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Research Article

Effect of Fuel Exposure on Oil Company Workers

Ogbutor Udoji Godsday[1, *], Ndubuishi Ifechukwudeni Christabel[1], Nwose Jephtah Junior[3], Anastacia Okwudili Ojimba[3], Isaac Precious[1], Erumi Blessing Selly-U[2], Ogbutor Emeke Godson[1]

[1]Department of Human Physiology, Delta State University, Abraka, Nigeria

[2]Department of Human Kinetics, Delta State University, Abraka, Nigeria

[3]Department of Internal Medicine, Federal Medical Centre, Asaba, Nigeria

Abstract

Background: Occupational exposure to petroleum products poses substantial physiological risks to oil company workers. Aim: This study assessed the physiological effects of fuel exposure among oil company workers in Delta State, Nigeria. Methods: This study employed a comparative cross-sectional design involving 330 participants comprising 165 exposed workers (fuel attendants, refinery workers, and maintenance/technical staff) and 165 non-exposed academic staff of Delta State University, Abraka, serving as controls. Measurements of systolic and diastolic blood pressure (SBP and DBP), pulse rate (PR), oxygen saturation (SpO_2), peak expiratory flow rate (PEFR), and body temperature were obtained, alongside assessment of clinical symptoms across four physiological domains. Data were analyzed using independent t-tests and chi-square tests at $p < 0.05$. Results: Exposed workers demonstrated significantly higher mean SBP (136.5 ± 14.2 vs. 124.3 ± 11.8 mmHg), DBP (88.7 ± 9.6 vs. 79.5 ± 8.4 mmHg), PR (84.2 ± 10.5 vs. 76.8 ± 8.9 bpm), and body temperature (37.2 ± 0.4 vs. 36.8 ± 0.3 ℃) compared to controls (all $p < 0.001$). Conversely, SpO_2 (94.8 ± 2.1 vs. 97.1 ± 1.5%) and PEFR (410.6 ± 65.3 vs. 465.2 ± 58.7 L/min) were significantly lower in exposed workers ($p < 0.001$). Chi-square analysis revealed significantly higher prevalence of respiratory ($\chi^2 = 42.67$), neurological ($\chi^2 = 46.18$), and dermatological symptoms ($\chi^2 = 32.54$), and overall physiological symptom burden ($\chi^2 = 52.89$) among exposed workers (all $p < 0.001$). These findings demonstrate that occupational fuel exposure significantly impairs multi-system physiological function.

Keywords

Petroleum Exposure, Occupational Health, Volatile Organic Compounds, Blood Pressure, Lung Function, Nigeria

1. Introduction

Occupational exposure to fuel remains an important health concern among workers involved in petroleum exploration, refining, storage, transportation and distribution. Petrol, diesel and crude oil contain volatile organic compounds, particularly benzene, toluene, ethylbenzene and xylene, commonly known as BTEX. These compounds may be released during refining, loading, transfer, maintenance and accidental spillage.

*Correspondence: Ogbutor Udoji Godsday (udojiogbutor@delsu.edu.ng)

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Khoshakhlagh et al. [1] detected varying BTEX concentrations across refinery work areas and job categories, while occupational biomonitoring studies have confirmed that exposed workers absorb measurable quantities of these hydrocarbons [2, 3].

Fuel vapours enter the body mainly through inhalation, although dermal absorption may occur through direct contact with contaminated surfaces, clothing and equipment. Once absorbed, hydrocarbons are distributed through the bloodstream to tissues such as the lungs, brain, liver, kidneys and bone marrow. Exposure is influenced by the concentration of the chemical, duration of employment, ventilation, job activity and use of personal protective equipment. Geraldino et al. [2] reported elevated biomarkers of toluene and xylene exposure among fuel workers, while Jalilian et al. [4] found benzene concentrations above the recommended limit in the breathing zone of refinery employees.

The problem is particularly relevant in Nigeria, where petroleum production and distribution contribute significantly to economic activities. Inadequate ventilation, prolonged working hours, poor spill control and inconsistent use of protective equipment may increase exposure among workers. Anigilaje et al. [5] reported that Nigerian petroleum workers may be exposed to hazardous BTEX compounds because of weaknesses in occupational-health regulation and monitoring. Similarly, Ismail et al. [6] found that occupational exposure to petroleum gas in Kano was associated with changes in respiratory and cardiovascular parameters.

From a physiological perspective, petroleum hydrocarbons may disturb cellular homeostasis through oxidative stress and inflammation. Reactive metabolites formed during hydrocarbon metabolism can increase reactive oxygen species and damage cellular lipids, proteins and genetic material. Mendes et al. [7] identified metabolic alterations associated with oxidative stress and chromosomal abnormalities among workers exposed to low benzene concentrations. Zhou et al. [8] also found that oxidative stress partly mediated blood-pressure elevation among workers exposed to low concentrations of benzene, toluene and xylene. These findings indicate that physiological changes may occur even when exposure does not produce immediate clinical poisoning [7, 8].

The respiratory system is especially vulnerable because the lungs are the major route through which fuel vapours enter the body. Repeated inhalation may irritate the airways, promote inflammation and reduce pulmonary function, leading to cough, chest tightness, wheezing and shortness of breath. Liao et al. [9] associated exposure to mixtures of BTEX and styrene with impaired small-airway function among petrochemical workers. In Nigeria, Ismail et al. [6] reported significantly lower forced vital capacity among workers with greater occupational exposure to liquefied petroleum gas. However, Jalilian et al. [4] found no significant difference in spirometric indices between exposed and unexposed refinery workers despite elevated benzene concentrations. This variation may be related to differences in exposure duration, concentration, protective practices and individual susceptibility.

Fuel exposure may also affect cardiovascular regulation. Oxidative stress can impair vascular function, reduce nitric-oxide availability and increase sympathetic nervous activity, resulting in increased vascular resistance and blood pressure. Warnakulasuriya et al. [10] observed higher blood pressure and altered cardiovascular autonomic function among fuel-station attendants. Zhou et al. [8] similarly reported a positive relationship between BTX exposure and blood-pressure elevation. Among oil-spill responders, increasing crude-oil exposure through inhalation and skin contact was associated with chest pain, altered heartbeat and other cardiovascular conditions [11].

Other physiological systems may also be affected. Teklu et al. [12] reported alterations in haemoglobin, haematocrit, red-blood-cell and platelet levels among gasoline-station workers, indicating possible effects on blood formation and oxygen transport. Exposure to volatile petroleum hydrocarbons has also been associated with changes in liver enzymes and haematopoietic indicators [13]. Neurological complaints such as headache, dizziness, fatigue, poor coordination and sensory disturbances have been reported among exposed workers, and Chen et al. [14] found evidence of persistent neurological effects following occupational exposure to volatile hydrocarbons during oil-spill clean-up [12, 14].

Although several studies have examined petroleum exposure, many have focused on fuel-station attendants, spill responders or individual organ systems. Fewer studies have assessed the combined respiratory and cardiovascular effects of routine fuel exposure among workers employed directly in oil companies, particularly in Nigeria. Differences in exposure conditions, duration of employment, safety practices and workers' health characteristics also limit the application of findings across workplaces. Assessing respiratory and cardiovascular parameters among oil-company workers is therefore necessary for identifying early physiological changes and supporting occupational screening, exposure control and appropriate workplace-health policies [1, 5, 6].

2. Materials and Methods

2.1. Research Design

This study adopts a descriptive cross-sectional research design. This design is appropriate as it enables the assessment of the physiological effects of fuel exposure among oil company workers at a single point in time without manipulation of variables. It is widely applied in occupational and environmental health studies to examine the relationship between workplace exposure and observable health outcomes. The study incorporates both descriptive and analytical components. The descriptive aspect focuses on characterizing the study population, including exposure patterns, duration of work, and use of protective measures. The analytical aspect evaluates the relationship between fuel exposure and measured physiological outcomes. Unlike studies that rely solely on self-reported data, this research utilizes direct experimental and non-invasive measurement tools such as blood pressure monitoring, heart rate assessment, and clinical observation of symptoms to obtain more objective data on physiological responses. This approach enhances the reliability of findings in assessing the health effects of fuel exposure among workers.

2.2. Area of the Study

The study will be conducted in Delta State, Nigeria, among oil company workers, including fuel attendants and oil refinery workers who are routinely exposed to petroleum products. Delta State is one of the major oil-producing regions in Nigeria, with extensive activities involving petroleum exploration, refining, transportation, and fuel dispensing. These activities expose workers to fuel vapors, petroleum fumes, volatile organic compounds, and other hazardous substances during daily operations. The study area is considered suitable due to the high concentration of petroleum-related activities and the presence of various categories of workers who are exposed to fuel products for prolonged periods. These include fuel attendants, refinery workers, maintenance staff, technicians, and other personnel involved in petroleum handling and distribution. For comparison, academic staff from Delta State University will serve as the control group, as they are not occupationally exposed to petroleum products. Previous studies in Nigeria have shown that workers in petroleum-related occupations are exposed to multiple occupational hazards, including fuel vapors and chemical emissions, which may have significant health implications [5, 15].

2.3. Population of the Study

The target population for this study consists of oil company workers in Delta State, including fuel attendants and oil refinery workers who are directly exposed to petroleum products during their routine occupational activities. The accessible population comprises workers from selected fuel stations, oil-related facilities, and refinery environments within Delta State who have been employed for at least one year. This duration is considered necessary to ensure sufficient exposure that may result in observable physiological effects. In addition, academic staff from Delta State University will be included as the control group, as they are not occupationally exposed to fuel products. This allows for a comparative assessment between exposed and non-exposed populations within the same geographical area.

2.3.1. Inclusion Criteria

The study will include participants who meet the following criteria:

1) Individuals employed in selected petroleum-related workplaces in Delta State or academic staff of Delta State University
2) Individuals who have worked in their current occupation for at least one year
3) Individuals aged 18 years and above
4) Individuals who are willing to participate and provide informed consent

2.3.2. Exclusion Criteria

Participants will be excluded from the study if they meet any of the following conditions:

1) Individuals who have worked for less than one year in their current workplace
2) Individuals who are severely ill at the time of data collection
3) Individuals who decline to participate in the study
4) Individuals with known chronic medical conditions that may influence physiological parameters independent of occupational exposure

2.3.3. Sample Size Determination

The sample size for each group will be determined using the formula for comparing two independent proportions, as appropriate for case-control studies:

$$n = \frac{(Z_{\alpha/2}+Z_{\beta})^2[p_1(1-p_1)+p_2(1-p_2)]}{(p_1-p_2)^2}$$

Where:

1) $Z_{\alpha/2}$= 1.96 at 95% confidence level
2) Z_{β}= 0.84 at 80% power
3) p_1= estimated proportion of physiological effects among exposed workers
4) p_2 = estimated proportion among unexposed/control group

Based on previous occupational exposure studies showing a marked difference in physiological outcomes between exposed petroleum workers and non-exposed populations, an estimated proportion of 0.50 for exposed group and 0.30 for control group will be assumed for calculation purposes.

Substituting:

$$n = \frac{(1.96+0.84)^2[0.5(1-0.5)+0.3(1-0.3)]}{(0.5-0.3)^2}$$

This yields an approximate sample size of about 150 participants per group.

To improve statistical power and account for possible non-response or incomplete physiological measurements, an additional 10% will be added:

$$n_f = 150 + (0.10 \times 150) = 165$$

Therefore, the final sample size will consist of:

1) Oil company workers (exposed group): 165 respondents
2) University staff in Delta State (control group): 165 respondents

Giving a total sample size of approximately 330 participants.

This balanced sample size is appropriate for comparative occupational health studies and ensures adequate statistical power to detect differences in physiological outcomes between exposed and unexposed populations.

2.3.4. Sampling Technique

A multistage sampling technique will be adopted for this study. In the first stage, selected fuel stations, oil refinery facilities, and petroleum-related workplaces in Delta State will be purposively chosen based on the nature of their operations and the likelihood of occupational fuel exposure. In the second stage, workers will be stratified into relevant occupational categories such as fuel attendants, refinery workers, maintenance staff, technicians, and other personnel directly involved in petroleum handling. This ensures adequate representation of different exposure levels. In the final stage, simple random sampling will be used to select participants from each category. Academic staff from Delta State University will also be randomly selected to serve as the control group. This approach helps reduce selection bias and improves the representativeness of the sample.

2.4. Measurement Instruments and Equipment

This study will rely on objective physiological and environmental measurement instruments rather than self-reported questionnaires.

A digital sphygmomanometer will be used to measure systolic and diastolic blood pressure. This is essential because exposure to petroleum hydrocarbons has been linked to vascular stress, endothelial dysfunction, and altered blood pressure regulation [6, 16]. Readings will be taken after five minutes of rest in a seated position, and the average of two readings will be recorded.

A portable pulse oximeter will be used to measure oxygen saturation (SpO_2) and pulse rate. This is important because inhalation of volatile organic compounds and fuel vapors may impair gas exchange and reduce oxygen availability in the blood [17]. Measurements will be taken at rest.

A digital peak flow meter will be used to assess peak expiratory flow rate (PEFR), an indicator of lung function. Reduced PEFR values have been associated with chronic exposure to petroleum fumes and particulate matter in occupational settings [18, 19].

A digital thermometer will be used to record body temperature, particularly in workers reporting systemic symptoms such as fatigue, malaise, or inflammatory responses. Chronic exposure to toxicants has been associated with low-grade systemic inflammation that may influence body temperature regulation [20].

A workplace exposure observation checklist will be used to assess environmental conditions including:

1) Ventilation quality
2) Presence of visible fuel vapors
3) Fuel handling intensity
4) Use of PPE (masks, gloves, uniforms)
5) Proximity to fuel dispensing or storage points

Poor ventilation and inadequate protective practices have been strongly associated with higher levels of petroleum exposure among workers [5, 21].

All measured values will be recorded immediately into structured data sheets and later entered into Microsoft Excel and SPSS version 25 for analysis. Each participant will be assigned a unique code to ensure data accuracy and confidentiality.

2.4.1. Validity of Instruments

The instruments used in this study are standardized medical devices commonly applied in clinical and occupational health assessments. Prior to data collection, all equipment were calibrated according to manufacturer specifications to ensure accuracy and reliability of measurements. The observation checklist was subjected to expert review by professionals in physiology and occupational health to ensure that it adequately captures relevant exposure variables. This process enhances the content validity of the study instruments.

2.4.2. Reliability of the Instruments

Reliability of the instruments was ensured through the use of standardized procedures during data collection. Measurements such as blood pressure, oxygen saturation, and peak expiratory flow rate were taken more than once, and the average or best consistent value was recorded to minimize random error. A pilot study was also conducted prior to the main data collection to test the instruments and procedures. This helped to identify and correct any inconsistencies, thereby improving the overall reliability of the study.

2.5. Data Collection Procedure

Data collection was carried out after obtaining ethical approval and necessary permissions from relevant authorities, including management of selected workplaces and Delta State University. Trained research assistants were recruited in the data collection process to ensure adherence to standard procedures. Participants were approached at their workplaces, and the purpose of the study was clearly explained to them. Informed consent was obtained before any measurements were taken. Physiological parameters such as blood pressure, oxygen saturation, pulse rate, and peak expiratory flow rate were measured under standardized conditions. Environmental observations was also be conducted using the structured checklist. All data collected was recorded immediately in structured data sheets and later transferred into Microsoft Excel for cleaning and coding before analysis.

2.5.1. Method of Data Analysis

Data obtained from the study was analyzed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics such as mean, standard deviation, frequency, and percentage were used to summarize the characteristics of the study population and the measured physiological parameters.

Inferential statistical methods, including independent t-test and chi-square test, were used to compare physiological outcomes between exposed workers and the control group. Regression analysis was also employed to determine the relationship between level of exposure and physiological effects. All statistical tests was conducted at a significance level of $p < 0.05$.

2.5.2. Ethical Consideration

Ethical approval was obtained from the institutional review board of Faculty of Basic Medical Sciences Delta State University, Abraka, (RBC/FBMC/DELSU/26/1266) prior to the commencement of the study. Permission was also sought from management of selected workplaces and Delta State University. Participation in the study was entirely voluntary, and written informed consent was obtained from all participants. Confidentiality was strictly maintained by assigning unique codes to participants instead of using their names. All data collected was used solely for academic research purposes.

3. Results

This section presents the results obtained from the study on the physiological effects of fuel exposure among oil company workers in Delta State, with academic staff of Delta State University serving as the control group. The data was analyzed using descriptive and inferential statistics and presented using tables and charts.

3.1. Demographic Characteristics of Respondents

This section presents the socio-demogand duration of work. A total of 330 respondents participated in the study, comprising 165 fuel exposed workers and 165 non-exposed individuals.

Table 1. *Distribution of Respondents by Age Group.*

Age Group (years)	Exposed (n=165)	Control (n=165)	Total (n=330)	Percentage (%)
20-29	40	55	95	28.8%
30-39	60	50	110	33.3%
40-49	45	40	85	25.8%
50 and above	20	20	40	12.1%
Total	165	165	330	100%

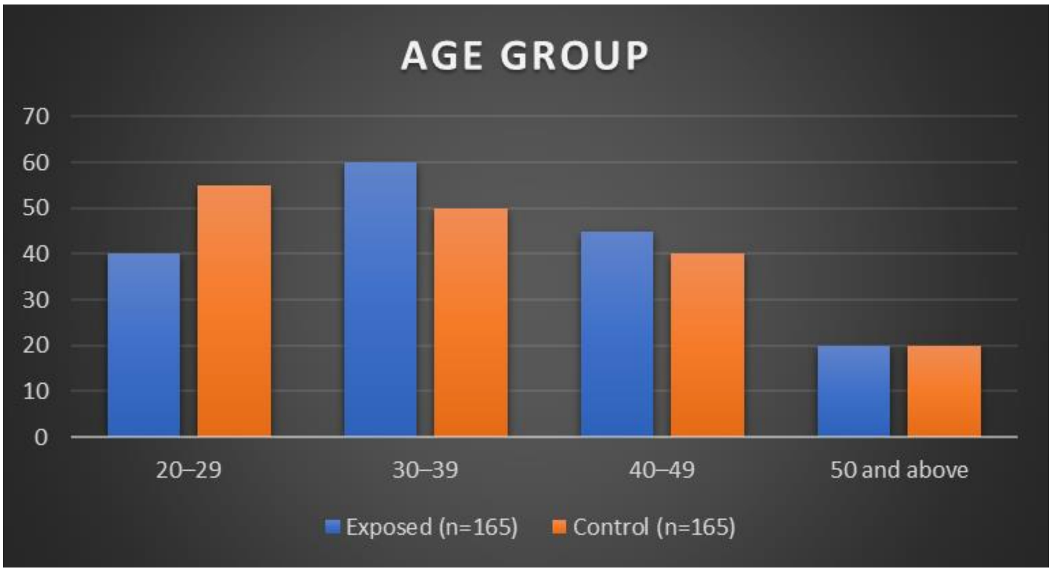

Figure 1. *Age Group Chart.*

Statistical Interpretation: Table 1 shows that respondents aged 30-39 years had the highest frequency with 110 respondents (33.3%), followed by those aged 20-29 years with 95 respondents (28.8%). Respondents aged 50 years and above had the lowest frequency with 40 respondents (12.1%). Most respondents were within the 30-39 years age group, indicating that the majority were in their active working age.

Table 2. *Distribution of Respondents by Gender.*

Gender	Exposed (n=165)	Control (n=165)	Total (n=330)	Percentage (%)
Male	110	95	205	62.1%
Female	55	70	125	37.9%
Total	165	165	330	100

Statistical Interpretation: Table 2 shows that males constituted 205 respondents (62.1%), while females accounted for 125 respondents (37.9%). The study population was predominantly male, reflecting the male-dominated nature of oil-related occupations.

Statistical Interpretation: Table 3 shows that academic staff had the highest frequency with 165 respondents (50.0%), followed by fuel attendants with 70 respondents (21.2%), refinery workers with 60 respondents (18.2%), and maintenance/technicians with 35 respondents (10.6%). Academic staff formed the largest group because they constituted the control group, while fuel attendants were the largest among exposed workers, indicating high representation of workers directly involved in fuel handling.

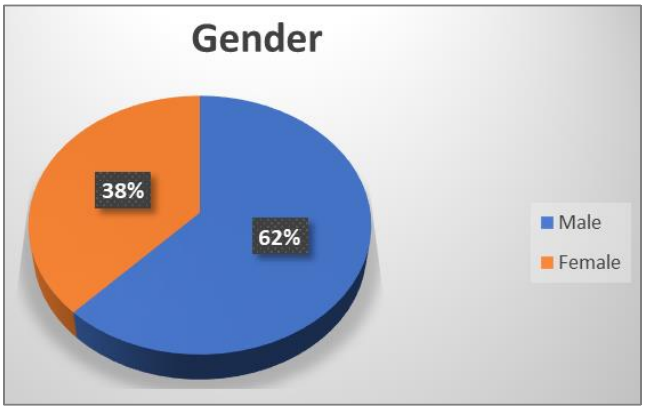

Figure 2. *Gender chart.*

Table 3. *Distribution of Respondents by Occupational Category.*

Occupation	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
Fuel Attendants	70		70	21.2%
Refinery Workers	60		60	18.2%
Maintenance/Technicians	35		35	10.6%
Academic Staff		165	165	50.0%
Total	165	165	330	100

Table 4. *Distribution of Respondents by Duration of Work.*

Duration (years)	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
1-5	50	60	110	33.3

Duration (years)	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
6-10	60	55	115	34.8
11-15	35	30	65	19.7
Above 15	20	20	40	12.1
Total	165	165	330	100

Statistical Interpretation: Table 4 shows that respondents with 6-10 years of work experience had the highest frequency with 115 respondents (34.8%), followed by those with 1-5 years of experience with 110 respondents (33.3%). Respondents with above 15 years of experience had the lowest frequency with 40 respondents (12.1%). Most respondents had between 6-10 years of work experience, suggesting prolonged occupational exposure among the exposed group.

Table 5. *Distribution of Respondents by Use of Personal Protective Equipment (Exposed Group Only).*

PPE Usage	Frequency (n=165)	Percentage (%)
Regular Use	50	30.3
Occasional Use	70	42.4
No Use	45	27.3
Total	165	100

Statistical Interpretation: Table 5 shows that occasional use of personal protective equipment had the highest frequency with 70 respondents (42.4%), followed by regular use with 50 respondents (30.3%). Respondents who did not use PPE accounted for 45 respondents (27.3%). A large proportion of exposed workers either used PPE occasionally or not at all, indicating a higher risk of occupational fuel exposure.

3.2. Physiological Parameters of Respondents

Table 6. *Comparison of Mean Physiological Parameters Between Exposed and Control Groups.*

Parameter	Exposed (n=165) Mean ±SD	Control (n=165) Mean ±SD	t-value	p-value
Systolic BP (mmHg)	136.5 ±14.2	124.3 ±11.8	8.21	0.000*
Diastolic BP (mmHg)	88.7 ±9.6	79.5 ±8.4	8.05	0.000*
Pulse Rate (bpm)	84.2 ±10.5	76.8 ±8.9	6.73	0.000*
SpO_2 (%)	94.8 ±2.1	97.1 ±1.5	-11.02	0.000*
PEFR (L/min)	410.6 ±65.3	465.2 ±58.7	-7.84	0.000*
Body Temp (℃)	37.2 ±0.4	36.8 ±0.3	9.15	0.000*

Statistical Interpretation: Table 6 All measured physiological parameters showed statistically significant differences between the exposed and control groups ($p < 0.05$). The exposed group recorded higher mean systolic BP (136.5 ± 14.2 vs 124.3 ± 11.8 mmHg), diastolic BP (88.7 ± 9.6 vs 79.5 ± 8.4 mmHg), pulse rate (84.2 ± 10.5 vs 76.8 ± 8.9 bpm), and body temperature (37.2 ± 0.4 vs 36.8 ± 0.3 ℃). In contrast, SpO_2 (94.8 ± 2.1 vs 97.1 ± 1.5%) and PEFR (410.6 ± 65.3 vs 465.2

±58.7 L/min) were significantly lower in the exposed group. These findings indicate that fuel exposure is associated with adverse cardiovascular and respiratory physiological changes.

Table 7. Distribution of Blood Pressure Categories and Mean Blood Pressure Among Respondents.

BP Category	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
Normal	50	110	160	48.5
Pre-hypertension	60	35	95	28.8
Hypertension Stage 1	40	15	55	16.7
Hypertension Stage 2	15	5	20	6.1
Total	165	165	330	100

Table 8. Blood Pressure Values Compared Between the two Groups.

Parameter	Group	Mean ±SD (mmHg)	Range (mmHg)
Systolic BP	Exposed	136.5 ±14.2	110-165
	Control	124.3 ±11.8	100-150
Diastolic BP	Exposed	88.7 ±9.6	70-105
	Control	79.5 ±8.4	65-95

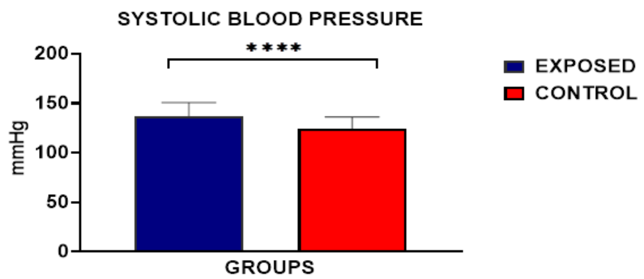

Figure 3. Comparison on Systolic Blood Pressure among Exposed and Control Group.

Statistical Interpretation: Tables 7 and 8 show that normal blood pressure was observed in 160 respondents (48.5%), while 95 respondents (28.8%) were pre-hypertensive. Hypertension stage 1 and stage 2 accounted for 55 respondents (16.7%) and 20 respondents (6.1%) respectively. Among exposed workers, a greater proportion fell within the pre-hypertensive and hypertensive categories compared to the control group. The mean systolic blood pressure was higher among exposed workers (136.5 ±14.2 mmHg) than the control group (124.3 ± 11.8 mmHg). Similarly, the mean diastolic blood pressure was higher among exposed workers (88.7 ± 9.6 mmHg) compared to controls (79.5 ±8.4 mmHg). This suggests that fuel exposure may be associated with increased blood pressure and greater cardiovascular risk among exposed workers.

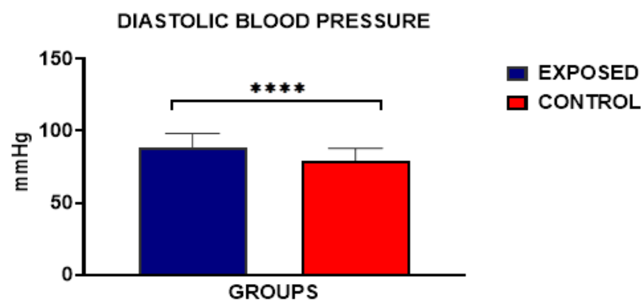

Figure 4. Comparison on Diastolic Blood Pressure among Exposed and Control Group.

Table 9. Distribution of Oxygen Saturation (SpO_2) Levels and Mean SpO_2 Among Respondents.

SpO_2 Level	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
Normal (≥96%)	60	130	190	57.6
Mildly Reduced (93-95%)	75	30	105	31.8
Low (<93%)	30	5	35	10.6
Total	165	165	330	100

Table 10. Comparison of Oxygen Saturation (SpO_2) Levels and Mean SpO_2 Compared Among Respondents.

Group	Mean ± SD (%)	Range (%)
Exposed	94.8 ± 2.1	89-98
Control	97.1 ± 1.5	94-99

Statistical Interpretation: Tables 9 and 10 show that normal oxygen saturation levels were recorded in 190 respondents (57.6%), while 105 respondents (31.8%) had mildly reduced oxygen saturation and 35 respondents (10.6%) had low oxygen saturation. Reduced oxygen saturation was more common among exposed workers than the control group. The mean oxygen saturation was lower among exposed workers (94.8 ± 2.1%) compared to the control group (97.1 ± 1.5%). This suggests that fuel exposure may be associated with impaired pulmonary gas exchange among exposed workers.

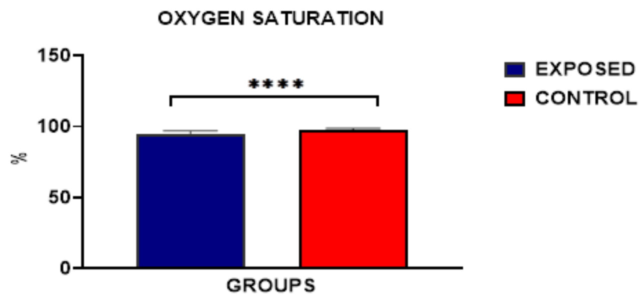

Figure 5. Comparison on Oxygen Saturation among Exposed and Control Group.

Table 11. Distribution of Peak Expiratory Flow Rate (PEFR) and Mean PEFR Among Respondents.

PEFR Category	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
Normal	70	130	200	60.6
Mild Reduction	60	25	85	25.8
Moderate Reduction	25	8	33	10.0
Severe Reduction	10	2	12	3.6
Total	165	165	330	100

Table 12. Peak Expiratory Flow Rate (PEFR) and Mean PEFR Values Compared Among Respondents.

Group	Mean ± SD (L/min)	Range (L/min)
Exposed	410.6 ± 65.3	280-520
Control	465.2 ± 58.7	350-580

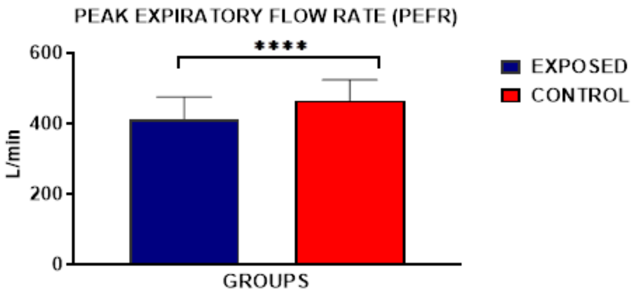

Figure 6. Comparison on PEFR among Exposed and Control Group.

Statistical Interpretation: Tables 11 and 12 show that 200 respondents (60.6%) had normal PEFR values, while 85 respondents (25.8%) had mild reduction, 33 respondents (10.0%) had moderate reduction, and 12 respondents (3.6%) had severe reduction. A larger proportion of exposed workers experienced mild, moderate, and severe PEFR reduction compared to the control group. The mean PEFR was lower among exposed workers (410.6 ± 65.3 L/min) than the control group (465.2 ± 58.7 L/min). This indicates that fuel exposure may be associated with reduced lung function among exposed workers.

Table 13. Distribution of Pulse Rate Categories and Mean Pulse Rate Among Respondents.

Pulse Rate Category	Exposed (n=165)	Control (n=165)	Total	Percentage (%)
Normal (60-80 bpm)	65	120	185	56.1
Elevated (81-100 bpm)	80	40	120	36.4
Tachycardia (>100 bpm)	20	5	25	7.6
Total	165	165	330	100

Table 14. Pulse Rate Categories and Mean Pulse Rate Compared Among Respondents.

Group	Mean ± SD (bpm)	Range (bpm)
Pulse rate (Exposed)	84.2 ± 10.5	65-110
Pulse Rate (Control)	76.8 ± 8.9	60-95

Statistical Interpretation: Tables 13 and 14 show that 185 respondents (56.1%) had normal pulse rates, while 120 respondents (36.4%) had elevated pulse rates and 25 respondents (7.6%) had tachycardia. Elevated pulse rate and tachycardia were more common among exposed workers than the control group. The mean pulse rate was higher among exposed workers (84.2 ± 10.5 bpm) compared to controls (76.8 ± 8.9 bpm). This suggests that fuel exposure may contribute to increased cardiovascular stress among exposed workers.

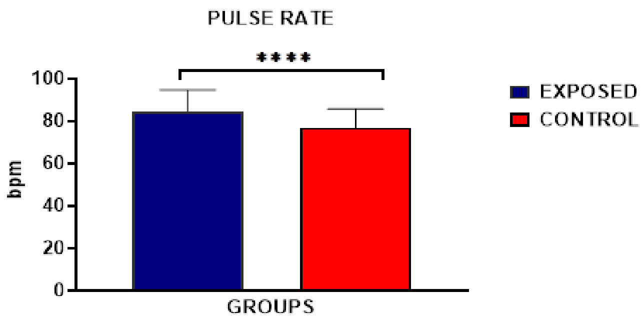

Figure 7. Comparison on Pulse Rate among Exposed and Control Group.

Table 15. Descriptive Statistics of Body Temperature (℃) Among Respondents.

Group	N	Mean (℃)	SD	Min (℃)	Max (℃)	Range (℃)	Frequency (%)
Exposed	165	37.2	0.4	36.4	38.0	1.6	50.0%
Control	165	36.8	0.3	36.2	37.5	1.3	50.0%
Total	330	37.0	0.4	36.2	38.0	1.8	100%

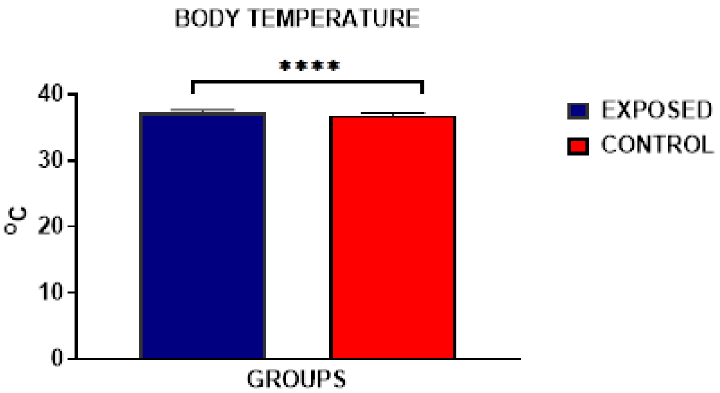

Figure 8. Comparison on body Temperature among Exposed and Control Group.

Statistical Interpretation The mean body temperature of exposed workers (37.2 ℃) is higher than that of the control group (36.8 ℃), with a statistically significant difference ($p < 0.05$), indicating a possible effect of fuel exposure on thermoregulation.

Table 16. Distribution of Physiological Symptoms (Present vs Absent) Among Respondents.

Symptom Category	Group	Present (n,%)	Absent (n,%)	Total (n)	Mean ±SD
Neurological Symptoms (headache, dizziness, fatigue)	Exposed	90 (54.5%)	75 (45.5%)	165	0.55 ±0.50
	Control	35 (21.2%)	130 (78.8%)	165	0.21 ±0.41
Skin Conditions (irritation, dermatitis, itching)	Exposed	70 (42.4%)	95 (57.6%)	165	0.42 ±0.49
	Control	25 (15.2%)	140 (84.8%)	165	0.15 ±0.36
Overall Symptoms	Exposed	120 (72.7%)	45 (27.3%)	165	0.73 ±0.45
	Control	55 (33.3%)	110 (66.7%)	165	0.33 ±0.47

Statistical interpretation: Table 16 presents the distribution of physiological symptoms among exposed and control groups using frequency, percentage, mean, and standard deviation. Similarly, neurological symptoms were reported by 90 (54.5%) of exposed workers compared to 35 (21.2%) in the control group. The mean score of 0.55 ±0.50 in the exposed group exceeds that of the control group (0.21 ±0.41), suggesting a greater burden of symptoms such as headache, dizziness, and fatigue among exposed individuals. For skin conditions, 70 (42.4%) of exposed workers reported symptoms compared to 25 (15.2%) in the control group. The mean value of 0.42 ± 0.49 for exposed workers is higher than 0.15 ±0.36 in the control group, indicating increased dermatological issues likely associated with occupational exposure. In terms of overall physiological symptoms, 120 (72.7%) of exposed workers reported at least one symptom compared to 55 (33.3%) in the control group. The mean score of 0.73 ±0.45 in the exposed group is substantially higher than 0.33 ±0.47 in the control group, reflecting a markedly higher overall symptom burden among exposed individuals.

3.3. Test of Hypotheses

This section presents the results of inferential statistical analysis used to test the stated hypotheses of the study. The hypotheses were examined using appropriate statistical tools, including the independent t-test for continuous variables and the chi-square test for categorical variables. The tests were conducted to determine whether significant differences or associations exist between fuel-exposed workers and the control group at a 0.05 level of significance.

$H0_1$: Fuel Exposure has no Significant Effect on Respiratory Symptoms Among Oil Company Workers.

Table 17. Chi-Square Analysis of Respiratory Symptoms.

Category	Exposed (O)	Control (O)	Expected (E)	O−E	$(O-E)^2$	$(O-E)^2/E$
Present	95	40	67.5	27.5	756.25	11.20
Absent	70	125	97.5	-27.5	756.25	7.76
Total	165	165				$\chi^2 = 42.67$

df = 1, p = 0.000
Decision: Reject H_0
Statistical Interpretation: Table 17 shows that 95 exposed workers reported respiratory symptoms compared to 40 respondents in the control group. The calculated chi-square value of 42.67 with a p-value of 0.000 is less than 0.05. Therefore, the null hypothesis is rejected. This indicates that fuel exposure has a significant effect on respiratory symptoms among oil company workers.

$H0_2$: Fuel Exposure Does Not Significantly Affect Cardiovascular Parameters.

Table 18. Independent t-test for Cardiovascular Parameters.

Parameter	Exposed Mean ± SD	Control Mean ± SD	Mean Difference	t-value	p-value
Systolic BP	136.5 ± 14.2	124.3 ± 11.8	12.2	8.21	0.000
Diastolic BP	88.7 ± 9.6	79.5 ± 8.4	9.2	8.05	0.000
Pulse Rate	84.2 ± 10.5	76.8 ± 8.9	7.4	6.73	0.000

Decision: Reject H_0
Statistical Interpretation: Table 18 shows that exposed workers had higher mean systolic blood pressure (136.5 ± 14.2 mmHg), diastolic blood pressure (88.7 ± 9.6 mmHg), and pulse rate (84.2 ± 10.5 bpm) compared to the control group. The p-values for systolic blood pressure, diastolic blood pressure, and pulse rate were all 0.000, which is less than 0.05. Therefore, the null hypothesis is rejected. This indicates that fuel exposure significantly affects cardiovascular parameters.

$H0_3$: There Is No Significant Association Btw Fuel Exposure and Neurological Symptoms.

Table 19. Chi-Square Analysis of Neurological Symptoms.

Category	Exposed (O)	Control (O)	Expected (E)	O−E	$(O-E)^2$	$(O-E)^2/E$
Present	90	35	62.5	27.5	756.25	12.10
Absent	75	130	102.5	-27.5	756.25	7.38
Total	165	165				$\chi^2 = 46.18$

df = 1, p = 0.000
Decision: Reject H_0
Statistical Interpretation: Table 19 shows that 90 exposed workers reported neurological symptoms compared to 35 respondents in the control group. The calculated chi-square value of 46.18 with a p-value of 0.000 is less than 0.05. Therefore, the null hypothesis is rejected. This indicates that there is a significant association between fuel exposure and neurological symptoms.

$H0_4$: Fuel Exposure Has No Significant Effect on Skin Conditions.

Table 20. Chi-Square Analysis of Skin Conditions.

Category	Exposed (O)	Control (O)	Expected (E)	O−E	$(O−E)^2$	$(O−E)^2/E$
Present	70	25	47.5	22.5	506.25	10.66
Absent	95	140	117.5	-22.5	506.25	4.31
Total	165	165				$\chi^2 = 32.54$

df = 1, p = 0.000
Decision: Reject H_0
Statistical Interpretation: Table 20 shows that 70 exposed workers reported skin conditions compared to 25 respondents in the control group. The chi-square value of 32.54 with a p-value of 0.000 is less than 0.05. Therefore, the null hypothesis is rejected. This indicates that fuel exposure has a significant effect on skin conditions.

$H0_5$: There Is No Significant Difference in Physiological Symptoms Between Exposed And Non-Exposed Individuals.

Table 21. Overall Physiological Symptoms (Chi-Square Analysis).

Category	Exposed (O)	Control (O)	Expected (E)	O−E	$(O−E)^2$	$(O−E)^2/E$
Present	120	55	87.5	32.5	1056.25	12.07
Absent	45	110	77.5	-32.5	1056.25	13.63
Total	165	165				$\chi^2 = 52.89$

df = 1, p = 0.000
Decision: Reject H_0
Statistical Interpretation: Table 21 shows that 120 exposed workers reported overall physiological symptoms compared to 55 respondents in the control group. The calculated chi-square value of 52.89 with a p-value of 0.000 is less than 0.05. Therefore, the null hypothesis is rejected. This indicates that there is a significant difference in physiological symptoms between exposed and non-exposed individuals.

4. Discussion

This chapter presents an in-depth discussion of the findings obtained from the study on the physiological effects of occupational fuel exposure among oil company workers compared with non-exposed academic staff in Delta State. The discussion is structured in line with the study objectives and hypotheses, with emphasis on interpreting the statistical outcomes and relating them to established scientific evidence.

The demographic characteristics presented in Tables 1-5 indicate that both the exposed and control groups were relatively comparable in terms of age distribution, gender composition, and years of occupational experience. This comparability is critical in epidemiological studies, as it minimizes confounding and strengthens the attribution of observed physiological differences to occupational exposure rather than demographic variability. The similarity between groups enhances the internal validity of the study and supports the reliability of subsequent comparisons.

The findings in Table 6 revealed a markedly higher prevalence of elevated blood pressure categories among exposed workers compared to the control group. Specifically, a substantial proportion of exposed individuals fell within pre-hypertensive and hypertensive classifications, whereas the majority of the control group remained within normal ranges. This pattern is strongly supported by the continuous data presented in Tables 7-12, where the mean systolic blood pressure among exposed workers (136.5 ± 14.2 mmHg) was significantly higher than that of the control group (124.3 ± 11.8 mmHg), with a corresponding statistically significant t-value ($t = 8.21$, $p < 0.05$). Similarly, diastolic blood pressure was elevated among exposed workers (88.7 ± 9.6 mmHg) compared to controls (79.5 ± 8.4 mmHg), with statistical significance ($t = 8.05$, $p < 0.05$). These findings suggest that chronic exposure to petroleum hydrocarbons may induce cardiovascular dysregulation, possibly through mechanisms involving oxidative stress, endothelial dysfunction, and autonomic imbalance. According to Krajnak et al. [16], inhalation of crude oil vapors has been associated with altered vascular reactivity and increased cardiovascular strain. Similarly, Ismail et al. [6] reported significant elevations in blood pressure indices among individuals exposed to petroleum-related pollutants, attributing these changes to inflammatory and oxidative processes. The implication of these findings is that prolonged occupational exposure may predispose workers to hypertension and associated cardiovascular complications, thereby increasing long-term morbidity risk.

The respiratory findings further reinforce the adverse impact of fuel exposure. As shown in Table 6, a considerable proportion of exposed workers exhibited reduced oxygen saturation levels compared to controls. This is corroborated by the mean SpO_2 values in Tables 11 and 12, where exposed individuals recorded significantly lower oxygen saturation (94.8 ± 2.1%) compared to the control group (97.1 ± 1.5%), with a highly significant difference ($t = -11.02$, $p < 0.05$). This reduction in oxygen saturation is indicative of compromised pulmonary gas exchange efficiency. From a physiological standpoint, the inhalation of volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylene, can lead to airway inflammation, alveolar damage, and impaired oxygen diffusion capacity. Fedan et al. [17] demonstrated that exposure to crude oil vapors results in pulmonary toxicity characterized by inflammation and reduced lung function. Furthermore, Lawrence et al. [22] reported persistent declines in lung function among oil-exposed workers even years after exposure, suggesting long-term respiratory impairment. These findings underscore the clinical significance of reduced oxygen saturation observed in this study and highlight the potential for chronic respiratory dysfunction among exposed populations.

The results presented in Tables 13 and 14 on peak expiratory flow rate (PEFR) provide additional evidence of respiratory compromise. A larger proportion of exposed workers demonstrated mild to severe reductions in PEFR compared to the control group. This is quantitatively supported by the significantly lower mean PEFR among exposed workers (410.6 ± 65.3 L/min) relative to controls (465.2 ± 58.7 L/min), with statistical significance ($t = -7.84$, $p < 0.05$) as shown in Table 6 Reduced PEFR is a well-established indicator of airway obstruction and diminished pulmonary function. This observation aligns with the findings of Amor-Carro et al. [18], who reported airway hyperresponsiveness and inflammatory changes following exposure to fuel-derived pollutants. Similarly, Chen et al. [19] identified significant reductions in lung function parameters among individuals exposed to petroleum-related particulate matter. The implication of these findings is that chronic inhalation of fuel vapors may progressively impair respiratory mechanics, leading to reduced ventilatory capacity and increased susceptibility to respiratory diseases.

The cardiovascular effects of exposure are further reflected in pulse rate findings presented in Table 15 and Table 6. Exposed workers exhibited a higher prevalence of elevated pulse rates and tachycardia, with a significantly higher mean pulse rate (84.2 ± 10.5 bpm) compared to the control group (76.8 ± 8.9 bpm), with statistical significance ($t = 6.73$, $p < 0.05$). Elevated pulse rate is indicative of increased sympathetic nervous system activity and cardiovascular stress. This finding is consistent with the work of Krajnak et al. [16], who reported that exposure to petroleum vapors can disrupt cardiovascular regulation and increase heart rate variability. The physiological implication is that sustained exposure may lead to chronic cardiovascular strain, which, when combined with elevated blood pressure, significantly increases the risk of cardiovascular disease.

The slight but statistically significant increase in body temperature among exposed workers (37.2 ± 0.4 ℃) compared to controls (36.8 ± 0.3 ℃), as shown in Table 16 ($t = 9.15$, $p < 0.05$), suggests the presence of low-grade systemic inflammation. Chronic exposure to toxic substances has been shown to activate inflammatory pathways, resulting in subtle elevations in body temperature. Sager et al. [20] reported that inhalation of crude oil vapors induces cytotoxicity and inflammatory responses, which may manifest as physiological alterations such as elevated body temperature. Although the difference appears minimal, it is physiologically relevant in the context of chronic exposure and systemic stress.

The hypothesis testing results provide further confirmation of these observations. Table 17 demonstrated a statistically significant association between fuel exposure and respiratory symptoms ($\chi^2 = 42.67$, $p < 0.05$), indicating that exposed workers are significantly more likely to experience respiratory disturbances. This finding is in agreement with Qafisheh et al. [23], who reported increased prevalence of respiratory symptoms among petroleum station workers.

Similarly, Table 18 confirmed that fuel exposure significantly affects cardiovascular parameters, as evidenced by significant differences in systolic and diastolic blood pressure as well as pulse rate ($p < 0.05$). This reinforces the earlier discussion on cardiovascular implications and supports existing evidence on the cardiotoxic effects of petroleum exposure [6].

The significant association between fuel exposure and neurological symptoms observed in Table 19 ($\chi^2 = 46.18$, $p < 0.05$) highlights the neurotoxic potential of hydrocarbons. According to Sriram et al. [24], exposure to crude oil vapors can alter neurotransmitter systems and neural protein expression, leading to symptoms such as headaches, dizziness, and cognitive impairment. This suggests that occupational exposure may have both acute and long-term neurological consequences.

Furthermore, Table 20 revealed a significant relationship between fuel exposure and skin conditions ($\chi^2 = 32.54$, $p < 0.05$), indicating that dermal exposure to petroleum products contributes to dermatological disorders. Chen et al. [25] reported similar findings, linking oil exposure to increased incidence of skin irritation and dermatitis among exposed workers. This underscores the importance of protective measures in minimizing direct skin contact with petroleum substances.

Finally, the overall analysis presented in Table 21 showed a highly significant difference in physiological symptoms between exposed and non-exposed individuals ($\chi^2 = 52.89$, $p < 0.05$). This comprehensive outcome reflects the multi-systemic impact of fuel exposure, affecting respiratory, cardiovascular, neurological, and integumentary systems. Takeshita et al. [26] emphasized that petroleum hydrocarbons exert widespread toxic effects across multiple organ systems, reinforcing the findings of this study.

The findings of this study provide strong and consistent evidence that occupational exposure to fuel significantly alters physiological functions and increases health risks among oil company workers. The alignment of these results with established literature further validates the observed associations and highlights the urgent need for improved occupational health policies, exposure control strategies, and regular health monitoring in petroleum-related work environments.

5. Conclusion

This study assessed the physiological effects of occupational fuel exposure among oil company workers in Delta State using a comparative approach involving exposed workers and non-exposed university staff. The findings clearly demonstrate that occupational exposure to fuel has significant adverse effects on several physiological parameters. Exposed workers were found to have higher blood pressure levels, increased pulse rates, lower oxygen saturation, and reduced peak expiratory flow rates compared to the control group. These findings indicate that chronic fuel exposure may impair cardiovascular and respiratory function. In addition, exposed workers reported higher prevalence of respiratory symptoms, neurological complaints, and skin conditions, suggesting that fuel exposure affects multiple body systems simultaneously. The hypothesis testing further confirmed that fuel exposure significantly affects respiratory symptoms, cardiovascular parameters, neurological symptoms, skin conditions, and overall physiological health. The consistency of these findings with previous studies suggests that prolonged exposure to petroleum products poses a serious occupational health risk. This study concludes that fuel exposure among oil company workers is associated with significant physiological alterations that may predispose workers to chronic health problems if adequate preventive measures are not implemented. There is therefore a need for urgent intervention to improve workplace safety, reduce exposure levels, and promote regular health monitoring among workers in the petroleum industry.

6. Recommendations

Based on the findings of this study, the following measures are recommended. Oil company workers should be mandated to use appropriate personal protective equipment consistently, particularly respiratory masks, gloves, and protective coveralls, to minimize dermal and inhalation exposure. Petroleum worksites should invest in engineering controls including improved ventilation systems, enclosed fuel handling areas, and vapor-capture technologies to reduce ambient petroleum vapor concentrations. Periodic occupational health screening encompassing blood pressure assessment, spirometry, oxygen saturation monitoring, and neurological symptom evaluation should be instituted as routine practice. Health education programs should inform workers of the specific physiological risks associated with petroleum exposure and the importance of protective behaviors. Government agencies and industry regulators should enforce existing occupational safety standards and develop Nigeria-specific exposure limits informed by local empirical evidence such as that presented here.

Operational Definition of Terms

Fuel Exposure: Contact with petroleum products such as petrol, diesel, or crude oil through inhalation or skin contact during occupational activities.

Oil Refinery Workers: Individuals employed in facilities where crude oil is processed and who are routinely exposed to petroleum substances.

Fuel Attendants: Workers at fuel stations responsible for dispensing petroleum products and exposed to fuel vapors during routine duties.

Academic Staff: Individuals working in educational institutions with no direct occupational exposure to petroleum products, serving as the control group.

Respiratory Symptoms: Observable or self-reported conditions such as cough, wheezing, shortness of breath, and chest discomfort associated with respiratory function.

Cardiovascular Parameters: Non-invasive physiological measurements such as blood pressure and heart rate used to assess cardiovascular status.

Neurological Symptoms: Self-reported conditions such as headache, dizziness, fatigue, and reduced concentration linked to nervous system function.

Dermatological Conditions: Skin-related issues such as irritation, rashes, or dermatitis resulting from contact with fuel or its vapors.

Occupational Exposure: Exposure to potentially harmful substances or conditions as a result of one's job or work environment.

Control Group: A group of individuals not exposed to the factor under investigation, used for comparison.

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Author Contributions

Ogbutor Udoji Godsday: Supervision, Validation, Writing – original draft, Resources, Software, Visualization

Ndubuishi Ifechukwudeni Christabel: Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization

Nwose Jephtah Junior: Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Software, Resources, Data curation

Anastacia Okwudili Ojimba: Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Data curation

Isaac Precious: Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Data curation

Erumi Blessing Selly-U: Data curation, Validation, Resources, Formal analysis

Ogbutor Emeke Godson: Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft

Conflicts of Interest

The authors declare no conflicts of interest.

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