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Haematological Profile of a Cross-Section of Workers Occupationally and Environmentally Exposed to Petroleum Products in Abuja and Its Environs

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Abstract

Aim/Objectives: This study investigates the impact of petroleum product exposure on haematological parameters in workers from various sectors, including petrol attendants, tanker drivers, automobile mechanics, and N.N.P.C.L. staff in Abuja. **Methodology:** A total of 250 male participants were assessed by analyzing their venous blood for various haematological parameters. **Results:** Revealed no significant difference in white blood cell (WBC) counts between the control group and workers in most categories, except for auto mechanics, who showed significantly lower ($p < 0.001$) WBC levels. Red blood cell (RBC) counts were higher in N.N.P.C.L. staff compared to the control and other worker categories. Hemoglobin (Hb) levels were lower in the control group compared to mechanics ($p < 0.001$), tanker drivers ($p = 0.003$), and

N.N.P.C.L. workers ($p < 0.001$), while petrol attendants had lower Hb than the other groups. Additionally, the control group had lower mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) compared to other groups. Platelet counts were significantly higher in N.N.P.C.L. staff compared to auto mechanics and tanker drivers, while petrol attendants had higher platelet levels than auto mechanics. **Conclusion:** These findings suggest that exposure to petroleum products can affect haematological health, particularly among auto mechanics, with notable variations in RBC, Hb, MCH, MCHC, and platelet counts. Further research is needed to understand the mechanisms behind these changes.

Keywords

Petroleum Products, Occupation, Environmental, Haematological Parameters, Exposed Workers

1. Introduction

Petroleum products are materials derived from crude oil (petroleum), which is processed in oil refineries. Some of the constituent parts derivable from the fractional distillation of crude petroleum include petrol (premium motor spirit), kerosene, and diesel. These fractions contain a mixture of hydrocarbon compounds, aliphatics, aromatics, such as benzene and toluene, and hundreds of saturated and unsaturated hydrocarbons. Benzene is a natural constituent of crude oil and a product of petrol refining, which is emitted in large quantities. By regulation, benzene is limited to 6 - 8% of the premium motor spirit (PMS) content in Nigeria [1] and between 1 to 5% in the USA and Europe [2]-[6].

To protect public health, the WHO (World Health Organization) and other regulatory agencies have established exposure limits for benzene in ambient air and at the workplace. Although occupational exposure limit to benzene levels remains high in some countries and industries, it poses a significant risk to workers. Therefore, monitoring benzene levels in ambient air and other workplaces is essential to protect public health. Various monitoring techniques and technologies have been developed for accurate measurement of benzene discussed in this article. Real-time monitoring and active and passive sampling methods have their advantages and limitations. Their selection depends on the specific monitoring objectives and available resources.

Accurate calibration of benzene measurement instruments is essential to establish the measurement traceability of results obtained [7]-[9]. Accurate and precise data on benzene in the atmosphere is needed due to its toxic nature and adverse health issues, even when exposed to very low concentrations. The accurate and traceable measurement is essential to support high-quality scientific research, regulatory compliance, the protection of human health, risk assessment, and environmental policy-making efforts to mitigate benzene pollution and its ecological effects.

In Nigeria, it is common knowledge that auto mechanics (AM) are usually exposed to PMS by sucking this petroleum product with their mouth through a tube in an attempt to siphon it from the vehicle tank. They also often wash vehicle parts with PMS without any gloves. In the process of loading, transporting, and off-loading petroleum products, tanker drivers (TD) are exposed to petroleum fumes. Petrol station attendants (PA) practice dispensing the fuel into vehicles without using any protective device to minimize their exposure. Through these practices, the AM, TD, and PA are exposed to petroleum products by inhalation or through contaminated food at their workplaces. Other petroleum industry workers (PIW), such as petrol refilling station managers, supervisors, and clerks by virtue of their supervisory roles, are also exposed to various degrees of petroleum fumes.

The gases and vapors emitted from petroleum stations, automobile mechanic workshops, and fumes from fuel tankers may contribute to various forms of pollution. The continuous occupational exposure to the vapors of these pollutants and working conditions at occupational places puts the workers at risk of various diseases that attack different body organs and systems, such as the respiratory system [10], cardiovascular system, immune system, and renal system [11]. Furthermore, the harmful effects due to petrol vapour toxicity include immunotoxicity and neurotoxicity, and these may make the exposed workers more susceptible to inflammatory diseases and injuries. These facts, therefore, raise a serious public health concern. Unfortunately, the above-mentioned classes of workers are hardly subjected to pre-employment medical examinations or provided with regular medical check-ups to detect the potential risks of exposure to these petroleum products on their health.

The toxicity of inhaled petroleum products has been linked to one of its natural constituents, benzene, due to its biotransformation to reactive oxygen species. Benzene is metabolized in the liver to phenol, which in turn is exposed to hydroxylation to form hydroquinone and 1,4-benzenetriol by peroxidase of the bone marrow or by autoxidation [12]. A case study by Baarson *et al.* [13] and full epidemiological studies by Irons *et al.* [14] and Tsai *et al.* [15] have reported hematological effects in workers with prolonged occupational benzene exposures in the range between 1 ppm and 30 ppm and higher. Data from animal studies indicate that decreases in the number of red blood cells, total number of white blood cells, and hemoglobin levels are not the most sensitive indicators of early benzene effects on blood cells. However, animal models have shown that peripheral lymphocytes are among the most sensitive cells, with decreases in peripheral counts of circulating lymphocytes appearing before other hematological effects [15]-[19]. Decreased lymphocyte counts are an early and consistent finding in workers in whom benzene toxicity was evident, and there is evidence that the conditions disappear when the workers are removed from benzene exposure [20]. Benzene and its metabolites have toxic effects on the hematopoietic system that lead to bone marrow suppression [21]. The increased susceptibility to injuries and infections because of leucopoiesis suppression has been reported to be the major toxic effect of benzene among workers who were continuously exposed to benzene-containing petroleum products [22].

To date, there is no known documented work on the effects of petroleum product exposure on haematological parameters among different categories of exposed workers in Abuja and its environs. Hence, the justification for this study. The present study, therefore, aimed at investigating the potential risk of exposure to petroleum products on haematological parameters of selected workers who have been continuously exposed to petroleum vapour for at least a year within Abuja, Nigeria's capital territory, and its environs.

2. Methodology

2.1. Study Design

The present study is a purposive, cross-sectional study involving apparently healthy adults exposed to petroleum products and their unexposed controls. The study was conducted between October 2021 and March 2023 in Abuja, the federal capital of Nigeria and its environs. A total of two hundred and fifty (250) working adults aged between 18 and 60 years participated in this study. The participants included automobile mechanics (n = 50), petroleum attendants (n = 50), tanker drivers (n = 50), and N.N.P.C.L. workers (n = 50), who were daily exposed to petroleum products at their places of work at low concentrations. The control group (n = 50) comprises unexposed healthy young men of the same age range as the exposed workers. Participants with a history of any acute or chronic illness were excluded from the study. Workers on part-time duties and those who were new on the job or had not spent up to one year on the job were also excluded from the study. The fifty (50) participants in each group for this study group were randomly selected among their coworkers by simple balloting. Every fifth automobile workshop was selected for balloting. One of the balloted members of the workshop who met the criteria was chosen. The same was done for petroleum attendants, tanker drivers, and N.N.P.C.L. staff. However, the control participants were chosen based on criteria and willingness to participate. The personal consent of each participant was sought after explaining the purpose of the research.

2.2. Questionnaire/Ethical Approval

A structured questionnaire was administered to all participants. This study utilized a pre-tested 30-item questionnaire to obtain information about the effect of exposure to petroleum products. The questionnaire pre-tested in a sample (n = 5 participants in each of the five selected workshops, petroleum loading centres, petroleum refilling stations, and N.N.P.C.L. staff), and necessary adjustment was made to suit the study aim and objectives. A thorough review of the entire questionnaire was done by senior research colleagues to ascertain its validity. The questionnaire was segmented into three sections (A - C) with sub-questions. Section A (social demographic) consisted of questions designed to elicit details about their personal data, sex, age, marital status, educational qualification, alcohol consumption, and cigarette smoking. Section B (occupation and awareness of exposure to petroleum products) comprises questions on exposure to petroleum products, route of petroleum product exposure, and duration of exposure. Section C (knowledge on protection against petroleum products) dealt with questions on the use of personal protective equipment (PPE), underlying diseases, diet, use of supplements, quality control, and government monitoring. The Ethics Committee of the Ministry of Environment, Abuja, Ethics Committee of the Nigerian National Petroleum Company Limited (N.N.P.C.L.), Nigeria, Abuja, as well as the managers of the various petroleum refilling stations and auto mechanic workshops and owners of the petroleum trucks, approved this study.

2.3. Exposure Assessment

After three consecutive days of exposure, blood samples from workers in all groups were collected and analysed at the end of their shifts. Environmental monitoring data from gasoline stations, offloading sites, and auto mechanic workshops were provided by the managers. These records indicated that the median airborne benzene concentrations were below the ACGIH's recommended Threshold Limit Value-Time Weighted Average (0.5 ppm) (ACGIH TLVs and BEIs, 2015) [23].

Sample Size Determination

$$\mathrm{n} = \frac{z^2 pq}{d^2}$$

(This formula is used when the prevalence of variable of interest is unknown).

where n = sample size

z = level of confidence, 95%, (1.96)

p = prevalence, 50% or 0.50

q = (1 − p)

d = tolerated margin of error, 5% or 0.05

$$\frac{1.96^2 * 0.5(1-0.5)}{0.05 * 0.05} = \frac{3.84 * 0.25}{0.0025} = \frac{0.96}{0.0025} = 384$$

2.4. Blood Collection and Analysis for Full Blood Count

Five milliliters of blood were collected from the participants (petroleum attendants, automobile mechanics, and N.N.P.C.L. staff after the day shift, while the petroleum tankers were collected at the point of product offloading on the day of exposure) and dispensed into an Ethylenediaminetetraacetic Acid (EDTA) container. Analysis for haematological parameters was done immediately using haematology autoanalyzer (Sysmex Poch 100i model, Germany).

2.5. Data Analysis

Data was expressed as mean and standard deviation for continuous variables and as percentages for categorical data. Analysis of variance (ANOVA) was used to compare multiple groups, whereas the independent sample t-test was used to compare two groups. Group differences were assessed using an LSD post-hoc multiple comparing test. A statistically significant level of $p < 0.05$ was used to evaluate statistical significance. Version 25.0 of IBM/SPSS was used for all the statistical analysis.

3. Results

Table 1 displays the socio-demographic features and lifestyles of those who have been exposed to petroleum products, as well as those who have not been exposed (controls). The control group was 68% males, the automotive mechanics group was 100% males, the tanker drivers group was 100% males, and the N.N.P.C.L. personnel group was 100% males. Most study participants were 40 or older. In particular, the control group had 76% 40-year-olds, fuel attendants 96%, automobile mechanics 68%, and tanker drivers 54%. The majority of N.N.P.C.L. workers, 92%, were aged 40 - 59. The participants were predominantly non-smokers, non-alcoholics, and did not take hard drugs. All the petrol attendants that smoke reported they take 1 stick of cigarette per day, 66.7% of the smoking mechanics reported they take not more than 2 sticks per day; all the smoking tanker drivers and N.N.P.C.L. staff indicated they take more than 2 sticks per day. The majority of those who drink alcohol across the study population reported they take just one bottle of alcoholic beverage per day.

Table 2 displays the work-related attributes of individuals who were exposed to petroleum products, as well as their control group. The research shows that 48% of the surveyed individuals, 94% of petroleum staff members, and 76% of N.N.P.C.L. officials had 1 - 5, 6 - 10, and 11 - 15 years of work experience. A higher proportion of the control group (96%), petrol attendants (58%), automotive mechanics (44%), and N.N.P.C.L. staff (82%) have a work duration of ≤ 10 hours per day, whereas every one of the tanker drivers (100%) reported working for more than 10 hours every day. The majority of the control group (100%), petroleum attendants (56%), and N.N.P.C.L. staff (84%) expressed awareness regarding the impacts of petroleum products. Conversely, a majority of auto mechanics (54%) or tanker drivers (64%) reported lacking awareness regarding the impacts of petroleum products.

Table 3 shows the comparison of the mean blood levels of hematological parameters between the control and the experimental groups, as well as comparisons within the experimental groups. Data indicated no significant differences in WBC between the control and petrol attendants, tanker drivers, and N.N.P.C.L. staff. However, there was a significantly ($p < 0.001$) lower mean WBC among auto mechanics compared with the control, petrol attendants, tanker drivers, and N.N.P.C.L. staff, respectively.

No significant differences were observed in RBC between the control and petrol attendants, mechanics, and tanker drivers. In contrast, The N.N.P.C.L. staff indicated significantly higher RBC compared with the control, auto mechanics ($p = 0.025$), and tanker drivers ($p = 0.016$).

The control group indicated significantly lower Hb concentration compared with mechanics ($p < 0.001$), tanker drivers ($p = 0.003$), and N.N.P.C.L. workers ($p < 0.001$). Similarly, the petrol attendants indicated lower mean Hb concentrations compared with the auto mechanics ($p < 0.001$), tanker drivers ($p = 0.003$), and N.N.P.C.L. staff ($p < 0.001$). Hb level did not differ between the control and petrol attendants.

Hct was significantly lower in control compared with tanker drivers ($p = 0.021$) and N.N.P.C.L. staff ($p < 0.001$). The petrol attendants also showed significantly lower mean Hct compared with the auto mechanics ($p = 0.028$), tanker drivers ($p = 0.010$), and N.N.P.C.L. staff ($p < 0.001$).

Significantly lower MCV was observed in the control group when compared with the mechanics ($p = 0.011$) and tanker drivers ($p = 0.001$) but did not differ when compared with petrol attendants and N.N.P.C.L. staff. In addition, the auto mechanics and the tanker drivers had higher ($p < 0.010$) mean MCV compared with the petrol attendants. The auto mechanics also presented higher MCV compared with the N.N.P.C.L. staff ($p = 0.044$).

The control group indicated lower MCH compared with the mechanics ($p < 0.001$) and N.N.P.C.L. staff ($p = 0.022$), but MCH did not differ when compared with petrol station attendants and petrol tanker drivers. Tanker drivers showed higher ($p = 0.044$) MCH values compared to the petrol attendants.

The control indicated lower ($p < 0.001$) MCHC compared with the petrol attendants, mechanics, and N.N.P.C.L. staff. The tanker drivers had statistically lower mean MCHC compared with the control ($p < 0.001$), auto mechanics ($p < 0.001$), and N.N.P.C.L. staff ($p = 0.030$).

The control group indicated higher platelet levels compared with mechanics ($p = 0.003$), but lower values compared with tanker drivers. No significant differences were observed in platelet level between the control and petrol station attendants and N.N.P.C.L. staff. Higher mean platelet level was observed in N.N.P.C.L. staff compared with auto mechanics ($p < 0.001$) and tanker drivers ($p = 0.002$). The petrol attendants also indicated higher platelet levels compared with the auto mechanics ($p < 0.001$) and tanker drivers ($p = 0.005$).

The control group had significantly higher neutrophil levels compared with the petrol attendants ($p = 0.004$) and mechanics ($p < 0.001$). The auto mechanics indicated significantly ($p < 0.001$) lower neutrophil levels compared with petrol attendants, tanker drivers, and N.N.P.C.L. staff. The auto mechanics indicated higher lymphocyte levels compared with the petrol attendants ($p = 0.004$), tanker drivers ($p < 0.001$), and N.N.P.C.L. staff ($p < 0.001$).

The control group had significantly lower lymphocyte levels compared with the petrol attendants ($p = 0.009$) and mechanics ($p < 0.001$). The petrol attendants also had higher lymphocyte levels compared with tanker drivers ($p = 0.020$).

The monocyte level was lower in control compared with mechanics ($p = 0.010$) and tanker drivers ($p < 0.001$). The auto mechanics presented higher monocyte level compared with the petrol attendants ($p < 0.001$) and N.N.P.C.L. staff ($p = 0.013$). Tanker drivers also showed higher monocyte levels compared with the petrol attendants ($p = 0.007$).

The control group indicated significantly lower eosinophil levels compared with the petrol attendants ($p = 0.036$), mechanics ($p = 0.022$), and tanker drivers ($p < 0.001$). The N.N.P.C.L. staff also indicated lower eosinophil levels compared with petrol attendants ($p = 0.025$), auto mechanics ($p = 0.020$), and tanker drivers ($p = 0.002$), but did not differ with the control.

Furthermore, the control group indicated higher ($p < 0.001$) values compared with the petrol attendants and N.N.P.C.L. staff, but lower values compared with the mechanics ($p = 0.004$) and tanker drivers ($p = 0.012$). The petrol attendants indicated a lower ($p < 0.001$) basophil level compared with the auto mechanics and tanker drivers. Similarly, the N.N.P.C.L. staff indicated lower ($p < 0.001$) basophil levels compared with auto mechanics and tanker drivers.

Pearson's regression analysis indicated significant negative correlations between WBC and the habit of sucking and washing hands with gasoline by some of the workers. There was a significant positive correlation between MCV and daily hours of exposure to petroleum products and the use of PPE by the workers. MCH also indicated a positive correlation with daily hours of exposure to petroleum products. Significant negative relationships were observed between platelets and the habit of sucking and washing hands with gasoline by some of the workers. On the other hand, those who made use of PPE indicated higher platelet levels. Neutrophils indicated a positive correlation with daily hours of exposure to petroleum products, but negative correlations with the habit of sucking and washing hands with gasoline by the workers. Lymphocyte levels of workers indicated a negative correlation with daily hours of exposure to petroleum products and the use of PPE, but a positive correlation with the habit of sucking by the workers. The workers also indicated significant positive correlations between their monocyte levels and years of exposure to petroleum products, and the habit of sucking and washing hands with gasoline. The workers' basophil levels indicated significant positive correlations with daily hours of exposure to petroleum products and the habit of sucking and washing hands with gasoline (**Table 4**).

Table 1. Socio-demographic characteristics and lifestyles of subjects exposed to petroleum products and their unexposed controls.

Characteristics		Control N (%)	Petrol Attendants N (%)	Automobile Mechanics N (%)	Tanker Drivers N (%)	N.N.P.C.L. Staff N (%)
Age Group	<40 years	38 (76.0)	48 (96.0)	34 (68)	27 (54)	1 (2)
	40 - 59 years	12 (24.0)	2 (4.0)	15 (30)	22 (44)	46 (92)
	≥60 years	0 (0)	0 (0)	1 (2)	1 (2)	3 (6)

Continued

Smoking Habit	No	50 (100.0)	48 (96.0)	44 (88)	48 (96)	48 (96)
	Yes	0 (0.0)	2 (4.0)	6 (12)	2 (4)	2 (4)
Number of Sticks Per Day	1 stick/day	0 (0.0)	2 (100)	2 (33.3)	0 (0)	0 (0)
	2 sticks/day	0 (0)	0 (0)	4 (66.7)	0 (0)	0 (0)
	>2 sticks/day	0 (0)	0 (0)	0 (0)	2 (100)	2 (100)
Drinking of Alcohol	No	50 (100.0)	46 (92.0)	38 (76)	46 (92)	42 (84)
	Yes	0 (0.0)	4 (8.0)	12 (24)	4 (8)	8 (16)
Number of Bottles Per Day	1 bottle/day	0 (0.0)	4 (100)	6 (50)	2 (50)	5 (63)
	2 bottles/day	0 (0)	0 (0)	5 (41.7)	2 (50)	2 (25)
	5 bottles/day	0 (0)	0 (0)	1 (8.3)	0 (0)	1 (12)
Supplements	No	50 (100)	50 (100)	50 (100)	50 (100)	50 (100)
	Yes	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Underlying Disease	No	50 (100)	50 (100)	50 (100)	50 (100)	50 (100)
	Yes	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Special Diet	No	50 (100)	50 (100)	50 (100)	50 (100)	50 (100)
	Yes	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 2. Work-related characteristics of test subjects and their control.

Characteristics		Control N (%)	Petrol Attendants N (%)	Automobile Mechanics N (%)	Tanker Drivers N (%)	N.N.P.C.L. Staff N (%)
Years of working experience	1 - 5	24 (48)	47 (94)	17 (34)	10 (20)	3 (6)
	6 - 10	18 (36)	3 (6)	16 (32)	25 (50)	9 (18)
	11 - 15	8 (16)	0 (0)	17 (34)	15 (30)	38 (76)
Working hours/day	≤10	48 (96)	29 (58)	22 (44)	0 (0)	41 (82)
	>10	2 (4)	21 (42)	28 (56)	50 (100)	9 (18)
Knowledge of petroleum products effects	No	0 (0)	22 (44)	27 (54)	32 (64)	8 (16)
	Yes	50 (100)	28 (56)	23 (46)	18 (36)	42 (84)
Types of petrol product effects experienced	None	50 (100)	15 (30)	14 (28)	9 (18)	12 (24)
	Breathlessness	0 (0)	2 (4)	0 (0)	0 (0)	16 (32)
	Dizziness	0 (0)	1 (2)	1 (2)	0 (0)	0 (0)
	Eye Irritation	0 (0)	3 (6)	1 (2)	2 (4)	7 (14)
	Nasal Irritation	0 (0)	1 (2)	0 (0)	2 (4)	0 (0)
	Skin Irritation	0 (0)	27 (54)	18 (36)	36 (72)	13 (26)
	Others	0 (0)	1 (2)	16 (32)	1 (2)	2 (4)

Continued

Measures taken to treat effects	Medical Care	0 (0)	11 (22)	3 (6)	0 (0)	23 (46)
	Disappearance of Symptom	0 (0)	24 (48)	33 (66)	24 (48)	16 (32)
	None	50 (100)	15 (30)	14 (28)	26 (52)	11 (22)
Routes of exposure to petroleum products	Eyes	0 (0)	3 (6)	3 (6)	1 (2)	4 (8)
	Nostril	0 (0)	10 (20)	8 (16)	2 (4)	21 (42)
	Skin	0 (0)	23 (46)	31 (62)	22 (44)	20 (40)
	None	50 (100)	14 (28)	8 (16)	25 (50)	5 (10)
Sucking petrol with the mouth	No	50 (100)	48 (96)	13 (26)	37 (74)	39 (78)
	Yes	0 (0)	2 (4)	37 (74)	13 (26)	11 (22)
Washing hands with petrol	No	50 (100)	43 (86)	9 (18)	22 (44)	34 (68)
	Yes	0 (0)	7 (14)	41 (82)	28 (56)	16 (32)
Knowledge of PPE	No	12 (24)	21 (42)	13 (26)	1 (2)	3 (6)
	Yes	38 (76)	29 (58)	37 (74)	49 (98)	47 (94)
Use of PPE	No	12 (24)	30 (60)	16 (32)	1 (2)	5 (10)
	Yes	38 (76)	20 (40)	34 (68)	49 (98)	45 (90)
Types of PPE used	Boot	-	2 (10)	0 (0)	0 (0)	10 (22.2)
	Facial Mask	-	8 (40)	0 (0)	1 (2)	3 (6.7)
	Helmet	-	0 (0)	0 (0)	43 (85.7)	4 (8.9)
	Hand Gloves	-	9 (45)	1 (3)	0 (0)	4 (8.9)
	Coverall	-	1 (5)	33 (97)	6 (12.3)	24 (53.3)

Table 3. The mean blood levels of hematological parameters were compared among the experimental groups.

Variables	Control	Petrol Attendant	Auto Mechanics	Tanker Drivers	N.N.P.C.L. Staff	F-Stat	P-Value
WBC	5.31 ± 0.83	5.48 ± 1.55	3.93 ± 1.35*	5.22 ± 1.39	5.12 ± 1.67	10.59	<0.001
RBC	4.71 ± 0.65	4.91 ± 0.67	4.84 ± 0.72	4.82 ± 0.84	5.16 ± 0.51*	2.46	0.064
HB	13.26 ± 0.95	13.26 ± 1.34	14.26 ± 1.11*	13.99 ± 1.35*	14.43 ± 0.93*	9.16	<0.001
HCT	40.41 ± 4.05	40.12 ± 4.103	42.36 ± 6.50	42.74 ± 5.72*	43.49 ± 3.12*	4.13	0.007
MCV	82.82 ± 4.87	82.14 ± 6.15	87.13 ± 10.65*	87.02 ± 7.35*	83.66 ± 9.39	4.22	0.006
MCH	26.62 ± 3.88	27.20 ± 2.42	29.90 ± 4.20*	35.21 ± 39.2	28.12 ± 2.37*	1.64	0.181
MCHC	29.67 ± 3.05	33.09 ± 1.20*	34.03 ± 4.58*	32.08 ± 1.73*	33.22 ± 1.30*	4.70	0.003
Platelet	214.7 ± 41.95	225.4 ± 83.1	181.0 ± 64.92*	190.68 ± 42.8*	229.6 ± 48.6	7.79	<0.001
Neutrophils	45.68 ± 5.49	41.12 ± 9.64*	30.47 ± 13.08*	42.72 ± 9.18	44.57 ± 11.0	17.04	<0.001
Lymphocytes	41.88 ± 4.88	45.62 ± 8.59*	51.62 ± 13.59*	40.75 ± 8.47	42.23 ± 10.08	10.98	<0.001
Monocytes	8.50 ± 2.38	8.18 ± 1.96	11.59 ± 7.94*	10.68 ± 3.38*	9.31 ± 2.16	5.41	0.001
Eosinophils	2.83 ± 2.17	4.33 ± 4.48*	4.39 ± 4.21*	4.96 ± 2.66*	2.75 ± 1.90	3.68	0.013
Basophils	1.31 ± 0.74	0.74 ± 0.38*	2.41 ± 2.54*	1.96± 1.61*	0.71 ± 0.34*	15.96	<0.001

*Significant difference between the control group and groups exposed to petroleum products.

Table 4. Association between hematological parameters and selected work-related characteristics of workers exposed to petroleum products.

		Years of Exposure	Daily Hours of Exposure	Mouth Suction of Petrol	Hand Washing with Petrol	Use of PPE
WBC	R	−0.084	0.098	−0.247	−0.241	0.025
	P-value	0.239	0.166	0.000*	0.001*	0.727
RBC	R	−0.018	−0.051	−0.083	−0.111	−0.102
	P-value	0.796	0.469	0.243	0.119	0.149
HB	R	0.130	0.124	0.020	0.059	0.071
	P-value	0.067	0.081	0.776	0.410	0.316
HCT	R	0.030	0.119	−0.024	0.007	0.068
	P-value	0.678	0.092	0.741	0.921	0.337
MCV	R	0.059	0.147	−0.020	0.093	0.208
	P-value	0.410	0.038*	0.773	0.191	0.003*
MCH	R	0.012	0.145	−0.031	−0.032	0.074
	P-value	0.868	0.041*	0.662	0.652	0.298
MCHC	R	0.112	−0.138	0.111	0.093	−0.066
	P-value	0.116	0.051	0.118	0.193	0.356
Platelet	R	−0.045	−0.119	−0.153	−0.166	0.174
	P-value	0.523	0.093	0.030*	0.019*	0.014*
Neutrophils	R	0.007	0.180	−0.256	−0.190	0.131
	P-value	0.927	0.011*	0.000*	0.007*	0.065
Lymphocytes	R	−0.046	−0.243	0.164	0.129	−0.194
	P-value	0.515	0.001*	0.020*	0.069	0.006*
Monocytes	R	0.142	0.078	0.223	0.207	0.135
	P-value	0.045*	0.270	0.002*	0.003*	0.057
Eosinophils	R	−0.115	0.077	−0.074	−0.162	−0.040
	P-value	0.105	0.278	0.299	0.022*	0.578
Basophils	R	0.027	0.179	0.180	0.124	0.131
	P-value	0.706	0.011*	0.011*	0.080	0.065

Abbreviations: R = Correlation Coefficient; PPE = Personal Protective Equipment. Note that in the regression model, the response 'no' was denoted by 1, while the response 'yes' was denoted by 2 for questions on whether or not subjects used mouth to suck petrol, or washed hands with petrol or if they made use of PPE.

4. Discussion

This study aimed to evaluate the effects of occupational exposure to petroleum products on various hematological parameters. Overall, the present findings showed mixed results regarding the effects of petroleum products on hematological parameters, thus highlighting the complexity of the relationship between occupational exposure to petroleum products and hematological markers like

WBC count, RBC count, hematocrit, hemoglobin concentration, MCV, MCH, and MCHC.

White blood cells play a key role in the immune response, and changes in their number can be indicative of immune system activation, inflammation, or other health disturbances. It is important to note that while this study did not find significant differences between the control and some of the groups (petrol refilling station attendants, petrol tanker drivers, and petroleum industry staff), significantly higher mean WBC was observed among the controls compared with the auto mechanics. Previous research has shown mixed results regarding the effects of petroleum products on immune parameters. Some studies suggest that exposure to petroleum products, such as those encountered in oil spills or industrial environments, can lead to alterations in immune function, including changes in WBC counts, though such effects may vary based on the type of petroleum product, the duration of exposure, and the specific population being studied [24] [25]. For instance, previous assessments of petroleum product exposure among workers indicated significantly lower white blood cells [26]-[29], which is in agreement with the current study. On the other hand, studies by Salem *et al.* and Emenike *et al.* [30] [31] on workers exposed to petroleum products indicated an increase in WBC profiles, while other studies [32] [33] reported no significant changes in WBC counts in subjects exposed to petroleum fumes. These discrepancies highlight the complexity of interpreting the immunotoxic effects of petroleum exposure and suggest that factors such as individual susceptibility, exposure duration, and environmental conditions could influence results. The finding that there were no significant differences in white blood cell count between the control group and petrol attendants, petrol tanker drivers, and N.N.P.C.L. staff exposed to petroleum products suggests that, within the parameters of this study, exposure to petroleum-based chemicals did not lead to a measurable impact on WBC levels in these groups.

Our study further revealed significant differences in various white blood cell differential counts—neutrophils, basophils, lymphocytes, monocytes, and eosinophils—between the control group and the other occupational groups, including petrol refilling station attendants, auto mechanics, petrol industry staff, and petrol tanker drivers. The auto mechanics indicated significantly higher lymphocyte, monocyte, eosinophil, and basophil levels compared with the unexposed control. The petrol refilling station attendants indicated higher levels of lymphocytes and eosinophils compared with the control. The petrol tanker drivers indicated higher monocyte, eosinophil, and basophil levels compared with the control group. Lower values of neutrophils and basophils were observed in auto mechanics, petrol station attendants, and N.N.P.C.L. workers compared with the control group. These findings suggest that the work environments in the petrol refilling stations, auto mechanics, and petrol tanker driving industries involve exposures that can alter immune function, particularly in terms of specific WBC types. The immune system might be responding to various environmental stressors in different ways: for instance, occupations with chronic exposure to petroleum products, solvents, and other chemicals may lead to immune system activation, reflected by higher levels of certain WBC types (such as basophils, lymphocytes, monocytes, and eosinophils) as part of the body's defense mechanism. Some occupations may also have immune-suppressive effects, particularly if workers are exposed to toxic substances that suppress normal immune function (e.g., lower neutrophil counts). Workers in certain occupations may exhibit compensatory increases in lymphocytes, monocytes, or eosinophils due to long-term exposure to inflammatory agents or allergens.

A previous study has shown occupational exposure to petroleum products and fumes may lead to suppressed neutrophil activity [34], which is in agreement with the present findings. In disagreement with our finding, another study by Abdrabouh *et al.* [28] indicated that prolonged gasoline inhalation induced significantly higher neutrophil levels in fuel station workers compared to unexposed control. In tandem with our findings, previous studies have shown that exposure to petroleum products can lead to increased lymphocyte response [11] [28] [31]. In contrast, another study indicated reduced lymphocyte levels in subjects exposed to petroleum products compared to the control [27]. Exposure to petroleum products, including solvents and oils, has also been shown to lead to immune activation and an increase in monocyte production [28] [34]. This may indicate that workers exposed to these chemicals are experiencing chronic inflammation or a greater need for immune surveillance, resulting in elevated monocyte levels. Our finding, which indicated a higher eosinophil level in exposed workers, is in agreement with a previous study [35], but in contrast with other studies [26] [27], which indicated lower eosinophil levels in workers exposed to petroleum products compared to unexposed control. The higher basophil levels observed in the auto mechanics and petrol tanker drivers compared to the control group could indicate that these two occupational groups might have a heightened inflammatory or allergic response to specific petrochemical exposures, such as pungent gasoline fumes, benzene or solvent vapors, which can lead to an increase in basophils [36]. A similar result was also observed in a previous study by Pesatori *et al.* [37].

The current study indicated that the N.N.P.C.L. workers exhibited significantly higher RBC, Hb, and Hct levels compared to the control group. Similarly, the petrol tanker drivers indicated higher Hb and Hct compared with the control. Furthermore, the mechanics showed a higher mean Hb value compared with the control group. These results are in agreement with previous studies which had indicated higher RBC count [38], higher Hb level [39] [40], and higher Hct (Salem *et al.*, 2022) [30] among different occupational groups exposed to petroleum products compared with the unexposed control group. In contrast, other studies, [26] [28] [33] indicated significantly lower RBC, Hb, and Hct levels among the exposed group compared with the control group. One plausible explanation for the higher red blood cell, hemoglobin, and hematocrit levels in these workers could be a compensatory mechanism in response to certain environmental stressors, such as reduced oxygen levels (hypoxia), or it may be a consequence of chronic exposure to specific chemicals or toxins [21] [22] [41]. In this case, the higher RBC counts in the exposed group could reflect adaptive changes related to the exposure to petroleum products (carbon monoxide, benzene, hydrocarbons), which may be causing mild hypoxia or other systemic effects not immediately obvious through traditional clinical measures [42]. An increase in the production of more RBC, in turn, causes an increase in Hb and Hct levels.

The absence of significant differences in RBC counts between the control and specific subgroups like petrol attendants, mechanics, and tanker drivers suggests that exposure to petroleum products in these particular professions may not lead to significant alterations in RBC counts. The lack of such changes could imply that the exposure levels in these groups were either too low, too brief, or insufficiently chronic to result in measurable hematological alterations. This is in agreement with previous studies, which showed no significant differences in RBC count [30] [33], Hb concentration [33] [36], and hematocrit level [33], between workers exposed to petroleum products and unexposed control. Generally, the current findings suggest variability in the effects of petroleum exposure based on occupation and exposure level. For instance, certain workers in industries involving more direct or prolonged exposure to petroleum fumes or products might show hematological changes, while others with less direct exposure may not show any significant effects [26] [43]. The variations could be attributed to the type of petroleum product being handled, the use of protective measures (e.g., ventilation, protective gear), or individual susceptibility. To further support these findings, none of the participants was on a special diet, supplements, or multivitamins that may have influenced their erythropoietic activities. It is also worth noting that all the participants responded through the questionnaire that they were not suffering from any underlying ailment.

This study found that the auto-mechanics and petrol tanker drivers had significantly higher MCV compared to the control group, but no significant differences were observed when the control was compared with the petrol refilling station attendants and N.N.P.C.L. staff. Similarly, the auto mechanics and N.N.P.C.L. staff indicated higher MCH compared with the control group. The petrol refilling station attendants, auto mechanics, and N.N.P.C.L. staff also indicated higher MCHC compared with the control, but lower values were found in petrol tanker drivers compared with the control. Similar results indicating higher MCV, MCH, and MCHC among workers exposed to petroleum products have been reported previously by Teklu *et al.*, 2021; Nair *et al.*, 2015, [44] [45] and in agreement with the present study. In contrast, some studies have shown higher MCV, MCH, and MCHC values in exposed workers compared to unexposed control [26] [28]. Other studies have shown that there were no significant differences in MCV, MCH, and MCH between the exposed workers and control groups (Abou-ElWafa *et al.*, 2015; Al-Jothery & Al-Hassnwi 2017) [32] [33]. The higher MCV may be due to occupational exposure to environmental stressors, including chemicals, heavy physical labor, and potential chronic exposure to pollutants such as hydrocarbons and benzene. Such exposures may lead to hemoconcentration, which can impact the size of the red blood cells. The significant differences observed in MCH and MCHC between the control group and various occupational groups (petrol refilling station attendants, auto-mechanics, petrol tanker drivers, and petroleum industry workers) could be explained by differences in environmental and occupational exposures, physical demands of the job, and nutrition. The differences in MCH and MCHC suggest potential alterations in erythropoiesis or red blood cell function due to these exposures. Studies suggest that exposure to solvents, chemicals, and other pollutants (hydrocarbons, lead, and benzene) commonly found in petrol stations and the petroleum industry can adversely affect MCV, MCH, and MCHC levels [33] [44].

This study indicated that the auto mechanics presented a lower mean platelet level compared with the control, while the petrol tanker drivers indicated higher values compared with the control. No significant differences were observed in platelet levels between the control and petrol station attendants and N.N.P.C.L. staff. These findings suggest that occupational exposure to chemicals and environmental stressors plays a significant role in altering platelet counts. Previous studies have shown higher platelet levels in workers exposed to petroleum products compared with the control [30] [42]. In other studies, platelet level was found to be lower among those exposed to petroleum products compared with the control group [35] [46]. Auto mechanics are frequently exposed to various chemicals, such as solvents, oils, and fuels. Some of these substances, particularly benzene, have been shown to affect platelet production by either damaging bone marrow or altering platelet function. Benzene exposure, for instance, is known to cause bone marrow suppression, leading to lower platelet counts [39]. The higher platelet count in the petrol tanker drivers could be a compensatory mechanism. There is some evidence suggesting that exposure to certain toxins like hydrocarbons and petroleum byproducts might lead to the body increasing platelet production in response to mild or subclinical damage (Salvi *et al.*, 1999; Loomis *et al.*, 2013) [47] [48]. This compensatory response could be an attempt to mitigate potential microvascular damage from chronic exposure to petroleum fumes. Furthermore, inflammatory responses related to chronic occupational exposure could stimulate platelet production. There is a well-documented connection between inflammation and elevated platelet levels, as platelets play a role in the inflammatory process [49]. Prolonged exposure to noxious chemicals could lead to a subtle, low-level inflammatory state, thus raising platelet counts.

5. Limitations

This study suffered limitations. Many of the participants who initially indicated interest in the study opted out along the line due to reasons ranging from personal and cultural to religion.

6. Conclusion

Our findings reveal complex and nuanced relationships between petroleum product exposure and hematological parameters. In some instances, we observed significantly higher values of certain hematological parameters, while in others, values were significantly lower compared to the control group. Additionally, some parameters showed no significant differences between the occupationally exposed groups and the control group. These mixed results highlight the multifaceted nature of how environmental exposures, such as those encountered in petroleum-related industries, can influence hematological health. Further research could explore the underlying mechanisms driving these changes, such as the role of specific hydrocarbons, genetic factors, or other environmental conditions that could be influencing the observed patterns. Other interesting avenues for future research could involve examining other factors, such as the workers' overall health status or lifestyle, which could influence their response to petroleum exposure. Additionally, considering the chronicity of exposure is critical, as workers with prolonged exposure may eventually show different patterns of RBC count changes compared to those with shorter or less intense exposure durations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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