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Traditional Khol as a Potential Source of Lead Exposure in the Algerian Population

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Abstract

Background

Kohl is a traditional eye cosmetic widely used in North Africa, the Middle East, and South Asia for aesthetic, cultural, and perceived therapeutic purposes. While historically composed of antimony trisulfide (stibnite), many modern products contain lead sulfide (galena), resulting in extremely high lead concentrations. Because lead has no safe exposure threshold, kohl may represent a significant source of systemic exposure. This study evaluated the association between kohl use and blood lead levels (BLLs) in the Algerian population.

Methods

A national descriptive cross-sectional biomonitoring survey was conducted in Algeria between 2017 and 2019. A total of 3,674 participants from 121 districts across 39 provinces were included. Participants completed a standardized questionnaire documenting kohl use frequency (daily, weekly, occasional, or never), underwent clinical examination, and provided venous blood samples. Blood lead concentrations were measured by inductively coupled plasma mass spectrometry (ICP-MS) using a PerkinElmer NexION 300-X instrument (quantification range 5–1000 µg/L; LOD 1.67 µg/L). Statistical analyses were performed using IBM SPSS Statistics v21, comparing mean BLLs across exposure categories with 95% confidence intervals.

Results

Overall, 33.7% of participants reported using kohl at least occasionally, predominantly adult women. Occasional use was most frequent (19.2%), followed by daily (6.5%) and weekly (5.8%) use. The mean BLL was 28.27 µg/L (median 22.22 µg/L; range 0.8–602.92 µg/L). Daily users showed the highest mean BLL (38.42 µg/L; 95% CI 31.96–44.88), significantly higher than weekly (28.14 µg/L), occasional (25.44 µg/L), and non-users (28.55 µg/L) ($P < 0.0001$). The highest BLL (602.9 µg/L) occurred in a woman reporting daily kohl use.

Conclusions

Kohl use is common in Algeria and is associated with increased BLLs, particularly among frequent users. These findings highlight kohl as a potential contributor to lead exposure and support the need for strengthened regulation, public health awareness, and preventive strategies.

Introduction

Kohl is a traditional dark eye cosmetic, widely used across North Africa, the Middle East, and South Asia for aesthetic and cultural purposes.(1) In Algeria, kohl remains widely applied by women as an eyeliner and is often believed to have therapeutic benefits for the eyes; it is also traditionally used on newborns's

eyes, based on beliefs about promoting ocular health and providing protection against harmful influences. (2)

Historically, Most brands of kohl were made of antimony trisulfide; the ore stibnite being known in Arabic as ithmed/ethmid (3). However, as this material was scarce and expensive, it was replaced over time by the much more common lead sulfide, the ore galena, PbS. Galena has almost the same black/grey-black color and shiny surface appearance as stibnite.(4)

As a consequence, Numerous chemical analyses have demonstrated that many traditional kohl products contain lead levels ranging from thousands to tens of thousands of milligrams per kilogram, and sometimes even exceeding 80% of the product by weight. (1) (5)

Lead is a systemic toxicant with no known safe threshold of exposure, associated with neurodevelopmental deficits in children, hematological impairments, and renal dysfunction in adults. (6),

The objective of the present study is to evaluate the association between the use of lead-contaminated khol and blood lead levels in the Algerian population, and to determine its contribution to overall systemic lead exposure.

Materiel and method

Population of study:

The Biomonitoring of Lead Exposure in the Algerian Population was a three-year, national, descriptive, cross-sectional survey conducted from 2017 to 2019, aiming to characterize kohl users within the study population. Each participant completed a structured questionnaire, underwent a clinical examination, and provided a blood sample. A total of 3,674 individuals, including both kohl users and non-users, were recruited from 121 districts across 39 provinces of Algeria.

Blood Lead Analysis:

The determination of lead in blood was performed by a Perkin Elmer Nexion 300-X® inductively coupled plasma mass spectrometer (ICP-MS). The plasma gas was argon Q5.0 (Linde®—Barcelona- Spain). The instrumental parameters are indicated as follows; plasma argon flow (18 L/min), nebulizer (0.8 L/min) and auxiliary (1.2 L/min). The quadrupole vacuum was set at 1.01 10 − 6 mbar. The analyzed isotopes were Pb 204, Pb 206, Pb207, and Pb 208 (quantification isotope). The plasma power was set at 1300 watts, and the nebulizer gas flow rate was 0.95 L/min, with a sample introduction time of 90 s and a rinse time of 20 s.

Each isotope was measured for 30 ms, with 30 scans and 3 replicates performed using a standard mode. The diluent used consisted of 1% propanol, 1 g/L EDTA, 0.05% Triton X-100, and 2% NH4OH, and the sample was diluted by 1/20. The internal standard selected was Yttrium. Three levels of certified

quality controls (Seronorm®) were used for each series of analysis. The glassware is cleaned and decontaminated according to the IRSST's standard protocols (Glassware Washing 2006), ICP-MS parts requiring cleaning are maintained according to Perkin Elmer guidelines (PerkinElmer. et al. 2013), The analytical method had an acceptable accuracy, with true values deviating no more than 18%. It could quantify concentrations from 0.25 to 50 µg/L of lead in diluted blood, equivalent to a range of 5 to 1000 µg/L

in pure blood. The detection limit was equal to 0.09 µg/L of lead in diluted blood, equivalent to 1.67 µg/L in sample blood. (7)

Statistical analysis:

To address the study objectives, descriptive and multivariate statistical analyses were performed focusing on the relationship between kohl use and blood lead levels (BLLs). BLL distributions were summarized using arithmetic means and selected percentiles (25th, 50th, 75th, and 95th), as well as geometric means with corresponding 95% confidence intervals (95% CI). The distribution of BLL according to kohl use status was illustrated using box-and-whisker plots (Fig. 1).

For values below the analytical limits, non-quantified measurements were imputed as follows: concentrations below the limit of detection (LOD) were replaced by LOD/2, and concentrations between the LOD and the limit of quantification (LOQ) were replaced by (LOD + LOQ)/2. (8)

Results were reported for the overall population, with kohl users and non-users distributed according to age group and sex. A generalized linear regression model was applied to evaluate the association between kohl use and BLL. Statistical significance was defined as $p < 0.05$. Quantitative variables were compared using Student's t-test and categorical variables using the chi-square (χ^2) test. All analyses were performed using IBM® SPSS® Statistics version 21 (student trial version).

Result

Khôl use in the study population

Among the total study population (n = 3,406), 1,149 individuals (33.7%) declared using khôl at least occasionally, whereas 2,257 participants (61.9%) reported never using khôl (Table 1).

Occasional use was the most frequently reported pattern, accounting for 700 individuals (19.2% of the total population). Regular use was less common, with 237 participants (6.5%) reporting daily use and 212 participants (5.8%) reporting weekly use.

When stratified by age group, khôl use was predominantly observed among adults. Among adult participants, 1,042 individuals (30.6%) reported khôl use at least occasionally, compared with 107

children (3.1%). Daily and weekly use were almost exclusively reported among adults, whereas khôl use in children was largely limited to occasional application.

Table 1
Distribution of Khôl Use Frequency by Age Group and Sex

Khôl Use Frequency	Children		Adults		Total
	(M) N (%)	(F) N (%)	(M) N (%)	(F) N (%)	N (%)
Daily	3 (0.8%)	8 (2.0%)	7 (0.6%)	219 (13.4%)	237 (6.5%)
Weekly	1 (0.3%)	7 (1.7%)	5 (0.4%)	199 (12.2%)	212 (5.8%)
Occasional	5 (1.3%)	36 (8.8%)	35 (2.9%)	624 (38.3%)	700 (19.2%)
Never	352 (91.0%)	328 (80.4%)	1099 (89.9%)	478 (29.3%)	2257 (61.9%)

With a predominance of female users observed, it should be noted that 25.6% of adult women in the adult population studied used kohl at least twice a week. More than 61% of individuals had never used kohl. (Fig. 2)

Blood lead levels were further analysed according to the frequency of traditional khôl use and stratified by age group and sex.

Among participants reporting daily khôl use (n = 237; 6.5% of the total population), the majority were adults, particularly females, who accounted for 219 cases (13.4% of adult women). In contrast, daily use was rare among children, reported in 3 girls (0.8%) and 8 boys (2.0%). Adult males represented a minor proportion of daily users (n = 7; 0.6%).

Weekly khôl use was reported by 212 participants (5.8%). This pattern was again predominantly observed among adults, with adult females representing 199 cases (12.2%) and adult males 5 cases (0.4%). In children, weekly use remained uncommon, affecting 1 girl (0.3%) and 7 boys (1.7%).

Occasional khôl use constituted the most prevalent exposure pattern among users, involving 700 individuals (19.2% of the total population). This practice was largely concentrated among adults, particularly females (n = 624; 38.3%), followed by adult males (n = 35; 2.9%). Among children, occasional use was reported by 5 girls (1.3%) and 36 boys (8.8%).

Participants who reported never using khôl represented the majority of the study population (n = 2,257; 61.9%). Non-use was especially frequent among children, with 352 girls (91.0%) and 328 boys (80.4%) reporting no khôl application. Among adults, non-use was reported by 1,099 men (89.9%) and 478 women (29.3%).

Blood lead levels according to khôl use

The results obtained are expressed in µg/L (ppb) in the blood of all individuals participating in the survey. The mean concentration, median, and different percentile values are shown in Table 2.

The mean blood lead level (BLL) was 28.27 µg/L [27.38–29.17], the median was 22.22 µg/L, and the 95th percentile was 73.83 µg/L. The minimum value was 0.8 µg/L, corresponding to half the detection limit, and the maximum value observed was

602.92 µg/L.

Table 2
Overall Distribution of Blood Lead Levels

Distribution Parameter	**Value**
Sample size (N)	3,674
Mean	28.27 µg/L
Minimum	0.8 µg/L (LOD/2)
Maximum	602.92 µg/L
5th percentile	0.8 µg/L (LOD/2)
25th percentile	12.53 µg/L
Median	22.22 µg/L
75th percentile	35.29 µg/L
95th percentile	73.83 µg/L
99th percentile	138.8 µg/L

Daily users (N = 237) had the highest mean BLL (38.42 µg/L; 95% CI: 31.96–44.88). Weekly users (N = 212) showed a lower mean BLL (28.14 µg/L; 95% CI: 24.43–31.85). Occasional users (N = 700) had the lowest mean BLL (25.44 µg/L; 95% CI: 23.48–27.41). Participants who never used khôl (N = 2257) had a mean BLL of 28.55 µg/L (95% CI: 27.53–29.58).

The higher BLL observed in daily users, with limited overlap of confidence intervals compared to other groups, indicates a clear and significant increase in lead exposure with frequent use. Weekly users and non-users had similar BLLs, with overlapping confidence intervals. (Table 3)

Table 3
Mean Blood Lead Levels (µg/L) According to Khol use

Kohl use	N	Mean 95% CI			p-value (overall)
Daily	237	38.421	31.960	44.883	0.000000007789 ***
Weekly	212	28.139	24.430	31.848	
Occasional	700	25.441	23.476	27.406	
Never	2,257	28.554	27.528	29.580	

Women who use kohl on a daily basis had blood lead levels 17.59 higher than those who use it on a weekly basis (Fig. 3).

Statistical analysis of the results showed that kohl is a significant source of lead in Algeria. The average blood lead levels among regular kohl users were very high (38.421 µg/L) compared to non-users (28.554 µg/L). This value is statistically significant ($P < 0.0001$).

Discussion

In Algeria, a blood lead value of 75 µg/L serves as the Reference Exposure Value,(9), According to Algerian legislation, lead and its compounds are included among substances prohibited for use in cosmetic and personal hygiene products, as stipulated by Executive Decree No. 10–114 of 18 April 2010, amending and supplementing Executive Decree No. 97 – 37 of 14 January 1997 regulating the manufacture, packaging, importation, and marketing of cosmetic and personal hygiene products on the national market.

The literature indicates that most kohl products contain high lead levels and are widely used across diverse populations, ranging from India and Pakistan to the Maghreb, the Near East, and the Middle East. This practice reflects an ancient cultural tradition, dating back several millennia, and was already established in Ancient Egyptian civilization.

An early Algerian analytical study of 45 samples reported lead in 100% of products, with concentrations ranging from 0.1% to 31.8% by weight, indicating systematic contamination of traditional formulations. (10).

Another algerian study by Kerdoun et al. analyzed 16 kohl samples marketed in Algerian Sahara and found that 81.2% contained lead, with concentrations ranging from 3,890 to 85,570 mg/kg and a mean of 46,400 mg/kg in locally produced products. Imported products showed lower but still elevated levels (mean 17,130 mg/kg). (2)

More recent regional investigations confirm this finding. In southern Algeria, 81.2% of kohl samples contained lead, with concentrations between 3 890 and 85 570 mg/kg, demonstrating very high contamination in artisanal products. (11)

These values are comparable to findings in neighboring MENA countries. In Saudi Arabia, kohl samples contained up to 53% lead, and regular users showed elevated blood lead levels. (1). In the United Arab Emirates, 38% of analyzed products were primarily composed of lead sulfide. (12).

Reviews of global data also indicate extremely high levels (54–89% Pb) in kohl from Morocco, Egypt, India, and Pakistan. (13).

The use of traditional eye cosmetics such as kohl has been consistently associated with elevated blood lead levels (BLLs) in exposed populations. Several studies confirm that kohl and related products can substantially increase children's lead body burden and represent a relevant source of exposure in culturally exposed communities.(14), In North Africa, analysis of traditional cosmetics in Morocco showed extremely high lead concentrations in kohl samples (up to 410 000 µg/g), and users exhibited significantly higher BLLs than non-users, confirming kohl as a major exposure source in Maghreb populations.(15)

In our study, among the 3,674 individuals included in the study, 1,149 reported using kohl at least occasionally. A predominance of female users was observed, with 25.6% of adult women in the studied population using kohl at least twice per week. Notably, women who reported daily use of kohl exhibited blood lead levels (BLLs) 17.59 times higher than those who used it on a weekly basis. The highest blood lead level observed (602 µg/L) was recorded in a woman who reported daily kohl use. in addition to cosmetic use, she regularly handled lead in other sorcellerie practices, which may have contributed to her extreme lead exposure.

Statistical analysis of the results confirmed that kohl constitutes an important source of lead exposure in Algeria. The mean BLL among regular kohl users was substantially elevated (38.42 µg/L) compared to non-users (28.55 µg/L), with this difference being highly statistically significant ($P < 0.0001$).

These findings highlight the potential health risks associated with the use of kohl as an ocular cosmetic.

Conclusion

Kohl has been identified as a significant source of lead exposure, with a demonstrated association between its use and elevated blood lead levels. Considering its prevalent use among women, targeted strategies to reduce exposure are essential. Furthermore, regulatory measures should be reinforced in coordination with national authorities responsible for consumer safety and trade, including systematic monitoring of traditional cosmetic products, to mitigate potential public health risks.

Declarations

Conflicts of Interest / Competing Interests

The authors declare that they have no conflicts of interest and no competing interests to disclose.

Ethics

This study received approval from the ethics committee at the University Hospital of BeniMessous. Participants were required to fill out informed consent documents, and those who were interviewed and sampled signed an informed consent form.

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Author Contribution

Y.Z. and B.A. conceived and designed the study. Y.Z., A.A., and M.A. contributed to data collection and investigation. A.A, M,Y,A and A.C. performed data analysis and interpretation. S.A. and A.L. contributed to methodology and validation of the results. Y.Z. and N.K. drafted the manuscript. A.K. revised the manuscript. All authors reviewed and approved the final version of the manuscript.

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Figures

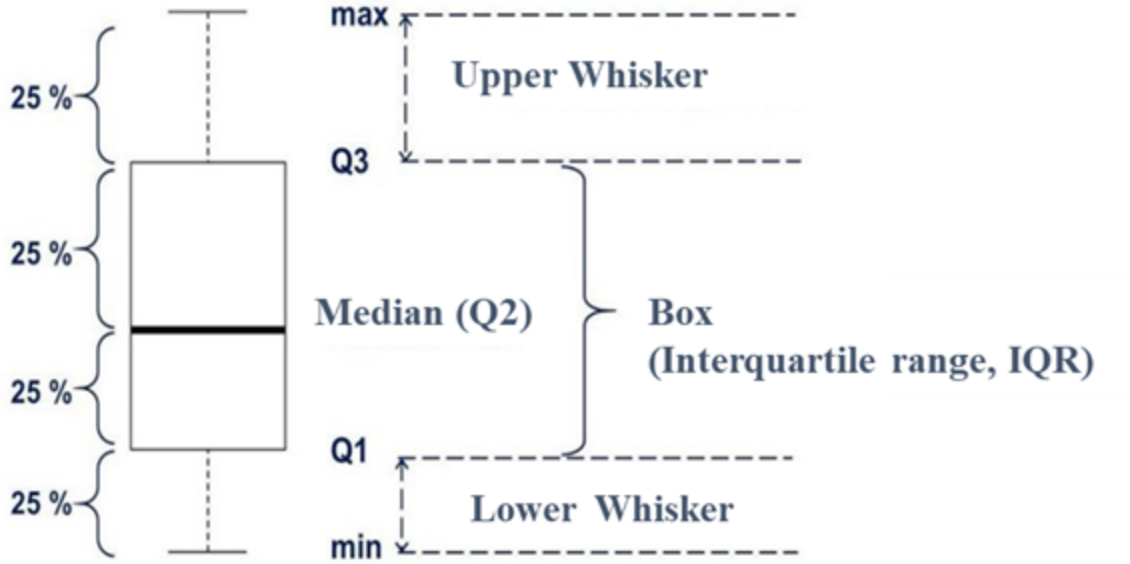


Figure 1

Box-and-Whisker Plot (Box Plot)

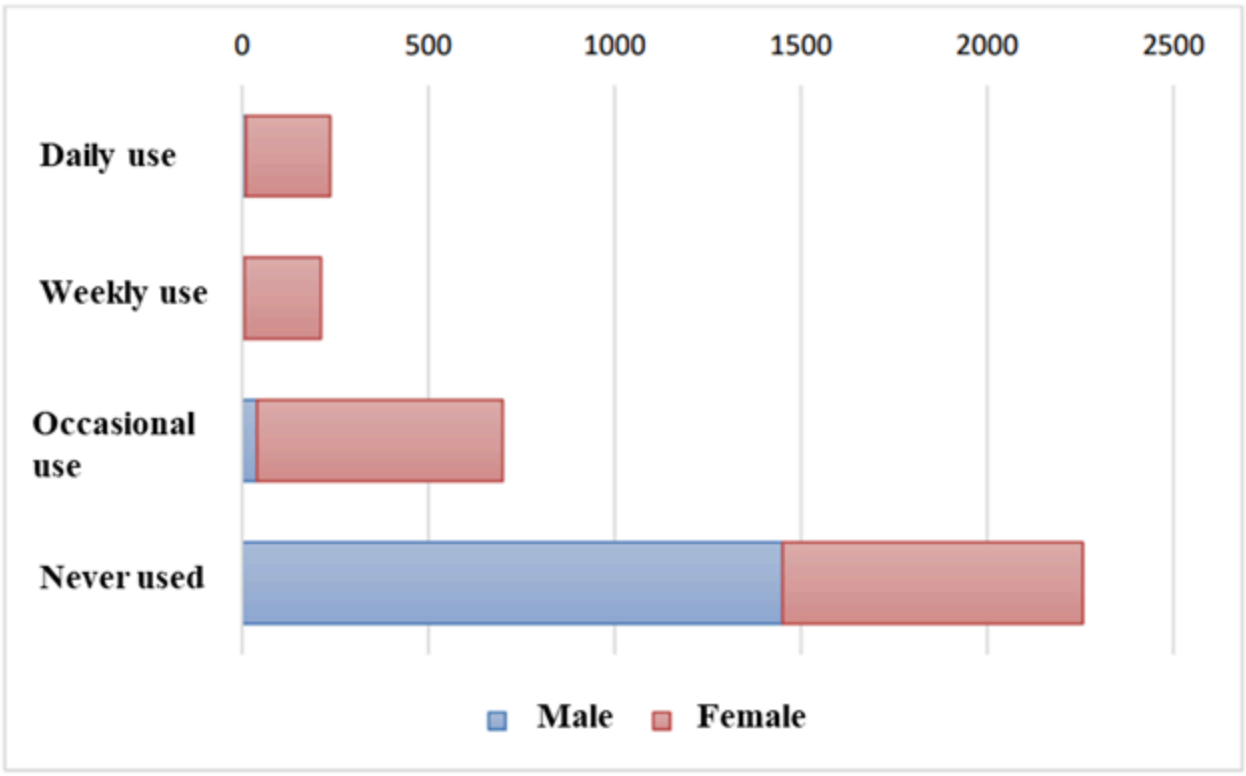


Figure 2

Distribution of Kohl Use According to Frequency and Sex

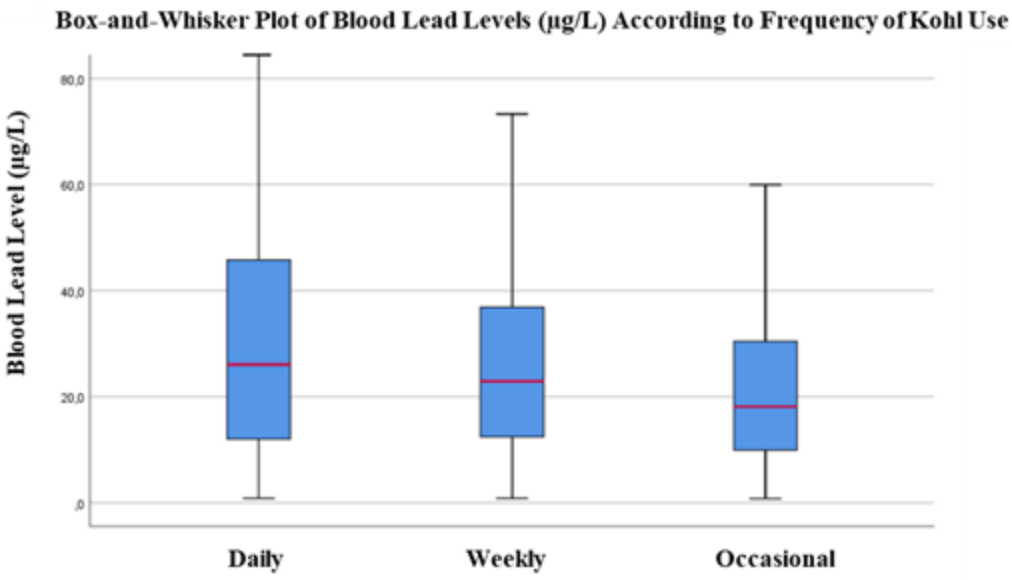


Figure 3

Distribution of Blood Lead Levels According to Frequency of Kohl Use