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Lead Levels in Breast Milk of Lactating Mothers in Lead-Contaminated Environment: A Systematic Review

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Abstract

The ingestion of Lead by an infant can cause the disruption of cytokine production and a weakened immune system. The World Health Organization recommends a 5 µg/L limit of Lead in breast milk. This study aimed to review the levels of lead in breast milk of lactating mothers in lead-contaminated environments. This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The databases of PubMed/MEDLINE and EBSCO essentials were systematically searched. Additional hand searching was done. Out of an identified 1499 records, 10 studies were included in the review. Most (80%) of the included studies found that the concentration of Lead in the breast milk of lactating mothers was above the WHO limit, with a pooled mean of 306.12 (873.74) µg/L which is approximately 61 times the WHO limit. This finding was partly consistent with previously published literature. These findings highlight the need for greater awareness and measures to address the sources of lead contamination in the environment, particularly in areas where breastfeeding is common.

Keywords: *Infant, Breast Feeding, Lactation, Milk, Human*

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1. Introduction

Breast milk is essential for newborn babies and is the only food the World Health Organization recommends for newborns (Koletzko et al., 2020). It has a unique composition of water, carbohydrates, lipids, proteins, vitamins, and minerals to support newborn growth and development (Christian et al., 2021). Although normal breast milk does not contain Lead metal, ingested Lead can accumulate in breast milk and pose toxicological threats to neonatal health (Lin et al., 2023). The ingestion of Lead by a newborn can cause the disruption of cytokine production and a weakened immune system (Pajewska-Szmyt et al., 2019). The World Health Organization recommends a 5 µg/L limit of Lead in breast milk (Vahidinia et al., 2019). Therefore, it is necessary to track concentrations of Lead in breast milk, particularly in areas where environmental pollution is a concern (Charkiewicz & Backstrand, 2020).

Environmental pollution is a global health concern that causes an estimated nine million deaths annually (Fuller et al., 2022). With the continued growth of mining and fossil fuel exploration, toxic metals like Lead get into the air, soil, and water (Ukaogo et al., 2020). Lead exposure primarily occurs via ingestion and inhalation (Charkiewicz & Backstrand, 2020). Research suggests that exposure to lead-contaminated environments can result in the accumulation of Lead in maternal tissue (Philip-Slaboh et al., 2023). Newborns that rely on breast milk for nutrition are especially vulnerable to ingesting the metal from their mothers through breast milk (Lin et al., 2023).

Thank you for publishing with us.

Lead is a heavy metal found in rocks and leaded gasoline (Meena et al., 2020). It has no known nutritional value in contaminated food and water (Philip-Slaboh et al., 2023). When humans ingest lead-contaminated food and water, the metal can remain bound to albumin in the blood for up to 30 days (Kumar et al., 2020). In the bone, it could remain bound for about 20 years (Charkiewicz & Backstrand, 2020). Lead from the bone can bond with albumin and enter breast milk when the Calcium level in breast milk is low (Philip-Slaboh et al., 2023). Therefore, a breastfeeding mother will continue to shed Lead for several days or months after the initial exposure (Samiee et al., 2019). Given that the exposed lactating mother may excrete lead into her breast milk, the newborn is thus at risk of Lead ingestion.

When a newborn ingests Lead, it affects many different body systems. Lead inactivates enzymes, weakens antioxidants, increases oxidative stress, changes Red Blood Cell parameters, and destroys immune-mediated cells (Fu & Xi, 2020). It also causes toxicity to bone marrow precursors, which prevents cell division enzymes from working and impairs red blood cell transport (Debnath et al., 2019). Invariably, exposure to Lead can have lasting damaging effects on newborns.

One of the initial measures to safeguard newborns is to analyze literature and comprehend the concentration of Lead in the breast milk of lactating mothers residing in environments contaminated with Lead (Charkiewicz & Backstrand, 2020). Presently, there are very few reviews of observational studies investigating the levels of Lead in the breast milk of lactating mothers living in environments polluted with Lead within the past ten years. The objective of this review is to summarize the evidence documented in observational studies that are available.

2. Methodology

This study systematically reviewed the evidence on the levels of Lead in the breast milk of lactating mothers' resident in lead-contaminated environments. This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Ethical approval for this study was waived by the relevant Institutional Review Board since it utilized data from secondary sources.

Eligibility criteria

This study defined the inclusion criteria of original studies as follows: (1) Community-based observational studies (cohort and cross-sectional studies); (2) participants aged between 15 and 49 years (childbearing age); (3) Lead metal; (4) lactating mothers; (5) full-text papers published between 2013 and 2023 (10 years); and (6) published in peer-reviewed journals. This study applied this timeframe to focus on the most up-to-date evidence that measured Lead concentration with standardized methods. This study expected that similar assessments and units of measurement would increase comparability between studies. This study set the exclusion criteria as follows: (1) studies not published in English; (2) studies including patients with pre-specified health conditions; (3) studies including participants taking medication during the investigation; and (4) studies involving colostrum's and transitional milk samples at 1-14 days postpartum due to high mineral and protein composition (John et al., 2019).

Search strategy

This study systematically searched the literature in *PubMed/MEDLINE* and *EBSCO essentials* databases to identify studies on Lead in the breast milk of lactating mothers' resident in lead-contaminated environments published between 1 January 2013 and 25 April 2023. This study developed a search string using a combination of key terms linked with Boolean operators, parentheses, and quotation marks as follows: (Lead OR Pb) AND (Breast Milk) AND (Lactating OR "Nursing Mothers"). Quotation marks searched for exact terms or expressions. Parentheses indicate a group of search terms or combine two or more groups of search terms to enable all possible combinations of sentences. This study applied the publication date filter for 10 years as advocated by Higgins et al. (2019) for up-to-date evidence. This study completed the search in the online databases and exported the results to a Microsoft Office Excel® document (Microsoft Corporation, Redmond, Washington, USA). Additionally, this study manually checked the lists of references of all included papers to identify additional relevant literature through hand search.

Study selection process

Two authors (CO and CE) independently screened the retrieved study titles and abstracts in line with the inclusion/exclusion criteria. The two authors retrieved and reviewed full-text copies of the studies for eligibility. They resolved discrepancies in entries into their independent study matrix in Microsoft Office Excel documents by dialogue and consensus. Whenever the two authors (CO and CE) could not agree, the two other more experienced authors (AM and CI) stepped in to resolve the discrepancy.

Data collection process

The two authors (CO and CE) independently extracted relevant data from each paper included in the review using spreadsheets in Microsoft Office Excel. The extracted data were: authors and year of publication, country, study design, population, analytical method, and Lead concentration in breast milk (Mean). The two authors (CO and CE) compared the two data extraction forms and resolved disagreements by consensus.

Study quality assessment

The two authors (CO and CE) independently assessed the quality of the included studies and resolved any discrepancies by dialogue and consensus. They examined the quality of the studies with the Critical Appraisal Skill Programme (CASP) Checklist for Cohort Studies tool. This tool guided the authors in focusing on the internal validity of the studies. The CASP Checklist has 13 rated study characteristics. Each of the items had "yes (Rated as 1)," "no (Rated as 0)," and "Can't tell (Rated as 0)" rating options.

Synthesis methods

Results from the included studies were organized around analytical methods used. The mean values of Lead in breast milk were documented. A vote count was done to identify the proportion of studies that reported values above the World Health Organization (WHO) recommended limits and those that reported normal levels of Lead in breast milk. A pooled mean was calculated to expedite comparison with the WHO reference limits and across studies.

3. Results

Figure 1 shows the study selection process on a PRISMA flow chart. The database search yielded 1,495 studies and 4 studies were further identified by hand-searching (n = 1499). A total of 1,218 duplicates were removed and the remaining 281 studies were screened by title and abstract. A further 271 studies were excluded during full-text screening for eligibility. Thus 10 studies were included in the review of which nine were cross-sectional studies and one was a prospective cohort study.

Table 1 showed the CASP quality score and characteristics of the included studies. No study obtained the highest quality score due to non-measurement of exposure, non-identification of confounding factors, and no adjustment for confounding factors in the design and/or analysis. Thus, the score ranged between 7 and 9 out of a maximum score of 13. The studies were published were conducted in Europe, Asia, and Africa and published between 2013 and 2023. All the included studies considered data from mature breast milk collected between 15 and 90 days postpartum (2 weeks to 3 months). All the included studies obtained breast milk by manual expression. Majority (70%) of the included studies specified that breast milk was stored at -20ºC until laboratory analysis. The level of Lead in breast milk ranged between 0.40 and 2,930 µg/L.

Table 2 shows a synthesis of evidence from the included studies. Majority (80%) of the included studies found Lead in breast milk above the WHO limits while 20% found it to be below WHO limit (5 µg/L). The studies had a pooled mean of 306.12 (873.74) µg/L.

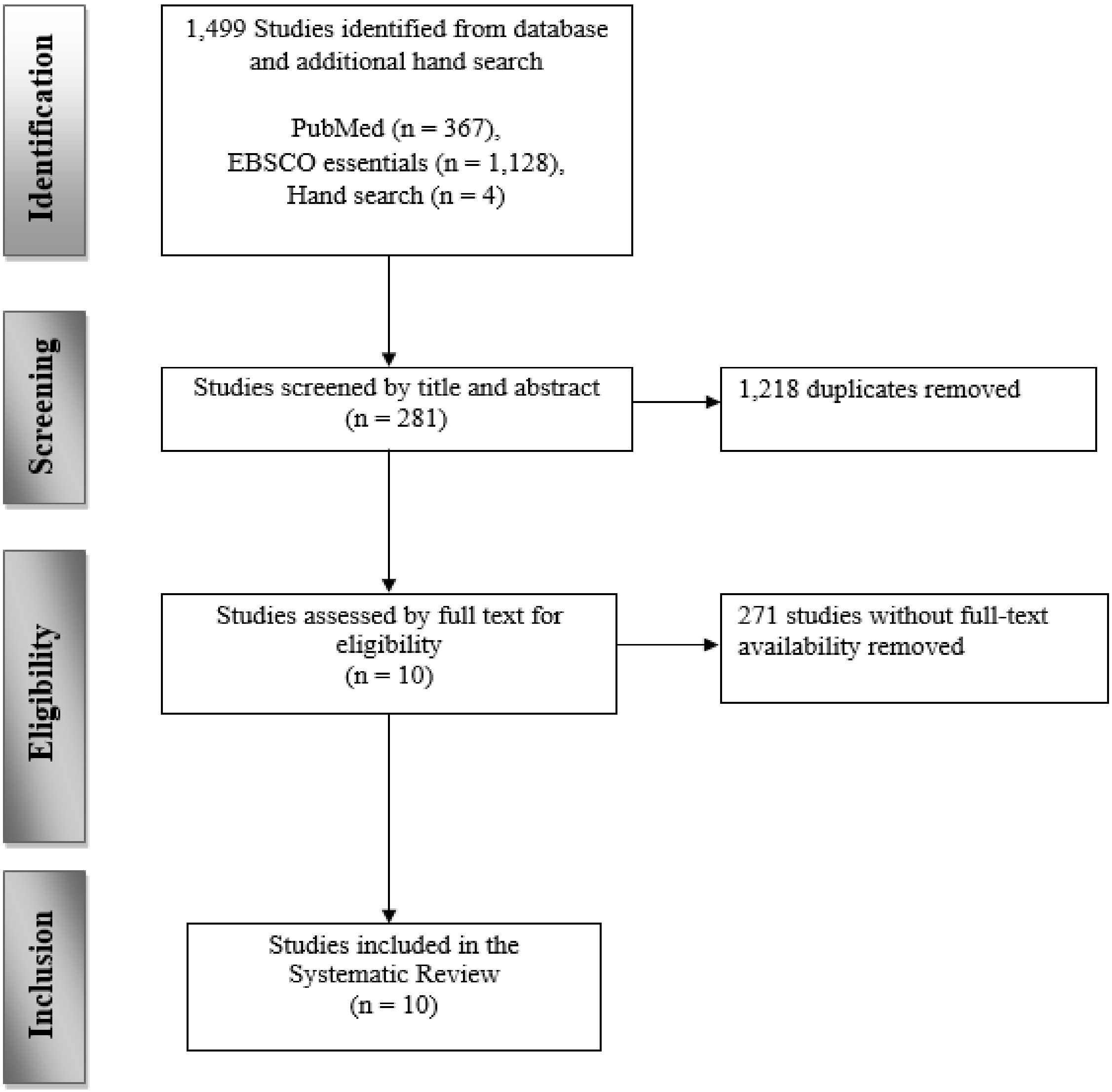

Figure 1: PRISMA flow chart of the study.

Table 1: CASP quality score and characteristics of the included studies (*n = 10*)

Study	Country	CASP score	Design	Sample size	Specimen	Analytical tool	Results on Lead in mature breast milk
Chao et al. (2014)	Taiwan	8	Cross-sectional	45 Purposively selected lactating women	15 mL Breast milk expressed at 2 months post-partum and stored at -80ºC until analysis	Graphite Furnace Atomic Absorption Spectrometer	2.93 (1.70) µg/mL (=2,930 µg/L)
Soleimani, et al. (2014)	Iran	8	Cross-sectional	43 Purposively selected lactating women	10-20 mL Breast milk expressed at 2 months post-partum and stored at -20ºC until analysis	Atomic Absorption Spectrophotometer	23.66(22.3) µg/L
Winiarska-Mieczan (2014)	Poland	9	Cross-sectional	320 Purposively selected lactating women	25 mL Breast milk expressed at 2 months post-partum and stored at -20ºC until analysis	Graphite Furnace Atomic Absorption Spectrometer	6.33 µg/L
Bansa, et al. (2017)	Ghana	9	Prospective cohort	114 Purposively selected lactating women	5 mL of Breast milk expressed at 3 months post-partum	Inductively Coupled Plasma Mass Spectrometer	13.80 ng/ml (= 13.80 µg/L)
Khanjani et al. (2018)	Iran	7	Cross-sectional	100 Purposively selected lactating women	5 mL of Breast milk expressed not less than 15 days post-partum	Graphite Furnace Atomic Absorption Spectrometer	53.60 (64.9) µg/L
Sadeghi et al. (2020)	Iran	7	Cross-sectional	160 Purposively selected lactating women	10-20 mL of Breast milk expressed not less than 15 days post-partum and stored at -20ºC until analysis	Anodic Stripping Voltammeter	7.15 (5.96) µg/L
Shawahna (2021)	West Bank Palestine	8	Cross-sectional	80 Purposively selected lactating women	5 mL of Breast milk after 15 days post-partum and stored at -20ºC until analysis	Inductively Coupled Plasma Mass Spectrometer	0.40 (0.20-0.40) µg/dL (= 4.00 µg/L)
Motas et al. (2021)	Spain	7	Cross-sectional	50 Purposively selected lactating women	50 mL of Breast milk after 1 month post-partum and stored at -20ºC until analysis	Inductively Coupled Plasma Mass Spectrometer	5.20 (16.7) µg/L
Toyomaki, et al. (2021)	Zambia	8	Cross-sectional	418 Purposively selected lactating women	5 mL of Breast milk after 15 days post-partum and stored at -20ºC until analysis	Atomic Absorption Spectrometer	5.30 µg/L
Philip-Slaboh et al. (2023)	Nigeria	8	Cross-sectional	75 Purposively selected non-diabetic lactating women	10 mL Breast milk expressed at 2 months post-partum and stored at -20ºC until analysis	Atomic Absorption Spectrophotometer	12.24 (5.13) ng/mL (=12.24 µg/L)

Table 2: Synthesis of evidence (*n = 10*)

Study	Country	Design	Analytical tool	Results on Lead in mature breast milk	WHO limit	Direction
Chao et al. (2014)	Taiwan	Cross-sectional	Graphite Furnace Atomic Absorption Spectrometer	2.93 µg/mL (=2,930 µg/L)	5.00 µg/L	↓
Winiarska-Mieczan (2014)	Poland	Cross-sectional	Graphite Furnace Atomic Absorption Spectrometer	6.33 µg/L	5.00 µg/L	↑
Khanjani et al. (2018)	Iran	Cross-sectional	Graphite Furnace Atomic Absorption Spectrometer	53.60 µg/L	5.00 µg/L	↑
Bansa, et al. (2017)	Ghana	Prospective cohort	Inductively Coupled Plasma Mass Spectrometer	13.80 ng/ml (= 13.80 µg/L)	5.00 µg/L	↑
Shawahna (2021)	West Bank Palestine	Cross-sectional	Inductively Coupled Plasma Mass Spectrometer	0.40 µg/dL (= 4.00 µg/L)	5.00 µg/L	↓
Motas et al. (2021)	Spain	Cross-sectional	Inductively Coupled Plasma Mass Spectrometer	5.20 µg/L	5.00 µg/L	↑
Soleimani, et al. (2014)	Iran	Cross-sectional	Atomic Absorption Spectrophotometer	23.66 µg/L	5.00 µg/L	↑
Toyomaki, et al. (2021)	Zambia	Cross-sectional	Atomic Absorption Spectrometer	5.30 µg/L	5.00 µg/L	↑
Philip-Slaboh et al. (2023)	Nigeria	Cross-sectional	Atomic Absorption Spectrophotometer	12.24 ng/mL (=12.24 µg/L)	5.00 µg/L	↑
Sadeghi et al. (2020)	Iran	Cross-sectional	Anodic Stripping Voltammeter	7.15 µg/L	5.00 µg/L	↑
Pooled mean				**306.12 (873.74) µg/L**	**5.00 µg/L**	↑

↑ *= above WHO limits,* ↓ *= below WHO limits*

4. Discussion

This study reviewed the levels (concentration) of Lead metal in the breast milk of lactating mothers in Lead-contaminated environments and found that most of the included studies found Lead in breast milk above the WHO limit. The pooled mean of reported levels in included studies was approximately 61 times the maximum WHO limit. The possible reason for this finding is that high levels of lead in the contaminated environment (air, water, and soil) may have been ingested by the lactating mothers and physiologically mobilized into their breast milk.

This finding is partly consistent with a meta-analysis of 23 studies on lead levels in breast milk published by Mohammadi et al. (2022) found a mean lead concentration of 25.61 µg/L which is higher than the WHO limit of 5 µg/L. The findings of Mohammadi et al. (2022) demonstrate that the majority of the evidence reported Lead levels in breast milk higher than 5 µg/L, thus aligning with the findings of this study. The similarity in findings was not expected given that Mohammadi et al. (2022) reviewed only studies conducted in Iran. Ghorani-Azam et al. (2016) noted that inadequate legislation and a lack of appropriate policies in Iran result in higher levels of environmental pollution. The high exposure in Iran may have resulted in the accumulation of inhaled and ingested Lead metal which found its way into breast milk. Additionally, in a study conducted in southeast Nigeria, Ekeanyanwu et al. (2020) reported a mean lead level in breast milk of 38.0 (1.3) µg/L which exceeds the WHO limit. The possible reason for the similarity in findings could be linked to Lead-contaminated borehole water sources that are widespread in southeast Nigeria as reported by Egbueri and Enyigwe (2020).

The results of this study did not support some previously published literature. Neshat et al. (2022) noted in a meta-analysis of 32 studies that the average concentration of Lead in breast milk was 0.03 µg/L and lower than the WHO limit of 5 µg/L. Additionally, the pooled mean concentration of Lead in breast milk (306.12 µg/L) reported in this study was significantly higher than that reported by Neshat et al. (2022). Since Neshat et al. (2022) included studies older than 2013, the results of this study suggest that Lead levels in breast milk may be rising. Siddique (2023) explained that the recent increase in Lead levels in breast milk could be due to rising global industrialization, which leads to increased pollution of the environment with toxic heavy metals.

5. Conclusion

This study reviewed the evidence on the level of Lead in the breast milk of lactating women in a Lead-contaminated environment and found that most of the studies included in this review found that Lead levels in breast milk exceeded the limit established by the World Health Organization (WHO). Combining the results from all the studies, the mean Lead concentration in breast milk was about 61 times higher than the WHO limit. Enhancing awareness and implementing actions to tackle the sources of Lead pollution in the environment is recommended, particularly in regions where breastfeeding is common.

Conflicts of Interest

Authors declare that there is no conflict of interest

References

Bansa, D., Awua, A., Boatin, R., Adom, T., Brown-Appiah, E., Amewosina, K., & Okwabi, W. (2017). Cross-sectional assessment of infants' exposure to toxic metals through breast milk in a prospective cohort study of mining communities in Ghana. BMC Public Health, 17(1), 1-12.

Chao, H., Guo, C., Huang, C., Chen, P., Li, H., Hsiung, D., & Chou, Y. (2014). Arsenic, cadmium, lead, and aluminium concentrations in human milk at early stages of lactation. Pediatrics & Neonatology, 55(2), 127-134.

Charkiewicz, A., & Backstrand, J. (2020). Lead toxicity and pollution in Poland. International Journal of Environmental Research and Public Health, 17(12), e4385.

Christian, P., Smith, E., Lee, S., Vargas, A., Bremer, A., & Raiten, D. (2021). The need to study human milk as a biological system. The American Journal of Clinical Nutrition, 113(5), 1063-1072.

Debnath, B., Singh, W., & Manna, K. (2019). Sources and toxicological effects of lead on human health. Indian Journal of Medical Specialities, 10(2), e66.

Egbueri, J., & Enyigwe, M. (2020). Pollution and ecological risk assessment of potentially toxic elements in natural waters from the Ameka metallogenic district in southeastern Nigeria. Analytical Letters, 53(17), 2812-2839.

Ekeanyanwu, C., Alisi, C., & Ekeanyanwu, R. (2020). Levels of Aflatoxin M1 and selected heavy metals (Pb, Cd, Cr, Cu, Zn, Fe, As, and Hg) in the breast milk of lactating mothers in South Eastern, Nigeria . Food Control, 112(1), e107150.

Fu, Z., & Xi, S. (2020). The effects of heavy metals on human metabolism. Toxicology mechanisms and methods, 30(3), 167-176.

Fuller, R., Landrigan, P., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., & Yan, C. (2022). Pollution and health: a progress update. The Lancet Planetary Health, 6(6), e535-547.

Ghorani-Azam, A., Riahi-Zanjani, B., & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. Journal of Research in Medical Sciences, 21(1), 65.

Higgins, J., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M., & Welch, V. (2019). Cochrane handbook for systematic reviews of interventions. John Wiley & Sons.

John, A., Sun, R., Maillart, L., Schaefer, A., Hamilton-Spence, E., & Perrin, M. (2019). Macronutrient variability in human milk from donors to a milk bank: Implications for feeding preterm infants. PLoS ONE, 14(1), e0210610.

Khanjani, N., Jafari, M., & Ahmadi-Mousavi, E. (2018). Breast milk contamination with lead and cadmium and its related factors in Kerman, Iran. Journal of Environmental Health Science and Engineering, 16(1), 323-335.

Koletzko, B., Hirsch, N., Jewell, J., Dos-Santos, Q., Breda, J., Fewtrell, M., & Weber, M. (2020). National recommendations for infant and young child feeding in the World Health Organization European Region. Journal of Pediatric Gastroenterology and Nutrition, 71(5), e672.

Kumar, A., Kumar, A., MMS, C., Chaturvedi, A., Shabnam, A., Subrahmanyam, G., & Yadav, K. (2020). Lead toxicity: health hazards, influence on food chain, and sustainable remediation approaches. International Journal of Environmental Research and Public Health, 17(7), e2179.

Lin, Y., Chang, W., Li, T., Iwata, O., & Chen, H. (2023). Health risk of infants exposed to lead and mercury through breastfeeding. Exposure and Health, 15(1), 255-267.

Meena, V., Dotaniya, M., Saha, J., Das, H., & Patra, A. (2020). Impact of lead contamination on agroecosystem and human health. Lead in Plants and the Environment, 1(1), 67-82.

Mohammadi, S., Shafiee, M., Faraji, S., Rezaeian, M., & Ghaffarian-Bahraman, A. (2022). Contamination of breast milk with lead, mercury, arsenic, and cadmium in Iran: A systematic review and meta-analysis. BioMetals, 35(4), 711-728.

Motas, M., Jiménez, S., Oliva, J., Cámara, M., & Pérez-Cárceles, M. (2021). Heavy metals and trace elements in human breast milk from industrial/mining and agricultural zones of southeastern Spain. International Journal of Environmental Research and Public Health, 18(17), e9289.

Neshat, A., Oghazyan, A., Kariminejad, F., Mahmudiono, T., Fakhri, Y., Asadi, A., & Khaneghah, A. (2022). The concentration of potentially toxic elements (PTEs) in human milk: A systematic review, meta-analysis, and health risk assessment. Journal of Food Composition and Analysis, 115(1), 104933.

Pajewska-Szmyt, M., Sinkiewicz-Darol, & Gadzała-Kopciuch, R. (2019). The impact of environmental pollution on the quality of mother's milk. Environmental Science and Pollution Research, 26(1), 7405-7427. https://doi.org/10.1007/s11356-019-04141-1.

Philip-Slaboh, T., Eleke, C., & Ezejiofor, A. (2023). Comparison of toxic heavy metals in the breast milk of diabetic and non-diabetic postpartum mothers in Yenagoa, Nigeria. PLoS ONE, 18(4), e0264658.

Sadeghi, N., Jannat, B., Behzad, M., Oveisi, M., Hajimahmoodi, M., & Ahmadi, F. (2020). Determination of zinc, copper, lead and cadmium concentration in breastmilk by anodic stripping voltammetry method and investigating their impact on infants' growth indicators. Human Health and Halal Metrics, 1(2), 24–30.

Samiee, F., Vahidinia, A., Javad, M., & Leili, M. (2019). Exposure to heavy metals released to the environment through breastfeeding: A probabilistic risk estimation. Science of the Total Environment, 650(1), 3075-3083.

Shawahna, R. (2021). Breast milk to blood lead ratios among women from the West Bank of Palestine: a cross-sectional study of associated factors. International Breastfeeding Journal, 16(1), 1-13.

Siddique, H. (2023). Industrialization, energy consumption, and environmental pollution: Evidence from South Asia. Environmental Science and Pollution Research, 30(2), 4094-4102.

Soleimani, S., Shahverdy, M., Mazhari, N., Abdi, K., Nejad, S., Shams, S., & Khaghani, S. (2014). Lead concentration in breast milk of lactating women who were living in Tehran, Iran. Acta Medica Iranica, 56-59.

Toyomaki, H., Yabe, J., Nakayama, S., Yohannes, Y., Muzandu, K., Mufune, T., & Ishizuka, M. (2021). Lead concentrations and isotope ratios in blood, breastmilk and feces: Contribution of both lactation and soil/dust exposure to infants in a lead mining area, Kabwe, Zambia. Environmental Pollution, 286(1), e117456.

Ukaogo, P., Ewuzie, U., & Onwuka, C. (2020). Environmental pollution: causes, effects, and the remedies. Microorganisms for Sustainable Environment and Health, 1(1), 419-429. https://doi.org/10.1016/B978-0-12-819001-2.00021-8.

Vahidinia, A., Samiee, F., Faradmal, J., Rahmani, A., Taravati-Javad, M., & Leili, M. (2019). Mercury, lead, cadmium, and barium levels in human breast milk and factors affecting their concentrations in Hamadan, Iran. Biological Trace Element Research, 187(1), 32-4.

Winiarska-Mieczan, A. (2014). Cadmium, lead, copper and zinc in breast milk in Poland. Biological trace element research, 157(1), 36-44.0

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