

## Impact of Occupational Exposure on Hematological Indices and Delta-Aminolevulinic Acid Levels among Al-Basra Oil Refinery Workers

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### ABSTRACT

One of the main significant health challenges in industrial field is the occupational exposure to petroleum derivatives and heavy metals, particularly among oil refineries workers. The most common issue is Lead exposure in such environments; it disrupts the heme biosynthesis and impairs renal function. Current study aimed to evaluate the impact of occupational exposure on hematological indices and Delta-Aminolevulinic Acid (ALAD) levels among workers at the Al-Basra Oil Refinery. Across-sectional study was conducted involving 118 participants; data were collected from the National Health Center, where workers used to perform their routine health screening, between August and November. The participants included refinery workers with varying exposure levels (Direct, Intermittent, and Indirect) and the control group was from the University of Technology. Blood and urine samples were analyzed for CBC parameters, Creatinine, and ALAD levels. Statistical analysis was performed using SPSS, employing Kruskal-Wallis for non-parametric data, Two-Way ANOVA to examine the interaction between occupation and smoking, and Pearson's Correlation to assess dose-response relationships. The results revealed that there is a significant effect of occupational status on ALAD levels ( $p = 0.002$ ), the highest mean values observed in the intermittent exposure group (2.30 mg/L). Other hematological parameters such as (HGB, MCV, PLT) did not show any significant differences ( $p > 0.05$ ), but there was a significant inverse correlation found between ALAD and Creatinine ( $r = -0.202$ ,  $p = 0.028$ ), and that indicates early renal physiological impact. Smoking was confirmed as a confounder for HGB but did not significantly affect ALAD levels ( $p = 0.795$ ). Workers in Al-Basra oil refinery, exhibited a significant metabolic disruption, evidenced by elevated ALAD levels and altered renal-metabolic correlations.

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## 1- INTRODUCTION

The petroleum industry has a positive effect on the global economy[1]; it is largely based on it, even though it has negative effects, especially on its workers. Exposure to a complex mixture of petroleum hydrocarbons and heavy metals may lead to significant health hazards [2]. The workers in oil refineries are frequently exposed to toxic agents in different ways, such as inhalation, dermal contact, and others, resulting in physiological and metabolic disruptions. One of the most significant hazards is the exposure to lead, which remains a critical concern in industrial environments, as it interferes with heme biosynthesis and renal function [3]. Delta-Aminolaevulinic Acid (ALAD) are conducted to detect and monitor lead toxicity. It considers as one of the most sensitive biomarkers, lead inhibits the enzyme delta-aminolaevulinic acid dehydratase (ALAD), causing an accumulation of ALAD in blood and its subsequent excretion in urine. It's very important to monitor ALAD levels, which provide a crucial "early warning" of metabolic disruption before the appearance of clinical symptoms of lead poisoning, such as severe anemia or chronic renal failure, manifest [4].

Other parameters are also affected by other oil-related substances. The chronic occupational exposure to these toxic substances is often associated with alterations in hematological parameters, including hemoglobin (HGB), red blood cell volume (MCV), and white blood cell (WBC) counts. Kidneys also affected gradually due to long-term industrial toxicity exposure, resulting in nephrotoxicity, and that reflected as altering in blood urea and creatinine levels [5, 6]. Workers in Al-Basra Oil Refinery face varying degrees of exposure based on their roles, ranging from direct contact, intermittent and indirect exposure according to the department they work in. Despite the established risks, there is a need for localised studies that evaluate the combined impact of occupational status and lifestyle factors, such as smoking, on these vital health indices[7].

This study aims to evaluate the hematological profile and ALAD levels among refinery workers in Al-Basra oil refinery, and to explore if there is any relationship between the duration of occupational exposure and biological disruption. By identifying these early markers, explaining the necessity of regular medical surveillance and applying the protective measures to protect the health of the industrial workforce. The study also aims at:

- Assess Biomarkers: Evaluate ALAD and hematological levels (CBC) among Al-Basra Oil Refinery workers to detect early lead and hydrocarbon toxicity.
- Evaluate Renal Impact: Analyze the correlation between ALAD and Creatinine to monitor subclinical renal impairment.
- Identify Confounders: Investigate the influence of smoking and work duration on the observed biological changes.

## 2- MATERIAL AND METHODS

### 2.1 Study Design

A cross-sectional study was conducted to evaluate the effect of lead exposure on Al-Basra oil refinery workers. Data and samples were collected at the National Health Centre in the period from August to November. The approval was obtained from the administration of the health center, following the issuance of a facilitation letter from the Middle Technical University. The study population consisted of two main groups: The Exposed Group, who were Employees in Al-Basra Oil Refinery and the Control Group, who were Employees in the University of Technology (visited the National Health Centre for routine or occupational health check-ups). The total samples were 200, after removing the missing data forms, the remaining participant became 132; following inclusion and exclusion application 118 remained for analysis the excluding done due to the participants who did not meet the study's health requirements, all exclusion were from the exposed groups but control group remain(n=32). Participation was entirely voluntary, and all individuals provided informed consent before their data and samples were used for research purposes.

### 2.2 Inclusion and Exclusion Criteria

Inclusion criteria were male workers aged 18 years or above, employed at Al-Basra Oil Refinery (exposed groups) or the University of Technology (control group), who provided voluntary informed consent. Participants with autoimmune diseases, pre-existing hematological disorders, chronic kidney disease, or renal failure were excluded to ensure that observed biological changes were attributable to occupational exposure rather than underlying medical conditions.

### 2.3 Data Collection and Biomarker Assessment

Demographic and occupational data were collected, including smoking status and work duration. We analysed the Blood samples(HGB, MCV, PCV) and Creatinine. In addition, Delta-Aminolevulinic Acid (ALAD) levels were measured as a primary biomarker for lead exposure, the exposure groups classified according the nature of them work, the direct exposure included the members who worked with routine daily roles including operators, production workers, electricians, and mechanical technicians, their work nature characterized by continuously presence around the processing zones. The second group of intermittent exposure included workers with specific task; such as maintenance technicians, welders, and firefighters, thier work nature was periodic but high-intensity exposure to lead dust, hydrocarbon fumes, and combustion byproducts inside the refinery operational zones, and the last group were the office worke, including administrative staff, managers, warehouse keepers, geologists, laboratory analysts, drivers, and security personnel, they had the minimum contact with the refinery operational zones.

### 2.4 Statistical Analysis

Data were analysed using SPSS software. Non-Parametric Analysis (Haematology and Creatinine): The Kruskal-Wallis test was employed for comparing haematological parameters and creatinine levels across different occupational groups. For parametric ALAD Levels, a Two-Way ANOVA was utilised to investigate the interaction between Occupation and Smoking Status. Before proceeding, Levene’s Test was performed to check for the homogeneity of variance. Since the result indicated unequal variances (p = 0.039), Welch’s ANOVA was used to ensure robust comparisons between groups. According to the confounder Analysis: An Independent T-test was conducted to compare smokers and non-smokers. This was crucial to determine if smoking acted as a confounder, particularly for HGB levels (which can rise due to carbon monoxide in cigarettes) and to confirm that ALAD elevations were specifically linked to lead exposure rather than lifestyle factors. Correlation Analysis: Pearson’s Correlation (r) was used to explore the linear relationship between Work Duration and key biomarkers (ALAD , HGB, MCV, and Creatinine). This analysis aimed to establish a Dose-Response Relationship, testing whether cumulative service years correlated with increased metabolic or physiological disruption. A p-value of less than 0.05 was considered statistically significant.

## 3- RESULTS AND DISCUSSION

### 3.1 No significant effect due to the occupational exposure on the hematological and renal profile pictures according (Kruskal-Wallis test).

**Table (1): Comparison of different parameters among different occupational exposure groups**

Variable	Control Mean Rank	Direct Mean Rank	Intermittent Mean Rank	Indirect Mean Rank	n	H	p-value
HGB	62.64	63.71	54.66	73.31	118	4.192	0.241 NS
MCV	57.97	56.69	65.69	71.81	118	3.563	0.313 NS
MCH	55.03	60.02	64.68	72.53	118	3.983	0.263 NS
RDW-CV	62.78	69.90	64.15	53.21	118	3.490	0.322 NS
WBC	49.00	68.61	65.55	69.29	118	6.642	0.084 (trend)
LYM	71.52	57.44	61.50	61.27	118	2.624	0.453 NS
PLT	56.06	54.45	69.19	66.17	118	3.901	0.272 NS
Creatinine	56.05	57.02	56.62	68.20	118	2.617	0.455 NS

The table shows the comparison of hematological and renal parameters across different occupational exposure groups (Kruskal-Wallis test). The results indicate no statistically significant difference (p > 0.05) in HGB, MCV,

MCH, RDW-CV, LYM, PLT, and Creatinine levels among the groups, the exclusion were within the exposed groups; but control group remain (n=32).

The main aim of our study is to evaluate the potential impact of occupational exposures on the haematological and renal profile of workers at Al-Basrah oil refinery. Table 1 showed that there was no significant effect according to the Kruskal-Wallis test, regarding all measured haematological parameters and serum creatinine levels ( $p > 0.05$ ), for all four studied groups (Control, Direct, Intermittent, and Indirect), which means there was no evidence of hidden anemia or renal impairment within the current occupational conditions, While the white blood cell (WBC) count showed a trend toward variation ( $p = 0.084$ ). But still, it did not yet reach the threshold of statistical significance, which may be due to several reasons such as the physiological adaptation to the surrounding environment or an insufficient duration of occupational exposure, which may limit the appearance of clinical symptoms and systemic alterations. Other research recorded that the impact on human health, especially in haematological profile (red and white blood cell counts) apparent cumulatively and gradually over 15 to 20 years [8, 9].

**3.2 Delta-aminolevulinic acid (ALAD) levels: A biomarker for metabolic stress in refinery workers.**

**Table (2): The levels of delta-aminolevulinic acid (ALAD ) among refinery workers**  
**A-Statistical analysis and levels of delta-aminolevulinic acid (ALAD) among refinery workers**

Test	Statistic (F)	df1 / df2	p-value
One-Way ANOVA	3.171	3 / 114	0.027 *
Welch ANOVA	5.712	3 / 58.124	0.002 **

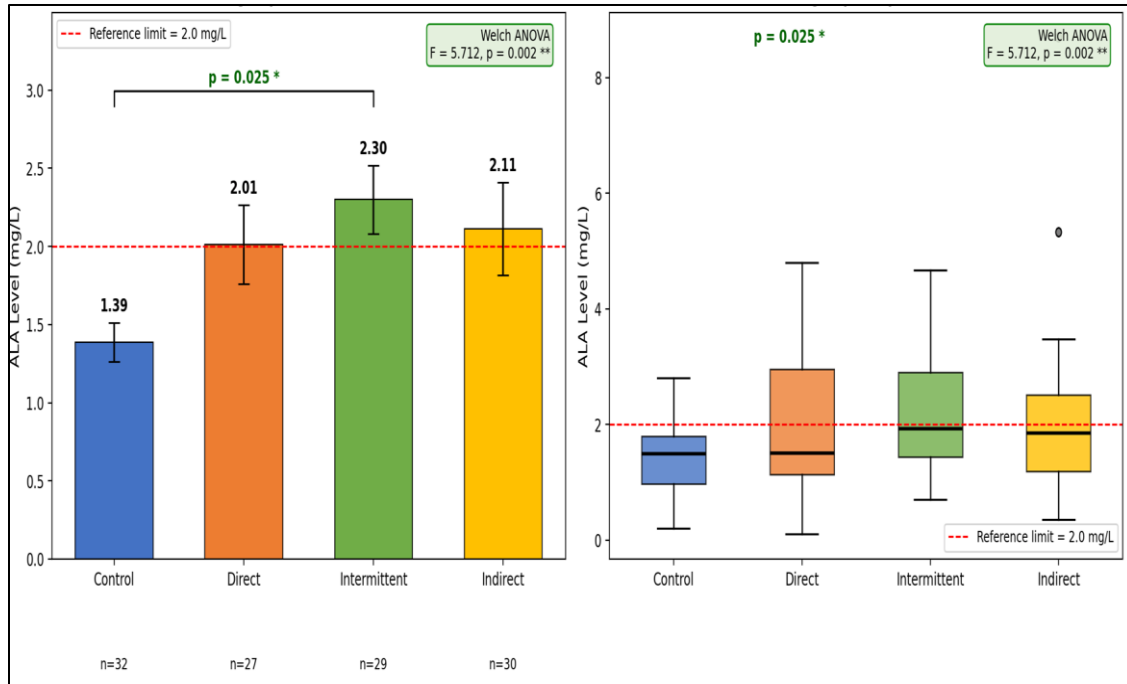
**B-The comparison of ALAD levels across study groups**

Group	n	Mean ± SD (mg/L)	95% CI	Min	Max	ANOVA F (p)	Welch F (p)
Control	32	1.39 ± 0.70	1.13 – 1.64	0.20	2.80	3.171 (p=0.027*)	5.712 (p=0.002**)
Direct	27	2.01 ± 1.32	1.49 – 2.53	0.10	4.80		
Indirect	30	2.11 ± 1.62	1.51 – 2.72	0.35	8.70		
Intermittent	29	2.30 ± 1.17	1.85 – 2.74	0.70	4.67		

**C- Post-hoc pairwise comparisons of ALAD levels**

group (I)	group (J)	Mean Difference (I-J)	Std. Error	p-value	Significance
Control	Direct	-0.627	0.324	0.220	NS
Control	Intermittent	-0.914	0.318	0.025*	Significant *
Control	Indirect	-0.728	0.315	0.102	NS
Direct	Intermittent	-0.287	0.332	0.822	NS
Direct	Indirect	-0.101	0.329	0.990	NS
Intermittent	Indirect	0.186	0.323	0.939	NS

Table 2 (a) Statistical validation using Welch ANOVA, which is more robust when variances are unequal ( $p=0.039$  by Levene’s test) (b) Summary of the results of statistics and One-Way ANOVA showing a significant difference across groups ( $p=0.027$ ). (c) Tukey’s post-hoc pairwise comparisons, showing a significant elevation in the Intermittent exposure group compared to the Control ( $p=0.025$ ). All data are presented as Mean ± SD.



**Fig (1): (a): ALAD levels by occupational Exposure group (Mean ± SEM)**

**Fig (1): (b): Distribution of ALAD by exposure group (boxplot)**

**Fig (1): Delta-aminolevulinic acid (ALAD) levels across occupational exposure groups. (A) Bar chart representing the Mean ± SEM of ALAD levels. (b) Box plot illustrating the distribution, median, and outliers of ALAD levels in each group. The dashed red line indicates the reference limit (2.0 mg/L). Statistical analysis was performed using the Welch ANOVA (F = 5.712, p = 0.002), followed by Tukey's post-hoc test, which revealed a significant difference between the Control and Intermittent groups (p = 0.025)**

In addition to the haematological and renal profiles, the delta-aminolevulinic acid (ALAD) levels were evaluated as a biomarker to measure the metabolic disruption triggered from the lead-inducing. Table 2 showed a significant elevation in ALAD levels in the Intermittent exposure group compared to the Control group (p = 0.025). The increase in the levels of ALAD indicates a subclinical inhibitory effect of lead on the (ALA-D) enzyme, and that means the heme biosynthesis pathway is disrupted, which appeared obviously in workers with intermittent exposure as a significant elevation. The group of chronic direct exposure may adapt by enhancing the body's resilience to metabolic stress. The elevated of ALAD levels in the intermittent exposure group reflected their work nature. This group includes welders, maintenance technicians, and firefighters. Welders generate concentrated lead fumes when working on aged pipelines with accumulated lead deposits [19].

The maintenance workers perform hands-on repairs in refinery zones, and that means they are exposed to frequent repetition of the lead dust and hydrocarbon vapors in a short time; the Firefighters also expose to frequent lead and chemical dust during their trying to put out the fire [20], The direct exposure group can adapt physiologically to continuous low-level exposure, but the intermittent group faces a frequent repetition of high-intensity exposure, and no adequate recovery, and that lead to progressive impairment of ALAD enzyme activity and the elevated ALAD levels observed.

**3.3 The effect of Smoking on ALAD, HGB and MCV (T-test)**

**3.3.1 The effect of smoking status on ALAD, HGB, and MCV levels.**

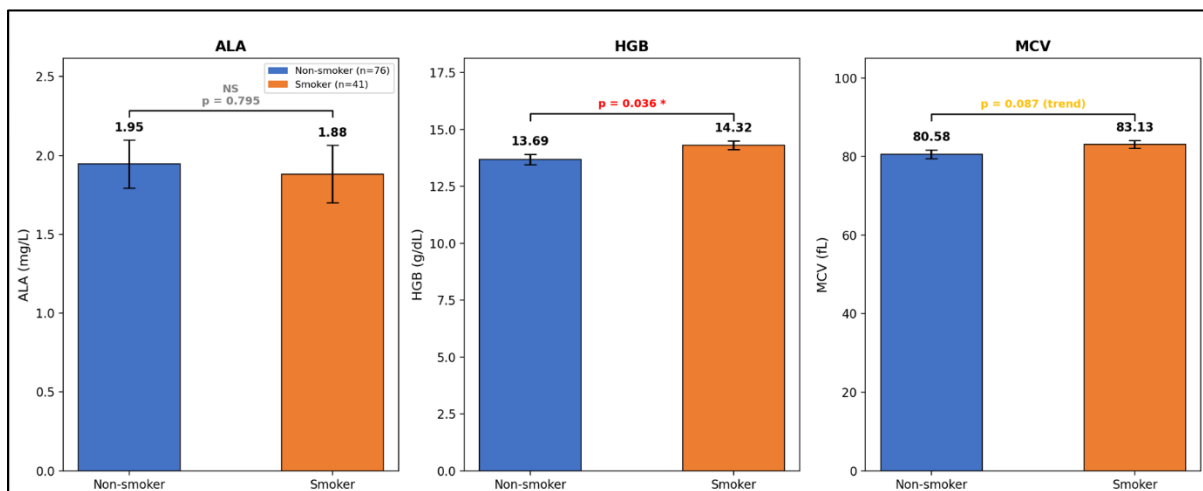
**Table (3): Assessment of the influence of smoking status on ALAD, HGB, and MCV levels**  
**A-Group Statistics**

Variable	Group	n	Mean	Std. Deviation	Std. Error Mean
ALAD (Final) (mg/L)	Non-smoker	76	1.946	1.326	0.152
	Smoker	41	1.882	1.168	0.182
HGB (g/dL)	Non-smoker	81	13.693	2.046	0.227
	Smoker	44	14.321	1.264	0.191
MCV (fL)	Non-smoker	80	80.58	9.646	1.078
	Smoker	44	83.13	6.664	1.005

**B- Independent Samples T-test Results**

Variable	Levene F	Levene p	t	df	P tailed (2-tailed)	Mean Diff.	Result
ALAD (Final)	0.121	0.729	0.261	115	0.795	+0.064	NS
HGB	1.371	0.244	-2.115*	120.882	0.036 *	-0.627	Sig. *
MCV	1.331	0.251	-1.729	115.631	0.087	-2.548	Trend

Table 3 shows the comparison between the two groups, the smokers and non-smokers. A- The descriptive statistics for ALAD, HGB, and MCV. B shows the results of the independent samples (t-test). The finding confirms that smoking has no significant impact on ALAD levels (p=0.795), but there was a significant difference in HGB (p=0.036), which reflects the standard process of physiological compensatory erythropoiesis. All values are reported as mean ± SD; p < 0.05 indicates statistical significance.



**Fig (2): Comparison of ALAD, HGB and MCV between smokers and nonsmokers: Mean ± SEM of ALAD, HGB, and MCV in smokers vs non-smokers. \* p < 0.05**

3.3.2 The effect of the interaction of occupation and smoking status on ALAD levels.

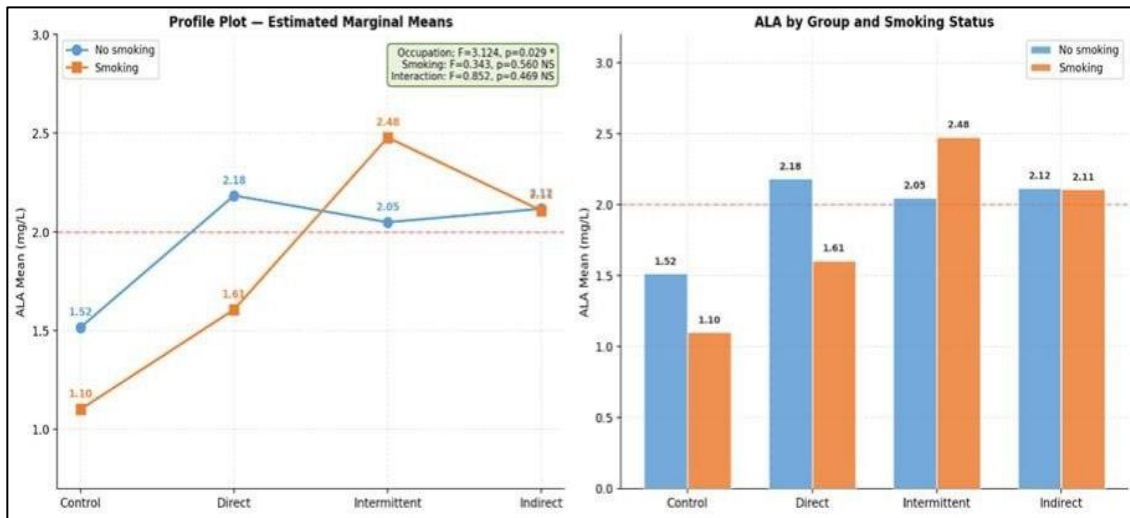


Fig (3): Left Profile plot of estimated marginal means of ALAD by exposure group and smoking status. The Right Grouped bar chart, dashed red line = reference limit (2.0 mg/L)

According to the potential impact of lifestyle on our results, we evaluated the effect of smoking on haematological and biochemical markers. Table 3 showed that smoking had no significant effect on ALAD levels ( $p=0.795$ ), that prove that the finding about the ALAD levels elevating, which was observed in refinery workers are independent of smoking, thereby strengthening our conclusion regarding occupational lead exposure. On the other hand, smokers exhibited high levels of HGB ( $p=0.036$ ), which happened due to compensatory erythropoiesis, which resulted as a physiological response to chronic carbon monoxide exposure, and not due to the occupational toxic effect [11, 12]. in Figure 3, the two-way ANOVA analysis revealed a statistically significant main effect for occupational status on ALAD levels ( $F(3, 109) = 3.124, p = 0.029$ ). Conversely, neither smoking status ( $F = 0.343, p = 0.560$ ) nor the interaction between smoking and occupation ( $F = 0.852, p = 0.469$ ) reached statistical significance. As shown in the profile plot and bar chart, the occupational exposure groups consistently demonstrated higher ALAD mean values compared to the control group, regardless of smoking habits. This visual and statistical evidence confirmed that the metabolic disruption is primarily driven by occupational lead exposure, independent of individual lifestyle confounders [13, 14].

3.4 Association of Lead Exposure Indicators with Work Duration and Renal Function

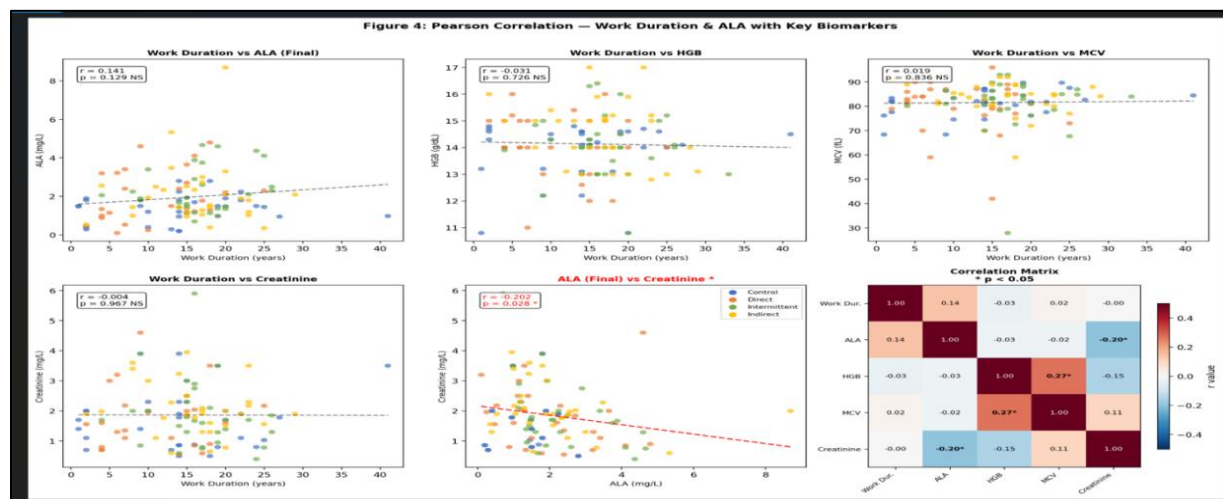


Fig (4): Top row scatter plots of Work Duration vs ALAD, HGB, MCV. Bottom row works Duration vs Creatinine, ALAD vs Creatinine (\* significant), and correlation matrix. Colors represent exposure groups

Figure 4 showed the correlation analysis of work duration and other biomarkers. The scatter plots indicated that there was no significant linear trend between duration of service and ALAD, HGB, or MCV levels, This finding was consist with previous studies that reported no dose-response relationship between occupational lead exposure duration and hematological indices [15, 16].The correlation matrix highlights a significant inverse relationship between ALAD and Creatinine ( $r = -0.202$ ,  $p = 0.028$ ), The absence of significant differences in creatinine levels across the groups (Table 1) and the significant inverse correlation between ALAD and creatinine ( $r = -0.202$ ,  $p = 0.028$ ) suggests that exposure to lead leads to an effect on the renal physiology at a subclinical level, and that leads to impaired tubular function and reduced urinary ALAD excretion, without yet causing overt clinical renal damage. This finding is consistent with early nephrotoxicity, where functional disruption precedes measurable structural damage [17, 18].

#### 4- CONCLUSION

The current study revealed that the occupational exposure in Al-Basrah oil refinery has a crucial effect on specific biological and metabolic markers, even if the results of other clinical parameters were normal. Delta-Aminolevulinic Acid (ALAD) levels were the most critical finding, which was recorded as a statistically significant elevation, particularly in people with intermittent exposure ( $p=0.029$ ), which means that the metabolic disruption occurred due to lead or chemical toxicity. Furthermore, the significant negative correlation between ALAD and Creatinine levels ( $r = -0.202$ ,  $p = 0.028$ ) indicates that the early renal physiological changes may be occurring as a result of cumulative exposure. About smoking, it was found as a potential confounder for some haematological indices, the two-way ANOVA confirmed that the increase in ALAD is primarily driven by occupational status, and not the lifestyle factors. Based on these findings, the current study recommends incorporating specific biomarkers such as ALAD into the programs of periodic health surveillance for refinery workers, as it acts as a more sensitive early warning system than traditional blood count (CBC) analysis. Moreover it high recommended to apply, and provide the personal protective equipment (PPE) and improved ventilation systems to minimise the risks of chronic chemical and lead inhalation. Regular renal function analyses, including creatinine and blood urea, should be performed for workers with long service durations (Work Duration) to detect subclinical nephrotoxicity. finally Implementing awareness programs for workers regarding the metabolic risks of petroleum exposure and the importance of early detection of biochemical changes.

In summary, these findings are fulfilling the study objectives the early biochemical impact resulted of refinery exposure were validated. Furthermore, these results serve as a reliable foundation for future longitudinal research, aiming to monitor the long-term renal and hematological health trajectories of workers with elevated ALAD levels. And that help to developing more precise national occupational health protocols and exposure limits within the Iraqi petroleum sector.

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