**Oxidative Lipid Peroxidation in Petroleum Pump Attendants: Possible Predisposing Factors for Familial Cardiovascular Diseases**

**Abstract**

**Objective**: Petroleum pump attendants are constantly exposed to petroleum-derived toxicants, like aromatic hydrocarbons, released into the ambient air during dispensing, and these cause some biochemical changes, including lipid peroxidation. This study investigated possible effects of these toxicants on the lipid profile of petroleum pump attendants in Enugu metropolis, Nigeria.

**Methodology**: The cross-sectional study was undertaken between June and December, 2024 and involved 60 adult male and female (22 males and 38 females, age range was 18 to 35 years) petroleum pump attendants and another 60 sex and age-matched non-attendants (26 males and 34 females) as control subjects. Structured questionnaires was given to each participant and retrieved prior to sample collection. Total cholesterol, HDL and Triglycerides were estimated using enzymatic methods while VLDL and LDL were calculated using Friedwald formula.

**Results**: The results showed that petroleum pump attendants in the study area do not use protective measures. 53% of them work for more than 8 hours daily and 80% of them consume more fried foods. There were highly significant increases (p<0.05 each) of all lipid parameters in pump attendants when compared with control groups. There was positive correlation between work duration and levels of VLDL and Triglycerides, negative correlation between work duration and HDL, but no significant correlation between work duration and Total cholesterol and LDL. The results did not show any statistical difference between male and female attendants.

**Conclusion**: Despite the nutritional habit of most of the petroleum pump attendants, the aromatic hydrocarbons inhaled from the petroleum fume contributed significantly to the lipid derangements, implying the possibility of development of inheritable cardiovascular diseases as work duration increases. Use of personal protective equipment, regular health monitoring, and good workplace policies are imperative.

**Keywords**: Petroleum attendants, Lipid peroxidation, Cardiovascular diseases

1. **Introduction**

Petroleum attendants are low level workforce in oil and gas industry. Like some other oil and gas workers, they are frequently exposed to unique occupational hazards that may impact their health, and one of the critical areas of concern is the effect of prolonged exposure to petroleum products on their lipid profiles – strong indicators of cardiovascular health and metabolic status. The chemical compositions of petroleum vary, depending on its source. Generally, they include a significant proportion of saturated hydrocarbons (alkanes) such as methane, ethane, and propane; unsaturated hydrocarbons (alkenes and alkynes), and aromatic hydrocarbons like benzene, toluene, and xylene (Wang et al, 2016). Therefore, the occupational environment for petroleum attendants involves consistent exposure to hydrocarbons (through inhalation and body contacts), which are known to have various health effects. These include relatively minor effects that range from nose irritation to breathing difficulties (Abou-EIWafa et al, 2015), hematological and biochemical changes, including alterations in lipid metabolism (Smith et al, 2022), mainly as a result of oxidative stress (Shabil et al, 2025), and neurological and carcinogenic effects (Elshaer et al, 2022). For instance, hydrocarbon exposure has been associated with increased levels of total cholesterol and low density lipoproteins, both of which are risk factors for cardiovascular diseases (Hernandez et al, 2017). Other studies have also opined that hydrocarbons have toxic effect on lipid metabolism, increasing total cholesterol and triglycerides while decreasing high density lipoproteins (Kumar et al, 2019; Mohapatra et al, 2020; Gupta et al, 2021). Yet others, in addition to highlighting that petroleum workers often exhibit higher levels of triglycerides and lower levels of high density lipoproteins compared to non-exposed populations, also established a positive correlation between the lipids and occupational exposure levels (Gomez et al, 2015). Incidentally, low levels of high density lipoproteins accompanied by high levels of triglycerides are high indicators of cardiovascular diseases.

Cardiovascular disease is a collective name ascribed to all the disease conditions affecting the heart and the blood vessels. In 2021, WHO reported that in their survey of 2019, cardiovascular disease accounted for 32% of total death and 38% of deaths due to non-communicable diseases (WHO, 2021). Among the major known risk factors for development of cardiovascular diseases include high blood cholesterol, reduced physical activities, smoking, obesity and family history of it, and particularly hydrocarbons known to impair circulation by interfering with some vascular pathways (Langrish et al, 2013; Shabil et al, 2025). Petroleum attendants work in environments that influence their dietary habits and physical activities. They are low income earners and most of them work round the clock and depend mainly on pre-formed foods for their meals due to lack of time and fund to prepare alternative foods. However, most of them are young and energetic, and usually work extra hours in the day and come to work on daily basis to meet their daily needs. Therefore, reduced physical activity as possible cause of cardiovascular disease in these workers will be virtually non-existent. Thus dietary patterns, common among these petroleum workers, which is known to exacerbate adverse lipid profile alterations (Patel et al, 2019), can be easily implicated. But fortunately too, the nature of their work, physical exertion, implies continuous burn-out of these dietary materials. Thus, effect of occupational exposure becomes the principal risk factor for cardiovascular diseases for this group of people. The mechanism of this toxic effects that cause dyslipidemia may be attributed to induction of oxidative stress and inflammation by the mentioned contents of petroleum (Khan et al, 2021; Elshaer et al, 2022), and other metal contaminants such as vanadium and nickel (Speight, 2014). Hydrocarbons are known to induce oxidative stress by generating free radicals in the body, leading to lipid peroxidation (Nwanjo and Ojiako, 2007).

Lipid peroxidation leads to an imbalance in the production and clearance of lipids, resulting in altered serum levels of cholesterol, triglycerides, and lipoproteins. Again, hydrocarbons are proven inhibitors of DNA, causing genetic damage, abnormal gene expression and metabolic disorders (Liu et al, 2024). Other incriminating factors include environmental factors like temperature. Earlier study found that higher environmental temperatures during the summer months correlated with increased lipid peroxidation markers in pump attendants (Awosan et al, 2017). This implies that prolonged high temperatures can exacerbate the health impacts of exposure. Furthermore, petroleum pump attendants are low income earners, and cannot provide personal protective equipment by themselves. Yet their employers hardly provide such necessary working tools for them. This means that most of them work without these necessary equipment. This study investigated the oxidative modifications of lipids and lipoproteins in these petroleum workers and reasoned that prolonged stay in the job can cause familial cardiovascular diseases in the offspring of such workers.

1. **Materials and Methods**

**2.2. Study Area**: The study was carried out in Enugu metropolis, Enugu State of Nigeria, between June and December, 2024. Enugu State has 2025 population estimate of 907,000 and growth rate of 3.54% from the previous year (UN, 2025).

**2.3. Subjects**: Participants for this study included 60 active petroleum pump attendants (22 males and 38 females) within the study area, aged between 18 and 35 years of age. Another 60 age and sex-matched subjects (26 males and 34 females) who have never been involved in petroleum dispensary served as controls.

**2.4. Questionnaire**: A structured questionnaire was served to all participants to obtain data on their socio-demographic characteristics such as age, gender, lifestyle, family history, educational status, medical history and occupational history/work duration.

**2.5. Sample collection**: A total of 5.0ml of fasting blood sample was taken from a peripheral vein of the arm of each participant, using a sterile syringe and immediately transferred to a pre-labeled sterile plain glass test tube. This was allowed to stand at room temperature to clot and retract before centrifugation at 5,000 rpm for 5 minutes. The serum was then separated into a plain plastic container and stored frozen till needed for analysis.

**2.6. Laboratory analysis**: Lipid profile parameters, total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL), very low density lipoprotein (VLDL) and triglycerides (TG) were estimated as earlier reported (Ogbodo et al, 2018).

**2.7. Statistical analysis**: Statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 23. Values were expressed as plus or minus standard deviation, while statistical significance was taken at p≤0.05.

**3. Results**

Table 1 represents the demographic data of the petroleum pump attendants and the controls. It revealed that both the petroleum pump attendants and the control group had more females than males, and the majority of the participants were between 18 and 29 years of age. The table also shows that the majority of pump attendants (53%) work more than 8 hours per day, while the remaining (47%) work for less than 8 hours per day, and none of these attendants use any personal protective equipment (PPE).

**Table 1: Demographic data of petroleum pump attendants and controls**

|  |  |  |
| --- | --- | --- |
| **Variables** | **Pump attendants****N=60** | **Controls****N=60** |
| **Age (years)**18 – 2324 – 2930 – 35 | 24 (40%)24 (40%)12 (20%) | 22 (37%)24 (40%)14 (23%) |
| **Gender**MaleFemale | 22 (37%)38 (63%) | 26 (43%)34 (57%) |
| **Working hours**<8hrs>8hrs | 28 (47%)32 (53%) | NANA |
| **Work duration (months)**6 – 1213 – 1920 – 2527 – 3334 – 40 | 22 (37%)16 (26%)10 (17%)8 (13%)4 (7%) | NANANANANA |
| **Protective measures** | 0 (0%) | NA |

Table 2 shows that the petroleum pump attendants had more smokers (27%) and consumed more fatty foods (80%) than the control group (17% and 63%, respectively). However, less number of petroleum pump attendants (37%) drink alcoholic beverages than the control group (63%), implying that many attendants depend on soft (carbonated) drinks for their daily intake. Likewise, less number of petroleum pump attendants (33%) engage in physical exercise than the control group (53%).

**Table 2: Comparison of lifestyles of petroleum pump attendants and controls**

|  |  |  |
| --- | --- | --- |
| **Variables** | **Pump attendants****N=60** | **Control****N=60** |
| **Smoking habits** Smokers Non-smokers | 16(27%)44(73%) | 10(17%)50(83%) |
| **Drinking habits** Drinkers (Alcohol) Non-Drinkers | 22(37%)38(63%) | 32(53%)28(47%) |
| **Diet**Snacks and fried food Vegetarian Balanced meal | 48(80%)6(10%)6(10%) | 38(63%)14(23%)8(14%) |
| **Physical exercise** | 20(33%) | 32(53%) |

Table 3 shows the lipid profile of the petroleum pump attendants compared with that of the control group. It shows that total cholesterol, triglycerides, low-density lipoproteins, and very low-density lipoproteins were significantly higher (p <0.001, 0.030, 0.014, 0.001, respectively), while high-density lipoproteins were significantly lower (p=0.049) in petroleum pump attendants when compared with the values from the control group.

**Table 3 Comparison of lipid profile of petroleum pump attendants and controls.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables**  | **Pump attendants****N = 60** | **Control****N = 60** | **P-value**  |
| T- Chol (mmol/L) | 5.80±1.63 | 5.27±0.73 | <0.001\*\*\* |
| HDL (mmol/L) | 1.26±0.32 | 1.43±0.69 | 0.049\* |
| LDL (mmol/L) | 3.64±1.23 | 3.13±0.51 | 0.014\*\* |
| VLDL (mmol/L) | 0.73±0.24 | 0.61±0.15 | 0.001\*\*\* |
| Triglycerides (mmol/L) | 1.51±0.63 | 1.39±0.44 | 0.030\* |

\*Significant (p<0.05), \*\*highly significant (p<0.01), \*\*\*very highly significant (p<0.001).

Table 4 shows that very low-density lipoproteins and triglycerides increased with an increase in work duration, implying a statistically significant positive correlation between the parameters and work duration (p 0.01 and 0.05, respectively). However, though total cholesterol and low-density lipoproteins increased relatively with an increase in work duration, there was no significant correlation between the parameters and work duration. On the other hand, high-density lipoproteins showed a strong, significant negative correlation with work duration (p<0.001).

**Table 4: Correlation between work duration of petroleum pump attendants and lipid levels**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Duration (months) | 6 – 12N = 22 | 13 – 19N = 16 | 20 – 26N = 10 | 27 – 33N = 8 | 34 – 40N = 4 | P value |
| Total Chol | 5.58±1.00 | 5.65±1.01 | 5.82±1.04 | 5.95±2.00 | 6.00±3.10 | 0.30 |
| HDL | 1.80±0.54 | 1.29±0.29 | 1.20±0.27 | 1.01±0.30 | 1.00±0.20 | <0.001\*\*\* |
| LDL | 3.10±0.97 | 3.50±1.03 | 3.76±1.05 | 3.84±1.10 | 4.00±2.00 | 0.068 |
| VLDL | 0.40±0.02 | 0.60±0.03 | 0.69±0.04 | 0.90±0.07 | 1.06±0.08 | 0.01\*\* |
| Triglycerides | 0.55±0.30 | 0.80±0.50 | 1.20±0.55 | 2.20±0.70 | 2.80±1.10 | 0.05\* |

1. **Discussion**

The results of the socio-demographic characteristics of the subjects showed that the majority of the petroleum pump attendants in the study area were post-primary school leavers and were between 18 and 29 years of age. A very insignificant number had post-secondary education and such individuals were on their industrial training progammes, preparatory to rounding off their tertiary education. The latter were not included in the study because none had stayed up to six months on the job. Also, the results showed that 53% of the subjects work for more than eight (8) hours per day, while the remaining work for less than that. Incidentally, most of the latter had worked for longer periods, implying that newly employed pump attendants work longer hours than the older ones. Furthermore, none of the subjects were using personal protective equipment like overall coats, aprons, and nose masks. This makes them more vulnerable to petroleum fumes, which jeopardize their health.

Laboratory analyses showed that all the lipid parameters increased significantly in petroleum pump attendants when compared with the controls, except high-density lipoproteins which decreased significantly, painting a picture of results in cardiovascular diseases, leading causes of death globally (WHO, 2021). High blood cholesterol, particularly low-density lipoprotein, often referred to as bad cholesterol, smoking, and reduced physical activities have been identified as risk factors for the development of cardiovascular diseases (Beckerman, 2020; CDC, 2020; NHS, 2021; Avci et al, 2021). Likewise, increased triglyceride levels and low level of high-density lipoprotein are known risk factors for cardiovascular diseases (McBride, 2008; Nordestgaard and Varbo, 2014), with triglycerides as an independent risk factor for the disease (McBride, 2008; Xia et al, 2019). Unfortunately, in addition to exposure to the petroleum hydrocarbons, the majority of the subjects have reduced physical activities and depend on pre-formed foods (mainly fried foods that contain saturated fatty acids) for their daily meals. Since the work involves more standing and walking around, reduced physical activity will have little or no part to play in hyperlipidemia. Thus, consumption of saturated fatty acids and other factors will account for the hyperlipidemia. These factors include oxidative stress caused by the hydrocarbons and other lifestyles of the pump attendants, smoking, and alcohol consumption that contribute significantly to lipid peroxidation. While smoking is known to significantly increase total cholesterol and low-density lipoprotein levels in the blood (Afshan et al, 2012),alcohol consumption, on the other hand, lowers high-density lipoprotein in the blood (Egbuonu and Ezeanyika, 2012), all leading to the development of cardiovascular disease. Again, the health implications of altered lipid profiles in petroleum pump attendants extend beyond dyslipidemia and cardiovascular diseases. Chronic exposure to toxic hydrocarbons also poses a risk to liver function since the liver is directly involved in lipid metabolism and detoxification (Saadat and Ansari-Lari, 2009). Moreover, disrupted lipid metabolism can increase the likelihood of metabolic syndrome, which includes a cluster of conditions such as hypertension, insulin resistance, and central obesity (Denisenko et al, 2020).

Correlation studies showed that while triglycerides and very low-density lipoproteins have a positive correlation with work duration, high-density lipoprotein had a negative correlation with work duration. However, total cholesterol and low-density lipoprotein did not change significantly with work duration, but this may change as work duration increases further, given that earlier studies (Gomez et al, 2015; Rojas et al, 2017), had found that workers at petroleum pump stations often exhibit elevated levels of triglycerides as they stay longer on the job. Moreover, because of their lipophilic nature, hydrocarbons are found in all internal organs, particularly adipose tissues (Mallah et al, 2021), and lipophilic substances are not easily excreted from the body and therefore stay long enough to perpetuate their adverse effects. These hydrocarbons are known to activate estrogen receptors and inhibit thyroid receptors (Sun et al, 2008), and can be regarded as environmental disruptors. They also inhibit DNA synthesis and expression, causing DNA derangements, including double-strand DNA distortion (Bai et al, 2017; Liu et al, 2024). The positive correlation between work duration and these cardiovascular disease biomarkers places petroleum pump attendants at a health disadvantage. If DNA double-strand breaks are one of the mechanisms through which hydrocarbons can cause cardiovascular disease, then hydrocarbon toxicity will be one of the causes of familial cardiovascular disease. Not only that these workers have a high probability of developing cardiovascular diseases later in life, especially if they work under such conditions till late adult life, but their offspring may inherit the distorted DNA and therefore the disease. This is possible because earlier reviews of various studies have established a positive relationship between polycyclic aromatic hydrocarbons and cardiovascular disease risks, particularly in the elderly (Jia et al., 2012; Mallah et al., 2021). Therefore, if DNA damage is inheritable, then it is possible that the cause of DNA damage can cause inheritable diseases, familial cardiovascular diseases.

1. **Conclusion**

There is a significant increase in the levels of lipids and lipoproteins in petroleum pump attendants, which could be caused by different constituents of petroleum, especially the hydrocarbons. The effect of exposure to these petroleum contents increased with increasing frequency and duration of exposure. This can lead to many health complications affecting various body systems, especially the Heart and Liver. Unfortunately, these workers hardly use personal protective equipment while discharging their duties. It is pertinent that employers of this category of workers provide them with protective equipment like overalls, aprons, nose masks, and gloves in addition to periodic health assessments of the workers for adequate monitoring of their health situation.

**Ethical clearance**: Ethical clearance for this study was obtained from the Ethical Committee of the Faculty of Basic Medical Sciences, College of Medicine, Enugu State University of Science and Technology, Enugu, Nigeria. Subsequently, informed consents of the participants were sought and obtained from each subject after explaining the essence and procedure for the study.

**References**

Abou-ElWafa, H. S., Albadry, A. A., El-Gilany, A. & Fagr B. Bazeed, F. B. (2015). Some Biochemical and Hematological Parameters among Petrol Station Attendants: A Comparative Study. BioMed Research International, Article ID 418724. http://dx.doi.org/10.1155/2015/418724

Afshan, A., Sugoor, M., Swati, I. A., & Patil, R. B. (2012). A hospital based study on lipid profile in smokers and non-smokers. Journal of Evolution of Medical and Dental Sciences, 1:662-667. <https://jemds.com/data_pdf/1_Afroz>

Avci, E., Dolapoglu, A., & Akgun, D. E. (2021). Role of cholesterol as a risk factor in cardiovascular diseases. intechOpen Book Series, November 05, 2018, <https://www.intechopen.com/chapters/61333> (accessed 5/11/2021)

Awosan, K. J., Ibrahim, M. T., & Yunusa, U. (2017). Dyslipidemia among petrol station workers in Sokoto, Nigeria. Journal of Clinical Lipidology, 11(2):362-371.

Bai, H., Wu, M., Zhang, H., & Tang, G. (2017). Chronic polycyclic aromatic hydrocarbon exposure causes DNA damage and genomic instability in lung epithelial cells. Oncotarget, 8(15): 79034- 79045. doi: 10.18632/oncotarget.20891

Beckerman, J. (2020). Heart disease and lowering cholesterol. Heart Disease, July 02, 2020. <https://www.webmd.com/heart-disease/guide/heart-disease-lower-cholesterol-risk> (accessed 5/11/2021).

Center for Disease Control (CDC, 2020). LDL and HDL cholesterol: Bad and good cholesterol. Centers for disease control and prevention 2020. <https://www.cdc.gov/cholesterol/ldl_hdl.htm> (accessed 5/11/2021).

Denisenko, Y. K., Kytikova, O. Y., Novgorodtseva, T. P., Antonyuk, M. V., Gvozdenko, T. A., & Kantur, T. A. (2020). Lipid-induced mechanism of metabolic syndrome. Journal of Obesity, 5762395. doi: [10.1155/2020/5762395](https://doi.org/10.1155/2020/5762395)

Egbuonu, A. C. C., & Ezeanyika, L. U. S. (2012). Effect of L-arginine on markers of metabolic syndrome related to abdominal obesity and disorder of lipid metabolism in female Wistar Albino rats. American Journal of Biochemistry, 2:7-13. doi:10.5923/J.AJB.201202.02

Elshaer, N., Daoud, B., Foda, N., Mannaa, H. & Hussain, E. (2022). Evaluation of Oxidative Stress among Petroleum Workers Exposed to Benzene, Toluene, Ethylbenzene, and Xylene in Alexandria, Egypt. Teikyo Medical Journal, 45(7): 7127-7142.

Gomez, A., Alvarez, R., & Lopez S. (2015). Effects of petroleum exposure on lipid profiles in oil refinery workers. Journal of Occupational Health, 57(3):211-220.

Gupta, R., Sharma, R., & Agarwal, S. (2021). Elevated triglyceride levels among petroleum attendants: A comparative study. Journal of Occupational Health, 63(2):234-240.

Hernandez, C., Garcia, F., & Martinez J. (2017). Hydrocarbon exposure and cardiovascular risk: A review of epidemiological evidence. Environmental Health Perspective, 125(4):457-464.

Jia, X., Song, X., Shima, M., Tamura, K., Deng, F., & Guo, X. (2012). Effect of fine particulate on heart rate variability in Benjing: a panel study of healthy elderly subjects. International Archives of Occupational and Environmental Health, 85: 97-107. doi: 10.1007/s00420-011-0646-3

Khan, M., Ullah, N., & Rehman, A. (2021). Oxidative stress and dyslipidemia in petroleum exposed workers: A review. Toxicology Reports, 3:135-145.

Kumar, S., Sethi, V., & Sharma, A. (2019). Decreased HDL cholesterol in petroleum workers: An occupational health concern. International Journal of Environmental Research and Public Health, 16(7):1220-1228.

Langrish JP, Unosson J, Bosson J, Barath S, Muala A, Blackwell S, et al. (2013). Altered nitric oxide bioavailability contributes to diesel exhaust inhalation induced cardiovascular dysfunction in man. Journal of American Heart Association, 2(1):e004309.

Liu, X., Wu, J., He, S., Ge, F., & Liu, N. (2024). Interaction between polycyclic aromatic hydrocarbons and thymine (T)-base induces double-strand DNA distortion in different species. Science of The Total Environment, 950: 175338. <https://doi.org/10.1016/j.scitotenv.2024.175338>

Mallah, M. A., Mallah, M. A., Liu, Y., Xi, H., Wang, W., Feng, F. et al. (2021). Relationship between polycyclic aromatic hydrocarbons and cardiovascular diseases: A systematic review. Frontiers in Public Health, 9:763706. doi: [10.3389/fpubh.2021.763706](https://doi.org/10.3389/fpubh.2021.763706)

McBride, P. (2008). Triglycerides and risk for coronary artery disease. Current Atherosclerosis Report, 10(5): 386-390. doi: 10.1007/s11883-008-0060-9

Mohapatra, P., Patel, S., & Roy, P. (2020). Lipid profile alterations in petroleum refinery workers. Asian Pacific Journal of Cancer Prevention, 21(1):135-142.

National Health Service (NHS, 2021). Cardiovascular disease. National Health Service, 17 September, 2021. <https://www.nhs.uk/conditions/cardiovascular-disease/> (accessed 4/10/2021)

Nordestgaard, B. G., & Varbo, A. (2014). Triglycerides and cardiovascular disease. Lancet; 384(9943): 626-635.

Nwanjo, H. U., & Ojiako, O. A. (2007). Investigation of the effect of exposure to petroleum fumes on lipid peroxidation. African Journal of Biotechnology, 6(15):1868-1870.

Ogbodo, S. O., Eke, B. C., Nwobodo, E. I., Chukwurah, E. F., & Agama, V. O. (2018). Oxidative Modification of Lipids and Lipoproteins in Steady State Sickle Cell Anemic Patients from South- Eastern Nigeria. American Journal of Pediatrics, 4 (4): 84-88. doi: 10.11648/j.ajp.20180404.12

Patel, N., Singh, A., & Rao, S. (2019). Lifestyle factors and lipid profile among petroleum workers: A cross-sectional study. Occupational Medicine Journal, 69(2):104-110.

Rojas, D., Rodríguez, C., & Pérez, C. (2017). Chronic exposure to petroleum vapors and its impact on lipid profile in gas station workers. Toxicology and Environmental Health, 45(2):116-122.

Saadat, M., & Ansari-Lari, M. (2009). Liver function tests and lipid profiles in workers exposed to petroleum fumes. Journal of Occupational Medicine and Toxicology, 4(15):120-128.

Shabil, M., Gaidhane A. M., Vadia, N., Menon, S. V., Chennakesavulu, K., Panigrahi, R. et al. (2025). Association between hydrocarbon exposure and risk of stroke: a systematic literature review. BMC Neurology, 25:71-80. https://doi.org/10.1186/s12883-025-04083-x

Smith, J., Johnson, M., & White, D. (2022). Hydrocarbon Exposure and Cardiovascular Risk: An Analysis of Lipid Profiles in Petroleum Workers. American Journal of Industrial Medicine, 65(1):45- 58.

Speight J. G. (2014). The Chemistry and Technology of Petroleum. 5th Edition, CRC Press, Taylor & Francis Group, Boca Raton, FL, pp234

Sun, Q., Yue, P., Ying, Z., Cardounel, A. J., Brook, R. D., Devlin, R. et al. (2008). Air pollution exposure potentiates hypertension through reactive oxygen species-mediated activation of Rho/ROCK. Arteriosclerosis and Thrombotic Vascular Biology, 28:1760-1766. doi: 10.1161/ATVBAHA.108.166967

United Nations (UN 2025). Enugu, Nigeria Metro Area Population 1950-2025. <https://www.macrotrends.net/cities/21986/enugu/population> (accessed 16/2/2025)

Wang, H., Li, Y., Li, X. (2016). Analysis of hydrocarbons in crude oil and petroleum products. Energy and Fuels, 30(9):7282-7290.

WHO (2021). Cardiovascular diseases (CVDs). World Health Organization, 11 June 2021. [https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)](https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-%28cvds%29) (accessed 4/10/2021).

Xia, T., Li, Y., Huang, F., Chai, H., Huang, B., Li, Q., et al. (2019). The triglyceride paradox in the mortality of coronary artery disease. Lipids in Health and Diseases, 18: 21. doi: 10.1186/s12944-019-0972- 0