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Assessment of Heavy Metal Contamination in Baby Formulas in Bani Waleed City/Libya

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Abstract:
This investigation sought to assess concentrations of metallic contaminants in infant nutritional products commercially available in Bani Waleed City, Libya. Thirty specimens were systematically acquired from retail establishments, promptly transferred to analytical facilities under controlled conditions, and preserved at 4°C until processing. Quantitative analysis of iron (Fe), lead (Pb), cadmium (Cd), and copper (Cu) was conducted using flame atomic absorption spectrometry (FAAS) following standardized protocols. Laboratory results demonstrated cadmium concentrations below instrumental detection limits (0.01 mg/kg), while measurable quantities of iron (8.2 - 16.4 mg/kg), copper (0.8 - 1.8 mg/kg), and lead (0.02-0.1 mg/kg) were identified. All values remained substantially beneath WHO-established safety thresholds (Pb/Cd < 0.1 mg/kg; Cu < 10 mg/kg), confirming regulatory compliance for infant consumption.

Keywords: Baby Formulas, Iron (Fe), Lead (Pb), Cadmium (Cd), Copper (Cu), Atomic Absorption Spectrophotometer.

تقييم تلوث المعادن الثقيلة في حليب الأطفال في مدينة بني وليد – ليبيا

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الملخص
سعى هذا البحث إلى تقييم تركيزات الملوثات المعدنية في منتجات التغذية للأطفال المتوفرة تجاريًا في مدينة بني وليد، ليبيا. تم الحصول على ثلاثين عينة بشكل منهجي من مؤسسات البيع بالتجزئة، ونقلها على الفور إلى مرافق تحليلية في ظروف خاضعة للرقابة، وحفظها عند 4 درجات مئوية حتى المعالجة. تم إجراء تحليل كمي للحديد (*Fe*) والرصاص (*Pb*) والكادميوم (*Cd*) والنحاس (*Cu*) باستخدام مطياف الامتصاص الذري باللهب (*FAAS*) وفقًا للبروتوكولات الموحدة. أظهرت نتائج المختبر تركيزات الكادميوم أقل من حدود الكشف الآلي (0.01 ملغم/كغم)، في حين تم تحديد كميات قابلة للقياس من الحديد (8.2 - 16.4 ملغم/كغم) والنحاس (0.8 - 1.8 ملغم/كغم) والرصاص (0.02-0.1 ملغم/كغم). ظلت جميع القيم أقل بكثير من عتبات السلامة التي حددتها منظمة الصحة العالمية (*Pb/Cd < 0.1* ملغم/كغم؛ *Cu < 10* ملغم/كغم)، مما يؤكد الامتثال التنظيمي لاستهلاك الأطفال.

الكلمات المفتاحية: حليب الأطفال؛ الحديد*(Fe)* ، الرصاص*(Pb)* ، الكادميوم*(Cd)* ، النحاس*(Cu)* ؛ مطياف الامتصاص الذري.

1. Introduction

The safety and nutritional quality of baby formulas are of paramount importance due to their critical role in the growth and development of infants. Baby formulas are often the primary source of nutrition for infants, and any contamination with heavy metals could pose significant health risks. Heavy metals such as iron (Fe), lead (Pb), cadmium (Cd), and copper (Cu) are known to have toxic effects on human health, particularly in vulnerable populations such as infants [1]. The presence of these metals in baby formulas can result from various sources, including contamination during manufacturing, packaging, or from the environment.

Lead (Pb) is a well-known neurotoxin that can cause developmental delays, learning disabilities, and behavioral problems in children [2], [3]. Cadmium (Cd) is also a toxic metal that can accumulate in the kidneys and liver, leading to chronic health issues [4]. Copper (Cu) is an essential trace element, but excessive intake can lead to liver damage and other health problems [5]. Iron (Fe) is essential for hemoglobin synthesis, but excessive levels can lead to oxidative stress and tissue damage [5], [6].

The World Health Organization (WHO) has set maximum permissible limits for heavy metals in food products, including baby formulas, to ensure consumer safety [7]. However, there is limited data on the heavy metal content of baby formulas in Libya, particularly in Bani Waleed City. This study aimed to assess the levels of Fe, Pb, Cd, and Cu in baby formula samples collected from markets in Bani Waleed City, Libya, and to compare these levels with WHO guidelines.

2.Materials and Methods

2.1. Sample Collection

Thirty commercially available infant formula specimens were procured through retail surveillance across Bani Waleed City, Libya, during Q1 2023. The sampling strategy targeted diverse retail outlets to capture variations in manufacturer formulations. Following standardized collection protocols, acquired samples were immediately sealed in sterile, hermetic containers to preserve integrity, then transferred under temperature-controlled conditions to accredited analytical facilities for subsequent contaminant profiling.

2.2. Sample Preparation

The baby formula samples were prepared for analysis by following standard procedures. For powdered formulas, a 10 g sample was dissolved in 100 mL of distilled water. For ready-to-feed formulas, a 10 g sample was directly weighed. The solutions were then filtered through a 0.45 µm membrane filter to remove any particulate matter. The filtrate was then subjected to acid digestion using a mixture of nitric acid (HNO3) and perchloric acid (HClO4) to dissolve any metal compounds present.

2.3. Heavy Metal Analysis

The levels of Fe, Pb, Cd, and Cu in the digested samples were determined using a Flame Atomic Absorption Spectrometer (FAAS) (Model: Varian AA240). The instrument was calibrated using standard solutions of known concentrations, and the readings were obtained at the following wavelengths: 248.3 nm for Pb, 228.8 nm for Cd, 324.7 nm for Fe, and 324.7 nm for Cu. Blank solutions were also prepared and analyzed to account for any background interference.

2.4. Statistical Analysis

Quantitative assessment employed descriptive analytical methods to evaluate central tendency, dispersion, and distribution parameters. Measured values underwent systematic evaluation against WHO-established safety thresholds for metallic contaminants in infant nutritional products. All computational procedures were executed through the SPSS statistical package (IBM Corporation, Release 25) following standardized protocols for environmental health analytics.

3. Results

3.1. Heavy Metal Levels in Baby Formulas

The levels of Fe, Pb, Cd, and Cu in the baby formula samples are presented in Table 1.

Table 1: Heavy metal levels in baby formula samples (n=30).

Metal	Mean (mg/kg)	Standard Deviation (mg/kg)	Range (mg/kg)
Fe	12.5	2.1	8.2 - 16.4
Pb	0.05	0.02	0.02 - 0.1
Cd	ND	ND	ND
Cu	1.2	0.3	0.8 - 1.8

ND: Not detected (below the detection limit of 0.01 mg/kg).

3.2. Comparison with WHO Guidelines

Current WHO safety thresholds for metallic contaminants in infant nutritional products stipulate maximum concentrations of 0.1 mg/kg for lead (Pb), 0.1 mg/kg for cadmium (Cd), and 10 mg/kg for copper (Cu) (World Health Organization, 2017). Iron (Fe), classified as a micronutrient rather than a contaminant, and remains exempt from these regulatory standards. Analytical findings revealed Pb and Cu concentrations consistently below prescribed thresholds across all tested samples. Cadmium concentrations fell below analytical detection capabilities (sensitivity threshold: 0.01 mg/kg) throughout the investigation, demonstrating compliance exceeding baseline regulatory requirements.

4. Discussion

The results of this study indicate that the levels of heavy metals in baby formula samples from Bani Waleed City, Libya, are generally within acceptable limits as per WHO guidelines. Iron, copper, and lead were detected in some samples, but their levels were below the recommended maximum permissible limits. Cadmium was not detected in any of the samples, which is a positive finding, as cadmium is a highly toxic metal with no known biological function.

The presence of lead in baby formulas is of particular concern, as lead is a known neurotoxin that can cause developmental delays and learning disabilities in children [8], [9]. However, the levels of lead detected in this study were very low, ranging from 0.02 to 0.1 mg/kg, which is below the WHO permissible limit of 0.1 mg/kg. This suggests that the baby formulas available in Bani Waleed City are not posing a significant lead-related health risk to infants.

Copper is an essential trace element that plays a crucial role in various enzymatic reactions in the body. However, excessive copper intake can lead to oxidative stress and tissue damage [10], [11]. The levels of copper detected in this study were within the acceptable range, with a mean value of 1.2 mg/kg, which is well below the WHO permissible limit of 10 mg/kg.

Iron is an essential nutrient for the synthesis of hemoglobin and myoglobin, and it plays a critical role in oxygen transport and storage [12].The levels of iron in baby formulas are not regulated by WHO, as it is an essential nutrient. The mean iron level in this study was 12.5 mg/kg, which is within the recommended range for infant nutrition.

4.1. Possible Sources of Contamination

The presence of heavy metals in baby formulas can result from various sources, including contamination during manufacturing, packaging, or from the environment. Lead contamination can occur through the use of lead-containing materials in the manufacturing process, such as lead solder in cans or lead-based paints on equipment [13]. However, the low levels of lead detected in this study suggest that such contamination is minimal or non-existent in the baby formulas tested.

Copper contamination can occur through the use of copper-containing materials in the manufacturing or packaging process, such as copper pipes or containers. However, the levels of copper detected in this study were within acceptable limits, indicating that copper contamination is not a significant concern in the baby formulas tested [14], [15].

Cadmium contamination can occur through the use of cadmium-containing materials in the manufacturing process or through environmental contamination of raw materials [16], [17]. The absence of cadmium in the samples suggests that cadmium contamination is not a significant issue in the baby formulas tested.

4.2. Implications for Infant Health

The findings of this study suggest that the baby formulas available in Bani Waleed City, Libya, are generally safe for infant consumption in terms of heavy metal contamination. However, it is essential to continue monitoring the heavy metal content of baby formulas to ensure their safety and nutritional quality. Regular monitoring can help identify any potential sources of contamination and ensure that regulatory standards are met.

4.3. Limitations of the Study

This study has several limitations. First, the sample size was relatively small, with only 30 samples collected from different markets in Bani Waleed City. A larger sample size would provide a more comprehensive assessment of heavy metal contamination in baby formulas in the region. Second, the study only assessed four heavy metals (Fe, Pb, Cd, and Cu), while other potentially harmful metals, such as mercury (Hg) and arsenic (As), were not evaluated. Future studies should consider assessing a broader range of heavy metals to provide a more complete picture of heavy metal contamination in baby formulas.

5. Conclusion

The analytical results from Bani Waleed City, Libya, indicate that infant nutrition products in the region demonstrate compliance with WHO safety standards for heavy metal content. Trace amounts of lead, copper, and iron were identified in select formula samples, though all measurements remained below established thresholds. Notably, cadmium concentrations fell beneath detectable limits across all analyzed specimens. These observations suggest that commercially available formulas in the study area contain acceptable heavy metal concentrations for infant consumption based on current international guidelines. While these findings provide reassurance regarding product safety, researchers emphasize the importance of maintaining vigilant surveillance programs to ensure sustained safety and conduct regular quality assessments of nutritional provisions for vulnerable populations.

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