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# ORIGINAL ARTICLE

## Mineral levels in lactating Lagos women: blood-breast milk correlation and environmental-nutritional influences

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## ABSTRACT

### BACKGROUND
Lifestyle choices and environmental exposure to certain materials have been reported to alter the distribution of key electrolytes in the blood and breastmilk of pregnant women and, in some cases, worsen micronutrient deficiencies. This study aimed to determine the association of sodium, iron, potassium, and calcium ions in maternal blood with those in breast milk and how maternal lifestyle routines could affect the level of these micronutrients.

### METHODS
A cross-sectional study was conducted involving 30 breastfeeding mothers with newborns. They were administered a pre-tested questionnaire following informed consent. Blood and breastmilk specimens were obtained thereafter to determine the serum and breastmilk levels of iron, potassium, sodium, and calcium. Data were analyzed using unpaired t-tests with the significance level of $p<0.05$.

### RESULTS
A significant reduction in serum and breastmilk potassium ion levels ($p<0.001$ for both) was found in lactating women taking vitamin D, vitamin B, calcium, and folic acid supplements, particularly with increased serum iron levels. Conversely, exposure to paints ($p<0.001$), radiation ($p<0.001$), borehole water ($p<0.05$) and tap water ($p<0.05$) increased potassium ion levels in both blood and breastmilk. Notably, significant correlations existed between blood and breastmilk levels of sodium and potassium ions.

### CONCLUSIONS
While breastmilk sodium and potassium ion levels are directly related to the level in the serum, supplemental intake of some vitamins as well as exposure to paints and radiation could significantly reduce blood and breastmilk potassium, thus further worsening the micronutrient deficiency (aka hidden hunger) in pregnant women.

**Keywords:** Blood nutrients, breastmilk nutrients, environmental pollutants, vitamin supplements, hidden hunger

## INTRODUCTION

Global health authorities, including the World Health Organization, universally recommend breastfeeding as the optimal standard for newborn care.[1] A mother's pre-conception, pregnancy, and postpartum nutrition and lifestyle choices significantly influence her child's long-term health. To support fetal development and lactation, mothers require adequate micronutrient levels. The critical 1,000-day period from conception to age two demands sufficient micronutrient intake, ensuring optimal growth and development.[2]

Research has documented worldwide micronutrient shortages. Worldwide estimates of the prevalence of prenatal iron deficiency anemia and zinc deficiencies in pregnant women are around 15–20% and 40%, respectively.[3,4] Estimates of the prevalence of zinc deficiencies in pregnant women range from 15% to 74% worldwide, with estimates of 61% in other regions.[5] Maternal micronutrient deficiencies, particularly of potassium and iron, increase the risk of non-communicable diseases and chronic illnesses in the offspring.[6,7] Micronutrient levels vary significantly among pregnant women, both within and between populations.[3] Undernutrition is common among pregnant women in low-income countries, exacerbating micronutrient deficiencies and potentially harming fetal health.[3] However, micronutrient deficiencies also affect women in high-income nations, despite access to balanced diets.[8] This suggests that factors beyond diet contribute to these deficiencies.

Previous research on micronutrient deficiencies during pregnancy did not account for lifestyle routines when estimating the incidence of nutritional deficiencies worldwide.[8,10] Breast milk nutrient levels vary during lactation, reflecting the mother's micronutrient status. An inadequate diet is the primary cause of micronutrient deficiencies, but lifestyle choices and other factors also play a role.[11] Diet and lifestyle significantly impact lactation and pregnancy, influencing micronutrient availability. Research suggests that micronutrient deficiencies can arise from multiple factors, including inadequate cleanliness, illness, parasite infestation, and poor nutrition.[12] Moreover, micronutrient deficiencies (aka hidden hunger) remains a persistent challenge in African countries such as Nigeria and other developing countries, affecting numerous populations.[13] Maternal malnutrition in Nigeria, particularly micronutrient insufficiency, has been linked to poor diets, food limitations, low socioeconomic levels, and a low body mass index.[14] This suggests that environmental exposures and lifestyle choices may impact micronutrient deficiencies during pregnancy and breastfeeding.

Despite extensive research, the mineral composition of breast milk remains poorly defined, with studies reporting disparate findings. In a study by Sánchez et al.[15], a comparative analysis of breast milk specimens from diverse sources showed substantial variations in the levels of sodium, potassium, calcium, magnesium, iron, selenium, and iodine, and no correlation between the levels of these ions in the blood and breastmilk was evaluated. A cross-sectional study involving 34 lactating women showed that they were at risk of micronutrient deficiency and that there was an association between zinc levels in human milk and plasma of lactating women with full breastfeeding.[16] A study [17] reported on significant reductions in the levels of sodium, potassium, selenium, and zinc in the breastmilk of lactating women and on the causes and implications of low levels and the factors that may be responsible for the reduction. Another cross-sectional study investigated the association between maternal dietary intakes and human milk maternal micronutrient composition in a group of mothers with exclusively breastfed infants. Although maternal intakes were substantially inadequate as compared to average requirement estimates of >40% for calcium, niacin, and vitamins A, B6, and B12, only a few positive associations existed between maternal nutrient intakes and breastmilk micronutrient concentrations.[18]

Previous studies have overlooked the relationship between serum and breastmilk levels of essential minerals such as sodium, potassium, calcium, and iron, as well as the potential impact of dietary intake and environmental exposures on these ions. Notably, despite the large population of lactating women in Lagos, Nigeria, there is a significant knowledge gap regarding the levels of these minerals in breastmilk and blood, as well as the factors influencing their concentrations. This study aimed to address this gap by investigating the correlation of sodium, potassium, calcium, and zinc levels in maternal blood with those in breastmilk among lactating women in Lagos. Additionally, we wished to explore how lifestyle habits affect the presence of these minerals in maternal blood and breastmilk.

## METHODS

### Research design

This observational, non-interventional clinical study was conducted at the Postnatal Wards and Postnatal Clinics of the Department of Obstetrics and Gynecology at Lagos University Teaching Hospital (LUTH). Prior to the study, announcements were made to inform potential participants about the study's objectives and benefits. On each recruitment day, researchers provided detailed explanations of the study to interested participants, emphasizing that participation was entirely voluntary and that they could withdraw at any time without affecting their medical treatment or hospital consultations. The recruitment period spanned from November 2019 to May 2021.

### Study participants

This being a pilot study, convenience sampling was used based on previously published research works[19,20] on related topics and based on the number of participants who indicated interest in participating voluntarily throughout the recruitment period. Thirty subjects who completed the assessments were included in the final statistical analysis.

The study participants were eligible breastfeeding mothers with newborns who gave informed written consent to register for the study. They were selected by applying consecutive non-random sampling in collaboration with the Obstetrics and Gynecology department, Lagos University Teaching Hospital, Lagos, Nigeria. The exclusion criteria for the study were participants who were hypertensive, diabetic, asthmatic, or smokers. Other criteria were complaints of ill health of either the mother or the newborn, and the inability of the mother to express milk.

### Questionnaire administration and sample collection

A mixed method involving the use of a questionnaire (qualitative) and taking blood and breastmilk specimens (quantitative) was used in this study. After obtaining informed consent, each potential study participant was counselled on the study, and relevant information was collected using a structured questionnaire designed for the study. The questionnaire sought information on sociodemographic characteristics (such as marital status, level of education, occupation, lifestyle, and smoking); obstetric variables (such as mode of delivery, gestational age at delivery, previous pregnancies; the number of children, and infant feeding practices); nutritional/dietary history (such as consumption of fish/seafood and nutritional supplements); Thereafter, biological (serum and breastmilk) specimens were obtained from each participant as per study protocol.

### Laboratory assessment of iron, potassium, sodium, and calcium in maternal blood and breastmilk

Five milliliters of venous blood were drawn from the antecubital vein and stored in plain vacutainer tubes, and three to five milliliters of expressed breastmilk was collected into a sterile sample bottle (after the participant cleaned her nipples and washed her hands properly). The blood sample was allowed to clot at room temperature for 20 minutes and centrifuged at 3000 rpm for 15 minutes using an Eppendorf 5415C centrifuge (Eppendorf AG, Germany). The serum was collected in 2mL sterile cryovials. The biological specimens (sera and breastmilk) were properly labeled and stored at -20$^0$C until analysis.

The specimens were analyzed for selected trace elements (zinc, iron, potassium, sodium, and calcium) at the Central Research Laboratory of the University of Lagos using atomic absorption spectroscopy. The stored specimens were brought out of the freezer and allowed to thaw on the workbench and all assays were performed at room temperature as a batch.

### Statistical analysis

Data were analyzed using STATA software version 13 (College Station, TX: StataCorp LP). A test of normality was performed using the Shapiro-Wilk test. Qualitative data were presented as frequencies and percentages while quantitative data were represented as mean ± standard error of mean with the significance level set at 95% using unpaired Student t-test for comparison. Pearson correlation was used to determine the correlation between the blood and breast milk variables.

### Ethical clearance

Ethical approval was obtained from the Health Research Ethics Committee of the College of Medicine, University of Lagos under number CMUL/HREC/06/19/55.

Table 1. General characteristics of the participants (n=30)

| Characteristics | N | Percent |
|---|---|---|
| Age (years) | | |
| 15-34 | 22 | 73 |
| 35-54 | 8 | 27 |
| Marital status | | |
| Single | 2 | 7 |
| Married | 28 | 93 |
| Number of full-term pregnancies | | |
| 1 | 10 | 34 |
| 2 | 7 | 23 |
| 3 | 8 | 27 |
| 4 | 4 | 13 |
| 5 | 1 | 3 |
| Region of origin | | |
| Northern Nigeria | 5 | 17 |
| South East Nigeria | 10 | 33 |
| South South Nigeria | 3 | 10 |
| South West Nigeria | 11 | 37 |
| Foreigner | 1 | 3 |
| Level of education | | |
| Secondary level | 14 | 47 |
| Tertiary level | 16 | 53 |
| Employment | | |
| Unemployed | 3 | 10 |
| Employed | 27 | 90 |
| Mode of delivery | | |
| Vaginal delivery | 17 | 57 |
| Cesarean delivery | 13 | 43 |
| Gestational age delivery | | |
| Preterm (< 37 weeks) | 4 | 13 |
| Term (≥ 37 weeks) | 26 | 87 |
| Parity | | |
| 1 | 10 | 33 |
| 2 | 8 | 27 |
| 3 | 7 | 23 |
| ≥4 | 5 | 17 |
| Cigarette smoking | | |
| Yes | 0 | 0 |
| No | 30 | 100 |
| Period of residence in Lagos | | |
| <120 months | 10 | 33 |
| ≥120 months | 20 | 67 |

Note: data presented as n (%)

## RESULTS

The general characteristics of the participants are presented in Table 1. Most of the participants (73%) were young adults in the age range of 15 to 34 years. They were married and originated from different regions of Nigeria. While their level of education was either secondary or tertiary, they were mostly employed (90%). There was a relatively fair representation of participants with vaginal and cesarean delivery among the participants. All the participants were non-smokers and were residents of Lagos during the study period. Other useful information about the participants is presented in Table 1.

**Comparison of serum levels of sodium, potassium, calcium, and iron between those who took the vitamins and those who did not**

The level of potassium in the serum was significantly lower in participants who took vitamin D (p=0.007), vitamin B (p=0.002), calcium (p=0.004), and folic acid (p=0.000) during pregnancy. The serum level of iron was significantly higher in participants who took vitamin C (p=0.033), vitamin D (p=0.003), vitamin B (p=0.000), and calcium (p=0.001) during pregnancy. This is illustrated in Table 2.

**Comparison of breastmilk levels of sodium, potassium, calcium, and iron between those who took vitamins/minerals and those who did not**

The level of potassium in the breastmilk was significantly lower in participants who took vitamin D (p=0.013), vitamin B (p=0.046), calcium (p=0.004), and folic acid (p=0.023) during pregnancy. The level of sodium was significantly higher (p=0.030) in those who took vitamin B. There were no statistically significant differences in the levels of the other microelements between those who took and those who did not take the supplements, as illustrated in Table 3.

**Comparison of serum levels of sodium, potassium, calcium, and iron between those exposed to environmental factors and those that were not**

The serum level of sodium was significantly higher (p=0.009) in participants who were exposed to caffeine during pregnancy. The serum levels of potassium were significantly higher in participants that were exposed to paints (p=0.000), radiation (p=0.000), borehole water (p=0.029) and tap water (p=0.002) during pregnancy. The serum levels of iron were significantly higher in participants who were exposed to asbestos (p=0.040) but significantly lower in those exposed to borehole water (p=0.029) and tap water (p=0.036) during pregnancy, as illustrated in Table 4.

Table 2. Comparison of serum levels of sodium, potassium, calcium, and iron between those who took vitamins and those who did not

| Supplement taken | Response | Elements | | | |
|---|---|---|---|---|---|
| | | Sodium (ppm) | Potassium (ppm) | Calcium (ppm) | Iron (ppm) |
| Vitamin C | No | 355.20 ± 85.73 | 56.35 ± 14.33 | 17.21 ± 2.34 | 18.43 ± 5.17 |
| | Yes | 455.60 ± 62.13 | 32.47 ± 7.78 | 17.24 ± 1.76 | 42.56 ± 7.12 |
| p value | | 0.355 | 0.120 | 0.992 | 0.033* |
| Vitamin D | No | 400.89 ± 69.46 | 54.72 ± 10.00 | 17.31 ± 1.45 | 23.02 ± 5.55 |
| | Yes | 458.13 ± 68.86 | 15.75 ± 2.09 | 17.09 ± 2.93 | 54.38 ± 8.61 |
| p value | | 0.587 | 0.007** | 0.940 | 0.003** |
| Vitamin B | No | 330.07 ± 72.55 | 63.04 ± 12.15 | 17.65 ± 1.79 | 15.59 ± 3.04 |
| | Yes | 502.69 ± 65.04 | 20.64 ± 4.58 | 16.86 ± 2.12 | 51.08 ± 7.77 |
| p value | | 0.086 | 0.002** | 0.782 | 0.000*** |
| Calcium | No | 350.58 ± 74.03 | 64.53 ± 13.28 | 17.16 ± 2.18 | 13.61 ± 2.51 |
| | Yes | 469.83 ± 66.90 | 24.36 ± 5.82 | 17.28 ± 1.84 | 48.46 ± 7.23 |
| p value | | 0.252 | 0.004** | 0.967 | 0.001*** |
| Folic acid | No | 178.50 ± 27.49 | 133.50 ± 7.50 | 21.10 ± 3.09 | 7.50 ± 0.50 |
| | Yes | 439.54 ± 52.28 | 33.78 ± 5.93 | 16.95 ± 1.46 | 36.44 ± 5.63 |
| p value | | 0.200 | 0.000*** | 0.465 | 0.188 |
| Iron | No | 534.71 ± 129.92 | 58.84 ± 20.79 | 16.03 ± 2.44 | 22.71 ± 6.34 |
| | Yes | 387.87 ± 52.05 | 34.82 ± 6.89 | 17.59 ± 1.67 | 38.11 ± 6.68 |
| p value | | 0.222 | 0.163 | 0.640 | 0.236 |

Note: Values represent as mean ± SEM. Significant difference (*p < 0.05, **p < 0.01, ***p < 0.001)

Table 3. Comparison of breastmilk levels of sodium, potassium, calcium, and iron between those who took vitamins/minerals and those who did not

| Supplement | Response | Element | | | |
|---|---|---|---|---|---|
| | | Sodium (ppm) | Potassium units (ppm) | Calcium units (ppm) | Iron units (ppm) |
| **Vitamin C** | No | 142.40 ± 47.84 | 23.61 ± 6.97 | 20.07 ± 1.71 | 24.97 ± 3.78 |
| | Yes | 237.53 ± 47.29 | 14.24 ± 4.24 | 20.99 ± 1.97 | 17.94 ± 2.81 |
| **p value** | | 0.216 | 0.237 | 0.766 | 0.153 |
| **Vitamin D** | No | 163.72 ± 35.74 | 24.15 ± 5.23 | 20.39 ± 1.79 | 22.81 ± 3.28 |
| | Yes | 278.55 ± 73.08 | 5.64 ± 0.71 | 21.18 ± 2.39 | 15.92 ± 2.38 |
| **p value** | | 0.124 | 0.013* | 0.792 | 0.153 |
| **Vitamin B** | No | 124.19 ± 39.81 | 25.16 ± 5.45 | 18.95 ± 2.25 | 20.79 ± 2.88 |
| | Yes | 277.25 ± 52.16 | 10.54 ± 4.48 | 22.19 ± 1.75 | 19.83 ± 3.59 |
| **p value** | | 0.030* | 0.046* | 0.261 | 0.839 |
| **Calcium** | No | 139.00 ± 35.13 | 29.63 ± 7.38 | 19.56 ± 1.67 | 25.29 ± 4.37 |
| | Yes | 250.37 ± 53.14 | 9.18 ± 2.28 | 21.43 ± 2.09 | 16.94 ± 2.29 |
| **p value** | | 0.129 | 0.004** | 0.526 | 0.076 |
| **Folic acid** | No | 83.50 ± 18.48 | 48.00 ± 4.99 | 24.50 ± 1.49 | 28.00 ± 2.00 |
| | Yes | 214.56 ± 37.86 | 15.17 ± 3.59 | 20.41 ± 1.49 | 19.73 ± 2.44 |
| **p value** | | 0.371 | 0.023* | 0.479 | 0.380 |
| **Iron** | No | 271.14 ± 74.06 | 22.16 ± 7.87 | 24.00 ± 2.97 | 15.57 ± 4.10 |
| | Yes | 185.94 ± 40.91 | 15.90 ± 4.21 | 19.67 ± 1.58 | 21.71 ± 2.71 |
| **p value** | | 0.323 | 0.482 | 0.199 | 0.267 |

Key: Values represent mean ± SEM. Significant difference (*p < 0.05, **p < 0.01)

Table 4. Comparison of serum levels of sodium, potassium, calcium, and iron between those exposed to environmental factors and those that were not

| Pollutants | Response | Element | | | |
|---|---|---|---|---|---|
| | | Sodium (ppm) | Potassium units (ppm) | Calcium units (ppm) | Iron units (ppm) |
| **Lipsticks** | No | 474.06 ± 71.93 | 36.92 ± 9.67 | 14.80 ± 1.50 | 32.27 ± 6.76 |
| | Yes | 362.79 ± 68.78 | 44.44 ± 11.09 | 20.01 ± 2.25 | 37.09 ± 8.90 |
| **p value** | | 0.277 | 0.612 | 0.059 | 0.665 |
| **Kohl/Lead use** | No | 483.78 ± 66.91 | 35.99 ± 9.16 | 15.43 ± 1.47 | 32.85 ± 6.17 |
| | yes | 329.67 ± 70.42 | 47.08 ± 11.90 | 19.93 ± 2.55 | 37.02 ± 10.22 |
| **p value** | | 0.135 | 0.461 | 0.112 | 0.714 |
| **Hair dyes** | No | 428.78 ± 52.99 | 39.09 ± 7.85 | 16.50 ± 1.47 | 35.65 ± 5.78 |
| | Yes | 362.33 ± 188.11 | 52.43 ± 15.83 | 23.80 ± 0.76 | 24.33 ± 17.34 |
| **p value** | | 0.699 | 0.588 | 0.115 | 0.541 |
| **Dental prosthetics** | No | 465.20 ± 56.46 | 39.63 ± 7.94 | 17.61 ± 1.54 | 31.82 ± 5.60 |
| | Yes | 209.25 ± 19.65 | 49.90 ± 23.67 | 17.68 ± 3.11 | 35.75 ± 14.78 |
| **p value** | | 0.086 | 0.643 | 0.987 | 0.798 |
| **Insecticide use** | No | 434.88 ± 83.32 | 39.24 ± 15.57 | 16.85 ± 2.99 | 29.41 ± 11.29 |
| | Yes | 417.5 ± 62.50 | 40.86 ± 8.28 | 17.36 ± 1.58 | 36.37 ± 6.26 |
| **p value** | | 0.882 | 0.923 | 0.872 | 0.579 |
| **Exposure to cigarette smoke** | No | 400.54 ± 56.51 | 36.01 ± 6.83 | 17.61 ± 1.67 | 35.51 ± 5.67 |
| | Yes | 508.50 ± 112.04 | 58.10 ± 23.93 | 15.70 ± 1.94 | 30.55 ± 15.99 |
| **p value** | | 0.399 | 0.227 | 0.589 | 0.721 |
| **Exposure to paints** | No | 446.55 ± 53.77 | 31.88 ± 5.84 | 16.66 ± 1.49 | 37.42 ± 5.76 |
| | Yes | 202.33 ± 28.64 | 117.33 ± 16.74 | 22.33 ± 2.17 | 8.33 ± 0.88 |
| **p value** | | 0.148 | 0.000** | 0.225 | 0.109 |
| **Exposure to radiation** | No | 439.54 ± 52.28 | 33.78 ± 5.93 | 16.95 ± 1.46 | 36.45 ± 5.63 |
| | Yes | 178.50 ± 27.49 | 133.5 ± 7.50 | 21.10 ± 3.09 | 7.50 ± 0.50 |
| **p value** | | 0.200 | 0.000** | 0.465 | 0.188 |
| **Exposure to asbestos** | No | 447.30 ± 66.40 | 45.34 ± 8.94 | 17.55 ± 1.76 | 26.88 ± 4.99 |
| | Yes | 394.89 ± 77.62 | 32.78 ± 13.46 | 16.78 ± 2.59 | 51.44 ± 13.10 |
| **p value** | | 0.644 | 0.442 | 0.809 | 0.040 |
| **Caffeine** | No | 388.32 ± 47.48 | 41.85 ± 7.67 | 17.58 ± 1.46 | 31.80 ± 5.17 |
| | Yes | 895.50 ± 71.50 | 20.55 ± 1.05 | 12.50 ± 1.49 | 72.50 ± 33.50 |
| **p value** | | 0.009 | 0.471 | 0.370 | 0.059 |
| **Borehole water** | No | 434.32 ± 59.46 | 32.88 ± 8.04 | 16.65 ± 1.69 | 41.23 ± 6.63 |
| | Yes | 303.60 ± 107.23 | 75.68 ± 15.29 | 21.54 ± 2.66 | 8.46 ± 1.99 |
| **p value** | | 0.343 | 0.029* | 0.209 | 0.029* |
| **Tap water** | No | 446.32 ± 59.98 | 30.57 ± 6.81 | 16.37 ± 1.68 | 40.56 ± 6.76 |
| | Yes | 237.17 ± 63.29 | 85.38 ± 16.46 | 22.47 ± 1.71 | 11.33 ± 2.42 |
| **p value** | | 0.095 | 0.002 | 0.082 | 0.036 |

Key: Values represent Mean ± SEM. Significant difference (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$)

Table 5. Comparison of levels of sodium, potassium, calcium, and iron in the serum between those exposed to the environmental factors and those who were not

| Pollutants | Response | Element | | | |
|---|---|---|---|---|---|
| | | Sodium (ppm) | Potassium units (ppm) | Calcium units (ppm) | Iron units (ppm) |
| **Lipsticks** | No | 205.23 ± 41.78 | 15.89 ± 4.76 | 19.84 ± 1.73 | 17.99 ± 2.61 |
| | Yes | 206.50 ± 61.90 | 19.04 ± 5.88 | 21.64 ± 2.33 | 22.89 ± 3.93 |
| **p value** | | 0.986 | 0.677 | 0.533 | 0.297 |
| **Kohl/Lead use** | No | 211.31 ± 37.63 | 14.73 ± 4.38 | 20.41 ± 1.55 | 19.49 ± 2.84 |
| | Yes | 197.58 ± 71.85 | 21.30 ± 6.52 | 21.08 ± 2.74 | 21.46 ± 4.00 |
| **p value** | | 0.855 | 0.392 | 0.820 | 0.684 |
| **Dye of hair** | No | 212.76 ± 39.21 | 16.99 ± 4.01 | 21.05 ± 1.52 | 19.56 ± 2.52 |
| | Yes | 143.33 ± 64.94 | 20.63 ± 9.05 | 17.33 ± 3.28 | 26.73 ± 1.73 |
| **p value** | | 0.570 | 0.773 | 0.439 | 0.359 |
| **Dental prosthetics** | No | 218.86 ± 40.95 | 17.57 ± 4.27 | 20.71 ± 1.64 | 18.44 ± 2.42 |
| | Yes | 155.25 ± 81.87 | 18.00 ± 8.19 | 20.93 ± 3.01 | 30.72 ± 6.87 |
| **p value** | | 0.561 | 0.969 | 0.960 | 0.075 |
| **Insecticide use** | No | 166.45 ± 62.49 | 17.43 ± 8.39 | 19.09 ± 2.70 | 17.24 ± 3.28 |
| | Yes | 220.14 ± 43.66 | 17.34 ± 4.13 | 21.26 ± 1.68 | 21.38 ± 2.91 |
| **p value** | | 0.517 | 0.992 | 0.506 | 0.436 |
| **Exposure to cigarette smoke** | No | 197.78 ± 41.88 | 16.63 ± 4.11 | 20.06 ± 1.61 | 20.98 ± 2.72 |
| | Yes | 238.00 ± 68.42 | 20.30 ± 8.95 | 23.17 ± 2.91 | 17.48 ± 3.94 |
| **p value** | | 0.661 | 0.697 | 0.388 | 0.553 |
| **Exposure to paints** | No | 215.61 ± 39.27 | 12.88 ± 2.87 | 20.53 ± 1.55 | 18.27 ± 2.03 |
| | Yes | 117.67 ± 35.79 | 57.67 ± 10.09 | 22.00 ± 2.64 | 38.33 ± 10.39 |
| **p value** | | 0.422 | **0.000** | 0.761 | **0.007** |
| **Exposure to radiation** | No | 214.56 ± 37.86 | 15.17 ± 3.59 | 20.41 ± 1.49 | 19.73 ± 2.44 |
| | Yes | 83.50 ± 18.49 | 48.00 ± 4.99 | 24.50 ± 1.49 | 28.00 ± 2.00 |
| **p value** | | 0.371 | **0.023** | 0.479 | 0.380 |
| **Exposure to asbestos** | No | 234.85 ± 50.04 | 19.67 ± 5.05 | 20.89 ± 1.72 | 20.29 ± 3.09 |
| | Yes | 162.56 ± 36.21 | 13.63 ± 4.91 | 21.78 ± 2.36 | 21.70 ± 3.30 |
| **p value** | | 0.368 | 0.471 | 0.769 | 0.785 |
| **Caffeine** | No | 192.66 ± 36.03 | 17.96 ± 3.92 | 19.69 ± 1.32 | 20.71 ± 2.43 |
| | Yes | 390.00 ± 175.99 | 8.90 ± 3.40 | 34.50 ± 1.49 | 14.30 ± 6.59 |
| **p value** | | 0.174 | 0.549 | **0.007** | 0.498 |
| **Borehole water** | No | 219.66 ± 45.29 | 13.30 ± 3.72 | 22.12 ± 1.69 | 18.96 ± 2.10 |
| | Yes | 114.40 ± 42.69 | 38.46 ± 11.28 | 13.40 ± 1.03 | 29.36 ± 9.44 |
| **p value** | | 0.295 | **0.013** | **0.025** | 0.102 |
| **Tap water** | No | 19.68 ± 2.27 | 216.35 ± 45.64 | 10.83 ± 2.38 | 20.88 ± 1.74 |
| | Yes | 26.50 ± 7.53 | 112.33 ± 38.56 | 44.93 ± 10.71 | 19.67 ± 3.03 |
| **p value** | | 0.248 | 0.262 | **0.000** | 0.744 |

Key: Values represent mean ± SEM. Significant difference (*p < 0.05, **p < 0.01, ***p < 0.001)

Table 6. Correlation of the elements in the serum and breast milk

| Serum | Breast milk | | | |
|---|---|---|---|---|
| | Sodium | Potassium | Calcium | Iron |
| Sodium Correlation coefficient | 0.622 | - | - | - |
| p value | 0.002 | | | |
| Potassium Correlation coefficient | - | 0.864 | - | - |
| p value | | 0.001 | | |
| Calcium Correlation coefficient | - | - | 0.232 | - |
| p value | | | 0.216 | |
| Iron Correlation coefficient | - | - | - | -0.091 |
| p value | | | | 0.629 |

**Comparison of levels of sodium, potassium, calcium, and iron in the breastmilk between those exposed to the environmental factors and those that were not**

The levels of potassium in the breastmilk were significantly higher in participants who were exposed to paints (p=0.000), radiation (p=0.023), and borehole water (p=0.013) during pregnancy. The levels of calcium in the breastmilk were significantly lower in participants who were exposed to borehole water (p=0.025) but significantly higher in those exposed to caffeine (p=0.007) and tap water (p=0.000) during pregnancy. The levels of iron in the breast milk was significantly higher (p=0.007) in participants who were exposed to paints during pregnancy. This is illustrated in Table 5.

**Correlation between elements in the serum and breast milk**

There was a linear relationship between serum and breast milk sodium levels (r=0.622, p=0.002). There was also a linear relationship between blood and breast milk potassium levels (r=0.864, p=0.001) (Table 6).

## DISCUSSION

In this study, intake of some supplements was found to have a profound impact on the blood chemistry of lactating Nigerian women, significantly elevating serum iron levels while reducing serum potassium levels. Interestingly, while breast milk potassium levels mirrored this decrease, iron levels remained unchanged. This highlights the complex relationship between maternal nutrient intake and breast milk composition[23] and the vital role vitamins play in supporting infant growth, immune function, and overall health.[24] Also, our study revealed that exposure to paints, radiation, or consumption of borehole or tap water significantly impacts potassium and iron levels in the blood of lactating women. Notably, increased potassium levels in breast milk were associated with exposure to paints, radiation, or borehole water (for consumption). Additionally, caffeine and tap water consumption were linked to higher calcium levels, whereas borehole water consumption led to reduced calcium levels. In addition, the present study found a strong correlation between blood and breast milk levels of potassium and sodium, but not for calcium and iron. This corroborates existing research suggesting that micronutrient levels in blood are reflected in breastmilk,[19] although conflicting findings have also been reported.[20] Furthermore, this study highlights the influence of environmental factors on human milk composition.[25]

Breastfeeding is a period of high energy and critical nutrient demands. Studies have shown that the therapeutic use of vitamins C and E has not been proven to prevent preeclampsia.[26,27] In this study, participants who took vitamin B as a supplement had significantly higher levels of sodium ions in their breast milk. In this study as well, the potassium levels in blood and breastmilk were significantly lower in participants who took vitamin D, vitamin B, and folic acid during pregnancy. Potassium is an important trace element required for fetal development, thus its level should not be reduced. The pivotal role of potassium ($K^+$) in cardiovascular disease and the importance of preserving potassium balance have become clinical hot points, particularly as it relates to new and emerging cardioprotective and renoprotective therapies that promote potassium retention.[28] In low socioeconomic settings such as Nigeria, supplementation with vitamins is an effective strategy to address nutritional deficiencies.[29]

One study discussed the correlation between different diets and the intake of supplements in pregnancy.[30] Anemia in pregnancy is prevalent in low-income countries[26] and increases the risk of maternal mortality, perinatal mortality, and low birth weight.[31] In our study, serum iron was significantly higher in participants who took vitamins C, D, and B, as well as calcium supplements during pregnancy. The intake of these vitamins should be encouraged in pregnant women in low-income countries such as Nigeria. This finding shows that vitamin intake could help boost blood mineral levels in pregnant women. Also, pregnancy substantially doubles iron demands, therefore iron supplements are frequently advised. Supplementing with vitamin C can help with the absorption of iron.[32] In the present study, iron and vitamin C were part of the supplements taken by the participants.

A significant increase in the serum levels of sodium was observed in participants who were exposed to caffeine during pregnancy. An increase in serum sodium level might be associated with gestational hypertension which might lead to preeclampsia. Other negative outcomes of caffeine intake during pregnancy include low birth weight and childhood overweight and obesity.[33] Our study further shows that pregnant women and women contemplating pregnancy should avoid caffeine. In this study blood and milk potassium levels were significantly higher in participants who were exposed to paints, radiation, borehole water, and tap water. Also, blood iron levels were significantly higher in participants exposed to asbestos while milk iron levels were significantly higher in participants exposed to paints during pregnancy. The concept of developmental origins of health and disease (DOHaD), demonstrates the link between adverse intrauterine development and risk for chronic metabolic consequences such as insulin resistance, obesity, cardiovascular disease, etc. In essence, what the mother consumes or is exposed to has a way of modifying the gene mechanisms of the offspring. Epigenetic modifications are easily affected by environmental factors. Paints, borehole water, and tap water could be termed environmental factors as well as low-dose radiation. Apart from observing heavy metal influences on blood and breast milk,[34] it is important to make routine checks of supplemental intake in pregnancy during ante-natal programs.

One limitation of this study was not taking into consideration the diets of participants viz-a-viz supplementation requirements. Other researchers opine that it is important to take into consideration the diets of pregnant women viz-a-viz supplementation intake even if they do not suffer from metabolic diseases such as obesity.[35]

Pregnant women often take various supplements based on recommendations, but extra caution is necessary when consuming vitamin D, vitamin B, calcium, and folic acid. These supplements can potentially alter potassium ion levels in serum and breastmilk, as observed in lactating women in Lagos. To gain a deeper understanding of these effects, future research should investigate the direct impact of these vitamin supplements on essential micronutrients. This would provide insight into potential causal relationships, underlying mechanisms, and regulatory strategies, ultimately informing better supplementation guidelines.

## CONCLUSION

While breastmilk sodium and potassium ion levels are directly related to the serum levels, supplemental intake of some vitamins as well as exposure to paints and radiation could significantly alter blood and breastmilk potassium and iron, thus further affecting the micronutrient deficiency, also termed “hidden hunger”, in pregnant women.

### Conflicts of Interest

The authors declare they have no conflicts of interest.

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### Author Contributions

OTO is the corresponding author who originated the research concept, prepared the study proposal, wrote the draft, reviewed and finalized the manuscript document. CCM and AAA analyzed the data, interpreted results, wrote the draft, and were involved in the evaluation and finalization of the document. OA and CD were responsible for overseeing participant recruitment, presenting the discussion, and drafting the initial manuscript.

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## Data Availability Statement

The datasets generated and/ or analyzed during the current study are available upon request from the corresponding author.

## Declaration of Use of AI in Scientific Writing

Nothing to declare.

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