Discussion

Haematological indices are of prognostic importance in chronic diseases, including the early onset of cancer and the progression of cancer patients [18–20]. Our study revealed a significant decrease in RBCs, PCV, and HB, although platelet counts were elevated among participants residing within a 5 km radius of the gas-flaring site compared to participants residing within a 10 km radius. Also, the levels of WBCs and lymphocytes were observed to be elevated among participants living within the same 5 Km radius of the gas-flaring site compared to participants residing within a 10 Km radius.

Our findings, which revealed a significant decrease in RBC, PCV, and HB levels, may have some prognostic importance, especially as anaemia or significantly decreased RBC, PCV, and HB levels have been reported to be associated with some haematological cancers that affect the bone marrow, such as leukaemia, lymphoma, and multiple myeloma [21–25]. Anaemia can further lead to impaired oxygen delivery to tissues and organs [26]. These findings of significant decreases in RBC, PCV, and HB levels were somewhat lower but within the same range as those previously reported by Adienbo and Nwafor [15] and Ihekwoaba et al. [27]. The findings are suggestive of alterations in haematological indices as a result of exposure to gas flaring. There exist plausible mechanisms by which air pollution may induce anaemia, including the downregulation of erythropoietin production, exacerbation of the refractoriness of hematopoietic precursors to endogenous erythropoietin, and the chronic and sustained upregulation of hepcidin [28–31]. Exposure to benzene, a constituent of flared gas, in environmental and occupational settings has been scientifically established to be associated with the development of leukaemia in individuals of all age groups, including adults and children. [32,33].

Overall, we observed a significant increase in WBC counts among participants residing in a 5 Km radius; these findings were corroborated by the increased lymphocyte counts of participants residing in the same 5 Km radius. Elevated levels of WBCs have been associated with inflammatory diseases and cancer [34]. Hence, our findings may be a potential indicator of infection, leukaemia, or lymphoma risks [35]. These findings are in

contrast with the findings reported by Ihekwoaba et al. [27], who observed a reduction in WBC levels. The authors speculated that the decrease in WBC levels observed in their study could be attributed to the stress experienced by the participants. Their findings may have been diluted since there were no measurements of the proximity of the residence to the gas-flaring site. Thus, it is difficult to compare previous studies using only binary exposure assessment methods (ever versus never) to the categorical exposures (5 Km and 10 Km) used in the current study. However, our results are similar to those of Adriano and Nwafor [15] as well as Egwurugwu et al. [14], though they did not evaluate lymphocytes, which were included in the present study.

For platelet counts, we observed a significant increase for those residing in a 5 Km radius compared to those in a 10 Km radius. This has not been previously reported with respect to gas-flaring exposure. Elevated platelet counts are referred to as thrombocythemia, a medical condition characterised by inflammatory conditions such as autoimmune diseases, cancer, trauma, specific infections, and iron deficiency [36–38].

The strengths of this study lie in the utilisation of human biological materials, which allows for a more precise exposure assessment. In addition, this study was not simulated but was rather conducted within the communities situated in close proximity to the gas-flaring site, with stratification based on distance. Despite these factors, the findings should be interpreted with caution because of some limitations. First, our study sample was small and may not be representative of all oil-producing communities in the Niger Delta region with gas-flaring sites, as participation was voluntary and limited only to individuals who consented. Second, although study participants appeared to be normal and healthy during sample collection, there was no pre-screening to determine their health status. Third, the nutritional status of the residents before sample collection was not determined. It is also possible that some of these findings may be attributed to nutritional deficiencies that are often associated with the poor socio-economic status of the rural populace in oil-producing areas of the Niger Delta region of Nigeria.

5. Conclusions

Our findings indicate that exposure to gas flaring may alter haematological indices, including RBCs and WBCs, which are known to play a crucial role in oxygen transportation to tissues and the immune system, respectively. However, it is also possible that nutritional deficiencies, which were not captured in our study, may have precluded our findings. It is, therefore, recommended that a comprehensive observational study with the long-term follow-up of participants is conducted to assess the potential health implications and mitigation strategies of environmental and occupational exposure to gas flaring on individuals residing and working in oil-producing communities of the Niger Delta region of Nigeria.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Niger Delta University (#13/1179) on 5 August 2018.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Data supporting the conclusions of this article can be made available upon reasonable request from the corresponding author.

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Conflicts of Interest: All authors declare that there are no conflicts of interest. It is important to note that the corresponding author during the research was a lecturer at Niger Delta University. He is currently a postdoctoral researcher at IARC/WHO and also states that there are no conflicts of interest.

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