

OCCUPATIONAL EXPOSURE TO LEAD AND ITS BIOLOGICAL EFFECTS AMONG WORKERS IN A LEAD REFINING AND BATTERY MANUFACTURING COMPANY IN A CITY IN EASTERN ALGERIA BETWEEN 2017 AND 2019.

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Abstract

Introduction: Occupational exposure to lead is a major public health problem in developing countries. The objective is to assess occupational exposure to lead and its biological effects.

Methods: Descriptive cross-sectional epidemiological study, carried out on 200 workers of a lead refining and battery manufacturing company in Setif between 2016 and 2019. Data were collected by questionnaire containing socio-professional data (age, sex, smoking, BMI, job position, seniority, occupational category and unit), biological (Blood count, serum iron, serum uric acid, blood urea and serum creatinine, Urinary Δ -ALA and ZPP levels) and toxicological (blood lead levels). **Results:** The study population was relatively young (mean age: $39,56 \pm 08,71$ years) predominantly male (98 %), the average length of service was $11,21 \pm 8,81$ years, the majority of workers (78,5%) worked shifts, two-thirds (64,5 %) were enforcement agents, the mean blood lead level was $59,81 \pm 21,72$ $\mu\text{g}/100$ ml that of Urinary Δ -ALA, ZPP of red blood cells and serum urate were $8,54 \pm 7,73$ mg/g creatinine, $11,31 \pm 8,28$ $\mu\text{g}/\text{g}$ Hb and $56,29 \pm 13,10$ mg/L, respectively, seven cases of saturnine anaemia were recorded at the time of the survey. There was a significant correlation between blood lead levels and Urinary Δ -ALA and PPZ levels ($p= 0,00$). **Conclusion:** Our study allowed us to assess occupational lead exposure and its biological effects. The results show that preventive measures are necessary to reduce workers' exposure.

Keywords: Exposure, occupational, Blood lead levels, Toxicity, biological effects.

Résumé

Introduction : Les expositions professionnelles au plomb constituent un problème de santé publique majeur dans les pays en voie de développement. L'objectif c'est d'évaluer l'exposition professionnelle au plomb et ces effets biologiques. **Méthodes :** étude épidémiologique transversale descriptive, portée sur 200 travailleurs d'une entreprise d'affinage de plomb et de fabrication d'accumulateurs à Sétif entre 2016 et 2019. Le recueil de donnée était fait par questionnaire comportant des données socioprofessionnelles (âge, sexe, tabagisme, IMC, poste de travail, ancienneté, catégorie professionnelle et unité) biologique (NFS, fer sérique, acide urique sérique, urée sanguine et créatininémie, taux d'ALAU et de PPZ) et toxicologique (plombémie). **Résultats:** la population d'étude était relativement jeune (moyenne d'âge : $39,56 \pm 08,71$ ans) à prédominance masculine (98 %), l'ancienneté moyenne au travail était de $11,21 \pm 8,81$ ans, la majorité des travailleurs (78,5 %) exerçait selon un rythme de travail posté, les deux tiers (64,5 %) étaient des agents d'exécution, La plombémie moyenne était de $59,81 \pm 21,72$ $\mu\text{g}/100$ ml celle de l'ALAU, de PPZ des hématies et de l'uricémie étaient respectivement de $8,54 \pm 7,73$ mg/g de créatinine, $11,31 \pm 8,28$, $\mu\text{g}/\text{g}$ d'Hb et $56,29 \pm 13,10$ mg/l, sept cas d'anémie saturnine étaient enregistrés au moment de l'enquête. Il y avait une corrélation significative entre la plombémie et les taux d'ALAU et de PPZ ($p= 0,00$). **Conclusion:** Notre étude a permis d'évaluer l'exposition professionnelle au plomb et ses effets biologiques, les résultats montrent que des mesures de prévention sont nécessaires afin de diminuer l'exposition des travailleurs.

Mots clés : Exposition, professionnelle, Plombémie, Toxicité, effets biologiques.

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1. Introduction:

Lead is one of the oldest and most widely used metals by humans. Its toxicity, known since antiquity, is still relevant today.

However, while better control of occupational exposure has made severe forms of lead poisoning rare, it has not eliminated the disease in the workplace. Occupational exposure to lead remains very common and constitutes a major public health problem in many countries [1].

In Algeria, as in developing countries, the industrialization process was accompanied by an increase in the use of lead in various fields, particularly battery manufacturing. Several factories were established in various regions of the country, such as Algiers, Tiaret, Batna, and Oum-Lebouaghi. In Sétif, the latter has been used for about forty years at two units: one produces secondary lead from used batteries, the other manufactures starter batteries. Faced with this increase in use, the challenge remains to control occupational and environmental exposure, and the industrialization process must be accompanied by a prevention policy; the latter is established as a fundamental principle in Article fifteen of the new health law recently published in the Official Journal in July 2018 [2].

According to the National Social Insurance Fund for Salaried Workers, fifteen occupational diseases linked to lead exposure were recorded in 2016 [3].

To assess occupational exposure to lead in the wilaya of Sétif and its biological effects, we conducted this study.

2. Material and methods

This is a descriptive cross-sectional epidemiological study conducted on 200 workers from two lead refining and battery manufacturing units at a company located in the wilaya of Sétif, Algeria, between 2016 and 2019.

Data collection was carried out using a questionnaire containing the following sections:

- Sociodemographic data: age; sex; smoking; weight; height; waist circumference using the method recommended by the World Health Organization (WHO) [4], classified according to the recommendations of the International Diabetes [5], and BMI classified according to WHO data [6].

- Occupational data: workstation, seniority, work schedule.

- Biological and toxicological data: blood samples were collected in heparinized tubes at the occupational health department to avoid contamination. Urine samples were collected from 24-hour urine:

- Biological assessment:

- o Completed blood count if pathological by blood smear to look for basophilic granulation red blood cells.

Therefore, they were considered pathological, anemia confirmed by repeated biological tests accompanied by basophilic granulation red blood cells and a biological syndrome characterized by a drop in hemoglobin to less than 13 grams per 100 ml in the blood, by a punctate red blood cell level greater than 1 per 1000 red blood cells and an elevation of Urinary Δ -ALA greater than 20 mg per 1000 ml [7].

- o Renal function assessment: blood urea level (normal: 0,10 – 0,50 g/l) and creatinine (normal: men: 7 - 13 mg/l, women: 5 - 11 mg/l) [8].

- o Blood iron levels (normal: men: 0,60 and 1,70 mg/l, women: 0,50 – 1,60 mg/l) and uric acid levels (normal: men < 70 mg/l, women < 60 mg/l) [8].

- o Red blood cell protoporphyrin zinc (RPZ) levels: a level exceeding 3 μ g/g of hemoglobin (Hb) was considered pathological [1].

- o Urinary delta-amino-levulinic acid (UALA) levels: a level exceeding 5 mg/g of creatinine was considered pathological [1].

- Toxicological assessment:

o Blood lead levels: By atomic absorption spectrometry, blood lead levels above 40 µg/100 ml in men and above 30 µg/100 ml in women were considered high [9]. The average blood lead level corresponds to that of all years of exposure. Blood lead levels, as well as UALA e levels of RPZ, were classified into four classes: low, moderately high, and very high [9].

• Statistical analysis of the data was performed using Epi info version 7 software: Qualitative variables were expressed as percentages, quantitative variables as means plus or minus standard deviation; comparisons of two quantitative variables were made using correlation.

3. Results

3.1 Sociodemographic data:

Table 1: sociodemographic characteristics.

N = 200.

Sociodemographic characteristics	n	(%)
Age (year) (mean ± standard deviation)		39,56 ± 8,71
Gender (male)	196	(98)
Tobacco (smoking)		88
Family situation (married)	145	(72,5)
Obesity		
BMI ≥ 30	45	(22,5)

BMI: body mass index.

Our study population was relatively young with an average age of 39,56 ± 8,71 years, predominantly male (98 %), (44 %) of workers were smokers, the majority were married and (22 %) were obese (Table 01).

3.2 Professional data:

3.2.1 Seniority, professional category, contract, work rate and unit:

Table 2: distribution of the population according to seniority, professional category, type of contract, work rate and unit.

N = 200.

Professional characteristics	n	(%)
Seniority (mean ± standard deviation) (year)		11,21 ± 8,81
Professional category (executive agent)	129	(64,5)
Type of contract (fixed-term contract)	171	(85,5)
Work rhythm (shift work)	157	(78,5)
Unit		
Refining	42	(21)
Accumulator	158	(79)

The average length of employment was 11,21 ± 8,81 years, two-thirds of the workers were operatives, the majority had a fixed-term employment contract (85,5 %), worked in the accumulator unit (79 %), on a shift schedule (78,5 %) (Table 02).

3.3.2 Workstation:

(23 %) of the workers in the refining unit worked in the furnace, (16 %) of the accumulator unit in the wrapping machine (figure 1 and 2).

N=42.

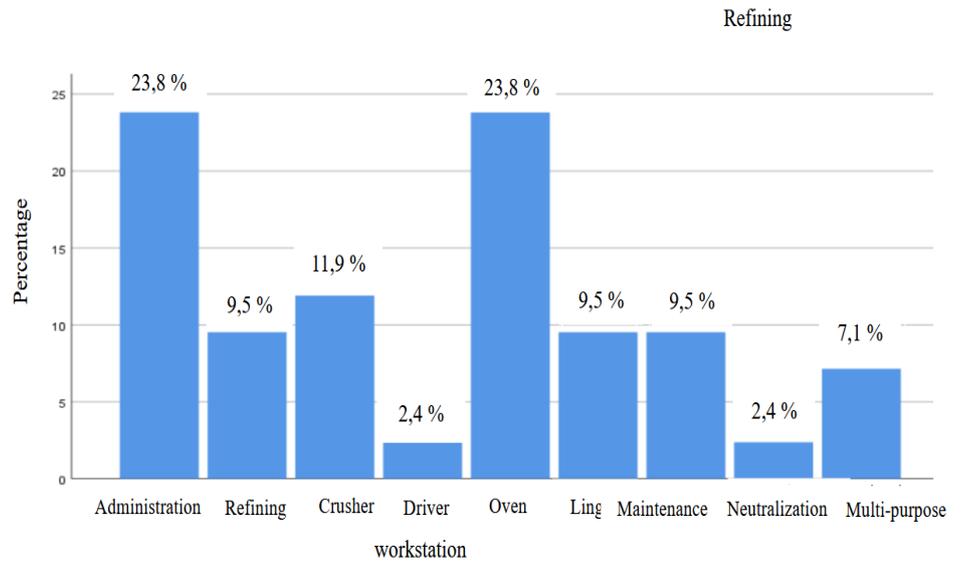


Figure 1. Distribution of workers in the refining unit according to workstation.

N=158.

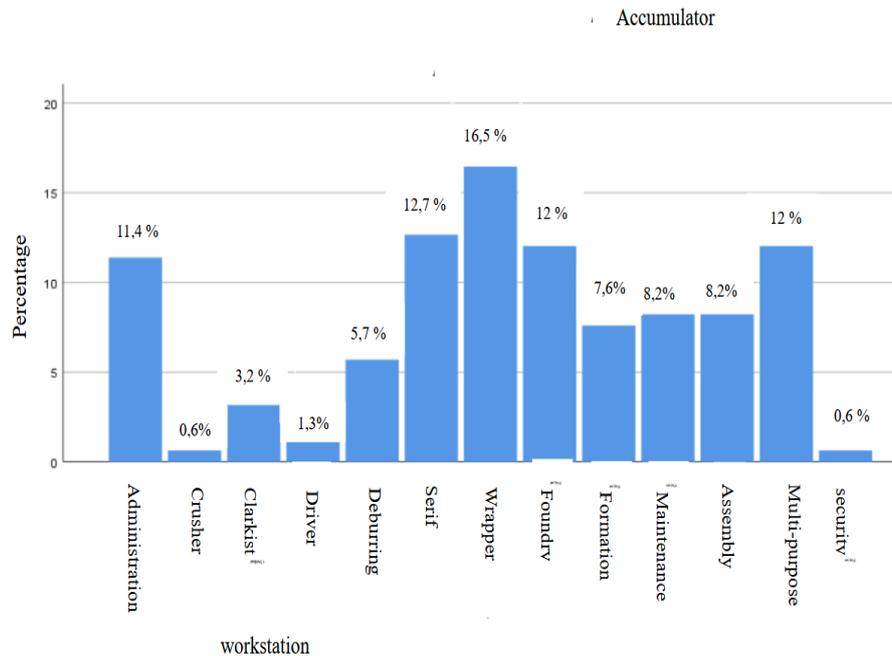


Figure 2. distribution of workers in the accumulator unit according to workstation.

3.3 Toxicological and biological assessment:

3.3.1 Blood lead levels:

Lead level of our population was $59,81 \pm 21,72 \mu\text{g}/100 \text{ ml}$, the average of all years of exposure was $48,77 \pm 18,54 \mu\text{g}/100 \text{ ml}$, the majority had high blood lead levels (81,0 %) and two-thirds (66 %) had an average of high years of exposure (table 03).

Half of the population (51,5 %) and a third (29,5 %) had respectively a very high blood lead level and an average of years of exposure (figure 03 and 04).

Tabl 3: population distribution according to blood lead levels.

⊥ Blood lead level (μg/100 ml)	Unit	n	(%)
Mean ± standard deviation	Refining	66,88 ± 21,9	
	Accumulator	57,67 ± 21,23	
	Total	59,81 ± 21,72	
Lead level (high)	Refining	37	(88,09)
	Accumulator	125	(79,1)
	Total	162	(81,0)
Average blood level (Mean ± standard deviation)	Refining	49,00 ± 16,70	
	Accumulator	48,47 ± 19,36	
	Total	48,77 ± 18,54	
Average blood level (high)	Refining	29	(69,04)
	Accumulator	103	(65,18)
	Total	132	(66)

population was 59,81 ± 21,72 μg/100 ml, the average of all years of exposure was 48,77 ± 18,54 μg/100 ml, the majority had high blood lead levels (81,0 %) and two-thirds (66 %) had an average of high years of exposure (table 03). Half of the population (51,5 %) and a third (29,5 %) had respectively a very high blood lead level and an average of years of exposure (figure 03 and 04).

N=200.

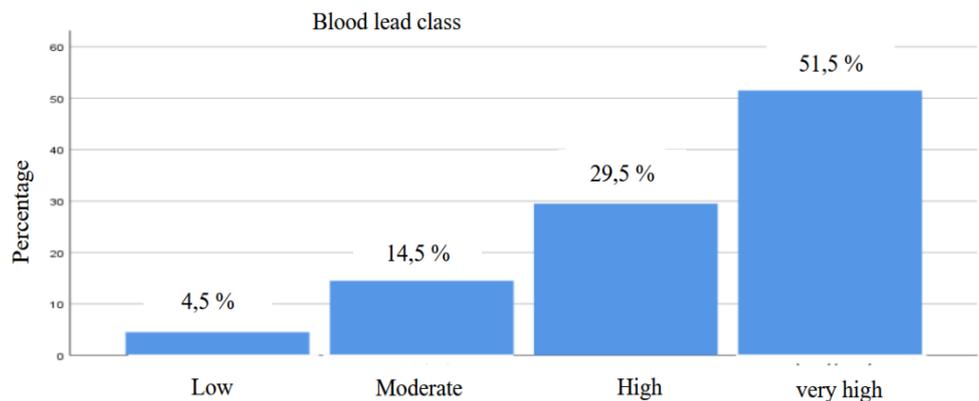


Figure 3. Distribution of the population according to blood lead class.

N=200.

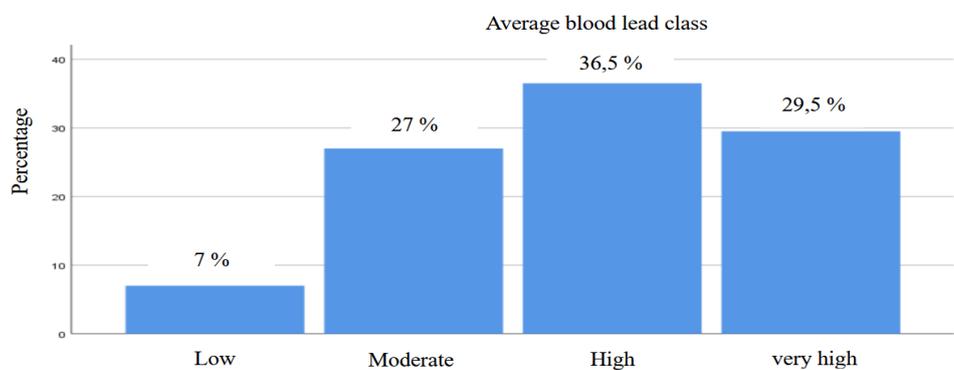


Figure 4. Distribution of the population according to the average blood lead level.

All workers in the refining, oven, crusher, and maintenance at the refining unit, as well as all workers in the serif and the majority of the wrapping machine (22/26) and the foundry (18/26) for the accumulator unit had high blood lead levels (figure 05 and 06).

N= 42.

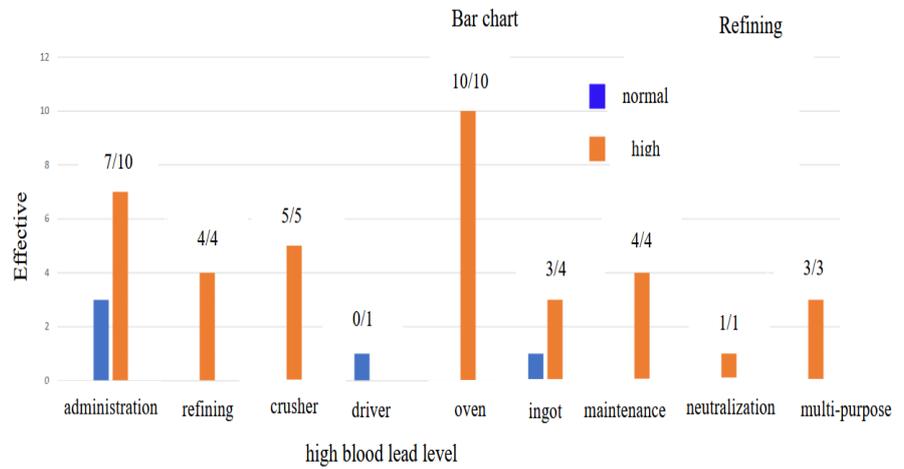


Figure 5. Distribution of the population according to high blood lead levels in the refining unit.

N= 158.

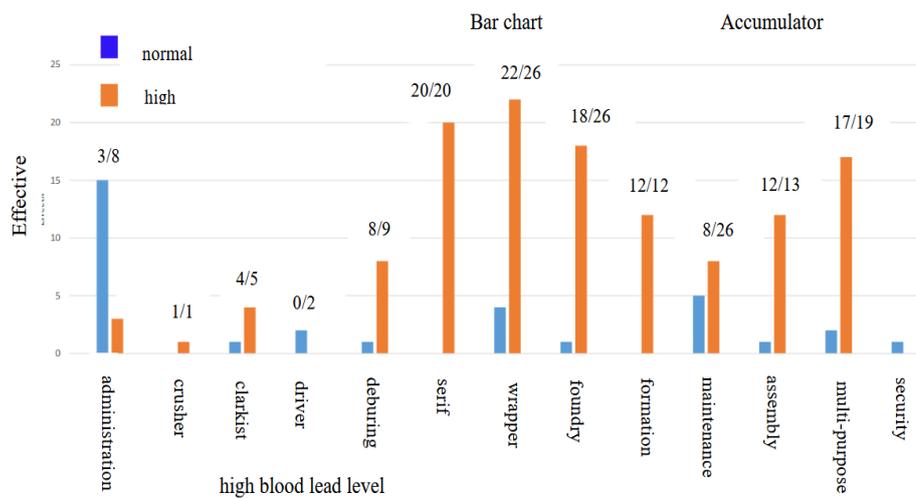


Figure 6. Population distribution according to high blood lead levels in the accumulator unit.

3.3.2 Biological assessment:

We recorded 07 cases of saturnin anemia, the average uricemia was $56,29 \pm 13,10$ mg/l, that of the UALA and ZPP levels was respectively $8,54 \pm 7,73$ mg/g of creatinine and $11,31 \pm 8,28$ μ g/g of hemoglobin; (18.5%) of the workers presented hyperuricemia, more than half (58,5 %) and the majority (80,5 %) presented respectively high levels of UALA and ZPP (table 04).

Table 4: Population distribution according to biological data.

N= 200.

Biological data	n	(%)
Blood urea, creatinine, serum iron (normal results)	200	(100)
Lead anemia	7	(3,5)
Uricemia (mg/l)	Mean ± standard deviation	56,29 ± 13,10
	Hyperuricemia	37 (18,5)
UALA (mg/g of creatinine)	Mean ± standard deviation	8,54 ± 7,73
	UALA high	117 (58,5)
ZPP (µg/g of hemoglobin)	Mean ± standard deviation	11,31 ± 8,28
	ZPP high	161 (80,5)

A quarter (24.5%) of the population had a high UALA rate and (14%) a very high rate (Figure 07).

More than a quarter (26.5%) of workers had a high ZPP rate and (9.5%) a very high rate (Figure 08).

N= 200.

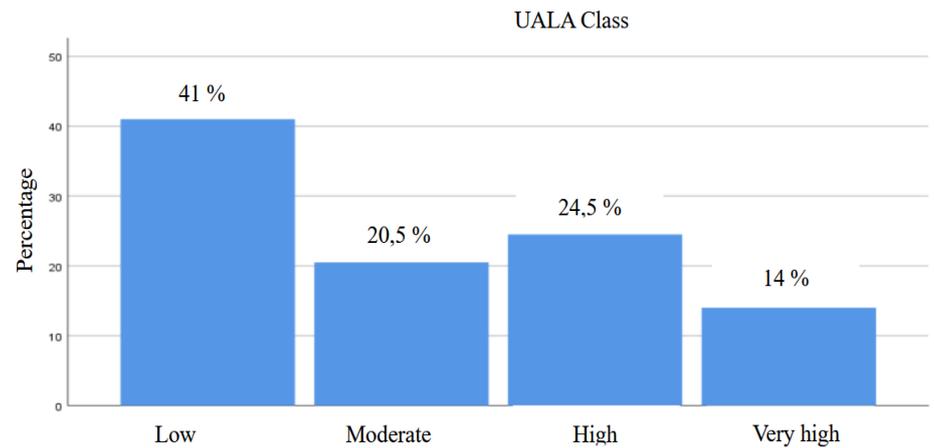


Figure 7. Population distribution according to the UALA rate.

N= 200.

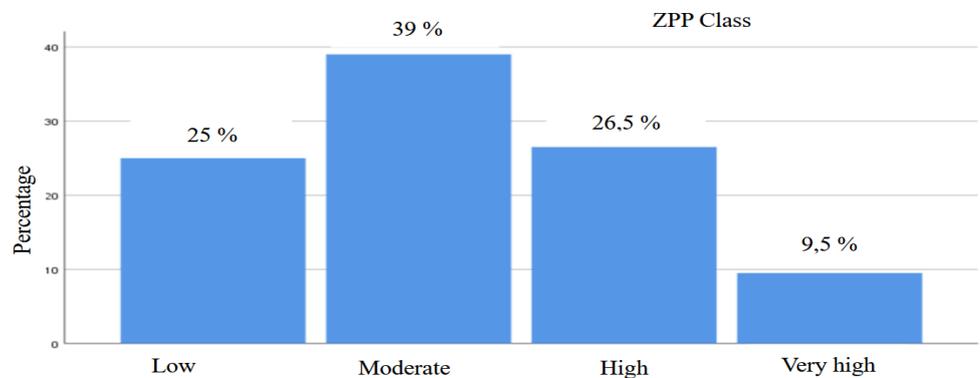


Figure 8. Population distribution according to the ZPP rate.

3.3.3 Bivariate analysis:

Table 5: Correlation between blood lead levels and UALA and ZPP levels.

N= 200.

		Lead level	Average blood level
UALA	Pearson correlation	0,634**	0,56**
	Sig. (bilateral)	,000	,000
ZPP	Pearson correlation	0,803**	,673**
	Sig. (bilateral)	,000	,000
**. The correlation is significant at the 0.01 level (bilateral).			

The values of blood lead and mean blood lead were significantly correlated with those of UALA ($p = 0.00$) on the one hand and with those of ZPP on the other hand ($p = 0.00$) (table 05).

4. Discussion

4.1 Socio-professional data:

Table 6: Comparison of professional data.

Study	Bouchala and al 2023	Sk. Akhtar Ah and al 2014	Our study Setif, Algeria 2019
Age (year)	40,9 ± 7,4	31,3 ± 11,4	39,56 ± 8,71
Gender (male)	96,5 %	-	98 %
Smoking)	46,4 %	48,3	44,5 %
Seniority	46,85 % < à 10	9,7 ± 7,8 ans	11,21 ± 8,81 53 < à 10 ans

Our study population was relatively young, had a working seniority of close to ten years, this result is close to those found by Akhtar Ah and al [10] and by Bouchala and al [11] (table 06). This can be explained by the massive retirement of the first generation of workers of the company which was put into service towards the beginning of the eighties which was replaced for about ten years by a new generation of young workers.

4.2 Socio-professional data:

The average blood lead level of our study population was above normal values; that of the refinery workers was higher than that of the battery unit workers.

This result is close to those found by Were F. H [12], Sk. Akhtar A and al [10], Bouchala and al [11] and Nouioui, MA and al [13], on the other hand our result is superior to that found by Olana, A.T [14] (table 07).

Our results reflect a recent excessive occupational exposure of the workers of this company to lead, which reflects the failure of technical and medical prevention in this company, therefore the need to develop a prevention plan adapted to the anomalies and inadequacies identified by studying working conditions and to strengthen medical surveillance, the latter is hampered by Algerian regulations, or excessive exposure to lead and saturnin impregnation are not repaired by the social security fund [7], which does not allow workers to be excluded at this stage, hence the need to revise and enrich table number 01 of occupational diseases.

It should also be noted that lead is a cumulative toxin that is mainly fixed at bone level [1], and the blood lead level that was used to assess workers' exposure to this metal in our study, despite being a good indicator of recent exposure to this metal (previous weeks), it underestimates it at a distance from any exposure [15]. The best tests for assessing the internal dose of lead remain induced leaduria which reflects the biologically active pool [16] and especially X-ray fluorescence which allows measurement of bone concentration; it is an excellent indicator of the internal dose of lead [17] and it provides cumulative data on exposure [18].

Table 07: Comparison of biological and toxicological data.

Study	Bouchala and al 2023	Nouioui, MA and al 2019	Were, F. H 2012	Sk. Akhtar A and al 2014	Olana, A. T. 2022	Our study Setif, Algeria 2019
Lead level (µg/100ml)	52,12	71,5	59,5 ± 10,1	65,25 ± 26,66	37,99	59,81 ± 21,72 Refining (66,8 ± 21,9) > Accumulators (57,6 ± 21,2)
UALA (mg/g of cr)	4,6 ± 3,5 (30,9 %) high	16,3	-	-	-	8,54 ± 7,73 (58,5 %) high
	Correlation with blood lead level p < 0,01	Correlation with blood lead level p = 0,004	-	-	-	Correlation with blood lead level p = 0,000
ZPP (µg/g of hb)	9,7 ± 7,1 (79,8 %) high	-	-	-	-	11,31 ± 8,28 (80,5 %) high
	Correlation with blood lead level p < 0,01	-	-	-	-	Correlation with blood lead level p = 0,000

To overcome this constraint, we calculated the average blood lead level for all years of exposure.

4.3 Biological data:

The average UALA and ZPP levels were above the standards and the majority of workers had high levels and therefore saturnin impregnation, which indicates that they were overexposed to lead. We also found a significant correlation between the UALA and ZPP values and those of blood lead levels, our results are consistent with those found by Bouchala and al and by Nouioui, MA and al [11,13] (table 07).

It should be noted that the UALA rate is not sensitive enough when the blood lead level is less than 300 µg/L, therefore used in massive poisonings, and that variations in the ZPP rate only follow those of the internal dose of lead with a delay of several weeks. It is therefore useful when exposure conditions are stable. The ZPP is a good indicator of the biologically active pool and its main disadvantage is the interference with iron deficiency and hemolytic anemia which increases it [15,16,19].

Regarding the hemoglobin level and the search for basophilic granular red blood cells (RBC), where seven cases of lead anemia with the presence of RBC were recorded, the literature reports that the correlations between the hemoglobin (Hb) level and blood lead levels are generally very weak [20].

The number of RBC does not reflect the amount of lead absorbed [21], and their increase occurs much later than other biological abnormalities [22].

Conclusion

Our study allowed us to assess the occupational exposure of this company's workers to lead and its biological effects, which reflect the technical and medical prevention efforts within the company. However, further studies using other tests, such as induced leaduria and, in particular, X-ray fluorescence, are necessary to assess the internal dose of lead, which is a cumulative toxicant.

Declaration of interests

The authors declare that they have no competing interests

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