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Original article

Blood Lead Levels among Gas Station Employees in Al Ajaylat City, Libya

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Abstract
A cross-sectional study was conducted in the city of Al Ajaylat, Libya, between June and August 2025. 30 randomly selected individuals from four fuel stations were selected among six fuel stations in the center of Al Ajaylat city. They provided verbal consent to give blood samples and complete a questionnaire designed to collect information on past and current medical records, including age, work duration, cigarette smoking, disease history, and total exposure time to lead. The first group (Case) was the study group, consisting of 15 fuel station workers randomly selected from those directly engaged in activities involving lead or gasoline exposure. The second group (Control) was the control group, consisting of 15 fuel station workers selected randomly from those who do not engage in activities involving lead. Their average weekly working hours were 12, and most had worked for at least six months. Blood samples were collected for analysis, and general characteristics of participants were assessed through interviews using the questionnaire. Exclusion criteria included participants unwilling to join the study, those younger than 15 or older than 65 years, and individuals reporting chronic diseases. Results indicate that every sample from the study group and every sample from the control group was reported as "<LOD". As no measurable blood lead concentration data were obtained, statistical comparisons were not performed. The evaluation was therefore restricted to detection frequency, which was uniformly 0% across both groups. This finding suggests that no differences were observed between the fuel station workers study group (Case) and controls with respect to detectable blood lead levels, suggesting the absence of any measurable increase in exposure among the occupational group. The analysis showed that all blood samples in both groups were below the detection limit (1.0 μg/dL).
Keywords. Blood Lead Concentrations, Fuel Station Workers, Al Ajaylat, Libya.

Introduction

Fuel station workers experience substantial occupational exposure to high concentrations of lead [1,2] primarily due to the presence of tetraethyl lead (TEL, $(CH_3CH_2)_4Pb$) in gasoline [3]. Fuel blended with tetraethyl lead (TEL), introduced in the 1920s. Tetraethyl lead is used as an antiknock agent [4], which is a fuel additive that minimizes engine knocking while enhancing the fuel's octane rating [4]. Commercial gasoline is rated by the octane numbers; the higher the octane number, the better the anti-knock ability of the gasoline [5]. Benzene is a clear yellow liquid, marked by its recognizable aromatic odor. Its pronounced volatility and affinity for lipids render it readily absorbed through inhalation and dermal contact. Lead exposure occurs during vehicle refueling, through automobile emissions, and via secondary contact with contaminated hands, food, water, and clothing [1].

Lead can enter the body primarily through inhalation of vapors, ingestion, or dermal contact [6]. Lead binds to blood cells and forms chemical complexes with hemoglobin [7]. Lead exposure is associated with coronary heart disease, stroke, and peripheral arterial disease [8, 9, 10, and 11]. Long-term exposure increases the risk of leukemia and aplastic anemia in humans, even at low doses. Although the use of leaded gasoline has been banned in most countries worldwide, including the United States and the European Union, it continues to be used in many Middle Eastern countries such as Algeria, Iraq and Yemen [12]. Consequently, fuel station workers are regularly exposed to leaded gasoline [13]. In Libya, the standard gasoline available at fuel stations primarily has an octane rating of RON 95. On April 25, 2003, Al-Brega Company, one of the subsidiaries of the National Oil Corporation in Libya, announced the introduction and design of unleaded 95-octane gasoline at all service stations across all regions in Libya. Blood testing is the most reliable method for measuring lead levels in the body.

Acceptable and permissible levels vary by country. For example, the U.S. Occupational Safety and Health Administration (OSHA) considers blood lead levels of 5 μg/dL or higher in adults to be elevated and requiring intervention. OSHA also sets the permissible exposure limit in air at 50 $\mu g/m^3$ in workplace air, expressed as an eight-hour time-weighted average. The harmful effects of benzene on workers' health were demonstrated by Choi et al. [14], who reported that workers exposed to petrochemical substances may develop diseases affecting the lungs, skin, and other organs, with severity depending on exposure duration. Kadhum et al. [15] reported that the mean blood lead level (BLL) among gasoline station workers was 1.92 ± 1.54 μg/dL. In comparison, the control group had a mean BLL of 1.63 ± 0.04 μg/dL, with no significant difference ($P = 0.238$). Although the study did not provide a specific percentage of detectable lead in workers' blood, it highlighted a correlation between age and BLL among workers. In contrast, in Basrah, Iraq, Al-Rudainy [13] reported that blood lead concentrations in fuel station workers ranged from 7.5–56 and is correlated with exposure duration; many exceeded WHO's 40 μg/dL occupational limit. In Nigeria, a two-phase scientific study [16] showed that occupationally exposed fuel station workers had high blood lead concentrations, with over 95% exceeding 40 μg/dL and nearly 70% surpassing 55 μg/dL.

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Recent studies have consistently associated chronic lead exposure with a spectrum of adverse health outcomes. Recently, Susiani and Lestari [17] indicated that occupationally exposed workers generally exhibited blood lead levels within the normal range, with a mean concentration of 2.83 µg/dL (range: 1.6–5.7 µg/dL). The highest level (5.7 µg/dL) was observed in a worker who smoked and consumed coffee, which may have contributed to the elevated value. Monitoring the health of fuel station workers chronically and directly exposed to benzene is therefore an important preventive measure against occupational diseases. The primary objective of this study is to measure blood lead concentrations among fuel station workers in Al Ajaylat city. A secondary objective is to compare these results with global permissible limits.

Materials and methods

Study Area

The study was conducted from June 2025 to the end of August 2025 at Al Ajaylat city, Western Region, Libya. Al Ajaylat is located 80 km northwest of Tripoli, the capital city of Libya. It lies at approximately 32° 45' N latitude and 12° 22' E longitude with a low elevation of about 19 meters above sea level. Al Ajaylat has an annual average ambient temperature of about 20.4 °C, with hot summers reaching 34 °C in August and mild winters averaging 12–13 °C in January. Al Ajaylat has an annual average rainfall of about 195 mm, making it one of the drier Mediterranean coastal cities, with mean annual relative humidity standing at 58–60% with some seasonal variation.

Study participants

A Comparative cross-sectional analysis was carried out on 30 randomly selected individuals who work in four fuel stations selected randomly among six fuel stations in the center of Al Ajaylat city. Their average weekly working hours were 12 hours, and most workers had worked for at least 6 months. They provided verbal consent to give blood samples and complete a questionnaire designed to collect information on past and current medical records, including age, work duration, cigarette smoking, disease history, and total exposure time to lead. The first group (Case), consisting of 15 fuel station workers randomly selected from those directly engaged in activities involving lead or gasoline exposure. The second group (Control) consisted of 15 fuel station workers selected randomly from those who do not engage in activities involving lead. Exclusion criteria included subjects with hepatitis B or C, cirrhosis, diabetes mellitus, and malignancy. The questionnaire was used to support the exclusion criteria. All participants in this study filled out a consent form. All participants were given a clear explanation regarding the methodology of the research.

Chemicals Used

High-purity chemicals were utilized throughout this study, including nitric acid with a concentration of 65%, hydrochloric acid with a concentration of 38%, and hydrogen peroxide with a concentration of 30%, all manufactured by LABBOX – Spain. In addition, deionized distilled water was also used.

Instruments

Lead concentrations in blood samples were measured using the Atomic Absorption Spectrophotometer (AAS) method, which offers a detection limit of 1.0 µg/dL.

Sample collection and examination

A 3 mL venous blood sample was obtained following skin disinfection with 70% alcohol. Samples were collected in sodium heparin-treated Vacutainer tubes specifically prepared for trace element analysis (Cañas, 2010). Lead concentrations in blood samples were determined by the AAS method. To minimize contamination, blood was collected in metal-free tubes. Each sample was subsequently treated with 3 mL nitric acid, 1 mL hydrochloric acid, and 2 mL hydrogen peroxide, followed by thermal digestion until a clear solution was achieved. The digested samples were diluted to a known volume with distilled water before analysis. Diluted aliquots were introduced into the spectrophotometer via aspiration, and absorbance was measured at 217 nm. To ensure analytical accuracy, all measurements were performed in triplicate.

Statistical analysis

All laboratory blood samples were analyzed for lead and came back with values below the detection threshold of 1.0 µg/dL. The dataset was subjected to rigorous quality control, including strict criteria for participant selection, standardized procedures for sample preparation, and triplicate measurements to ensure reliability. On this basis, the data were considered fully validated. As no measurable blood lead concentrations were detected, quantitative analysis could not be carried out. Therefore, the comparison between the two study groups (Case and Control) was restricted to detection frequency, which was uniformly 0% across both groups.

Results

Blood lead concentrations from gas station workers were analyzed using the Atomic Absorption Spectrophotometry method (AAS). Figure 1 shows the average blood lead concentrations (µg/dL) measured in blood samples from workers in

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four service stations (A, B, C and D), comparing Case (green) and Control (orange) groups. The black dashed line represents the method detection limit (LOD = 1.0 µg/dL). All measured values were below this threshold and are reported as "<LOD." The green bars indicate blood concentrations below the detection limit, confirming that no quantifiable lead was detected.

As shown in (Figure 1), every sample from gas station workers (Case) and every sample from the control group was reported as "<LOD". As no measurable blood concentration data were obtained, statistical comparisons were not performed. The evaluation was therefore restricted to detection frequency, which was uniformly 0% across both groups. This result indicates that no differences were observed between gas station workers (Case) and controls with respect to detectable blood lead levels, suggesting the absence of any measurable increase in exposure among the occupational group (Case). The analysis showed that all blood samples in both groups were below the detection limit (1.0 µg/dL). These findings indicate that blood lead was not quantifiable with the applied method. Trace amounts below 1.0 µg/dL may still be present, though they are below the sensitivity of the instrumentation used. The results suggest that the gasoline in Al-Ajaylat complies with regulatory standards for unleaded fuel and support the conclusion that lead contamination is negligible within the analytical sensitivity of the method.

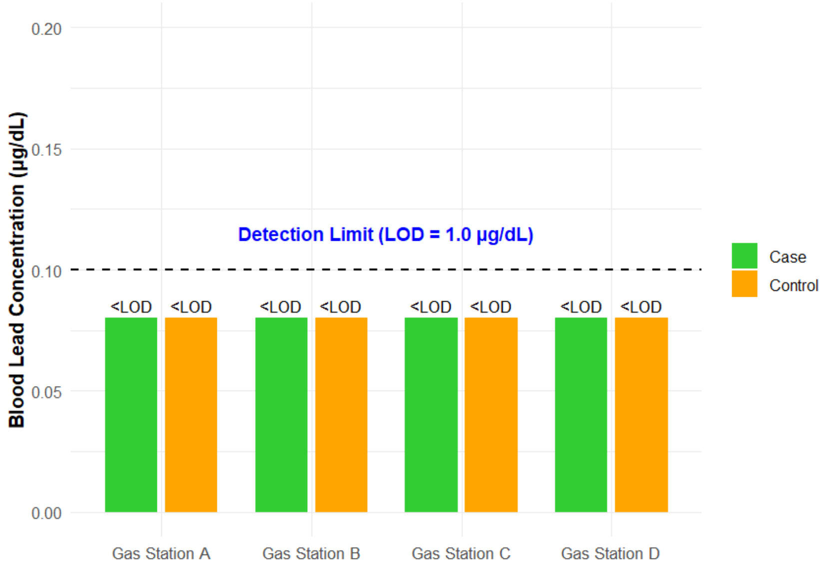

Figure 1. Average blood lead concentrations in gas stations workers (Case vs Control)
LOD = 1.0 µg/dL using AAS.

Discussion

Analysis of lead concentrations in the blood samples indicated that all values were below the detection threshold of 1.0 µg/dL. This outcome does not definitively prove the absence of lead, but it does show that concentrations fall below the AAS method's sensitivity limits. The results of this study, with values reported "<LOD") demonstrate compliance with international standards that require gasoline to be unleaded or contain only negligible amounts of lead, and therefore support the conclusion that the tested samples meet current requirements for unleaded fuel. While these findings do not agree with the results of Al-Rudainy [13] and Adeniyi and Anetor [16] as there are three different types of gasoline sold in Iraq and Nigeria: Regular, Midgrade, and Premium, with respective values of 87.5, 89.8, and 91.1 [18], and the Nigerian fuel has low octane number (86.5) in comparison to others [19]. The findings of this current study agree with [20], which reported that the elimination of lead from gasoline has enabled many countries to achieve population mean blood lead levels of 1 µg/dL or lower. For example, in the United States, which adopted a phase-out strategy for leaded gasoline, the current mean blood lead level has declined to less than 1 µg/dL [20]. The environmental and public health implications are equally important.

Leaded gasoline was once a major contributor to atmospheric contamination, with well-documented effects on soil, water, and human health, particularly the neurological development of children. The absence of detectable lead in the present samples may not contribute measurably to these hazards, although the possibility of trace concentrations below the detection limit cannot be dismissed. Therefore, continued monitoring with sensitive analytical techniques remains necessary to ensure that even very low exposures are minimized. Overall, the findings highlight the success of lead phase-out policies in fuel production in Libya and emphasize the importance of maintaining strict detection standards. The evidence provides reassurance that the gasoline in Al-Ajaylat complies with international regulatory frameworks and poses minimal risk to environmental and public health.

Conclusion

The analysis of lead concentrations in gasoline samples from Al Ajaylat City revealed that all measured values were below the detection threshold of 0.01 mg/L, as determined by ICP-MS. While this does not categorically exclude the presence of trace lead, it confirms that concentrations are beneath the sensitivity limits of the method and comply with international

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standards requiring unleaded fuel. These findings provide strong evidence that the tested gasoline meets current regulatory requirements and poses minimal risk to environmental and public health.

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Conflict of interest

The authors declare no conflicts of interest.

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