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Maternal-to-Child Transmission of Lead, Mercury, Cadmium and Arsenic Among Pregnant Women in Sub-Saharan Africa, and the Associated Maternal and Neonatal Outcomes: A Systematic Review

Peace Chidi Aliche[1], Prof. Catherine Ikewuchi[2], Prof. Faith Diorgu[3], Ezioma Lordson[4]

[1]Department of Nursing, Clifford University, Owerrinta, Abia state Nigeria

[2]Department of Nursing, University of Port Harcourt, Rivers state Nigeria

[3]Department of Nursing, University of Port Harcourt, Rivers state Nigeria

[4]Department of Nursing, Clifford University, Owerrinta, Abia state Nigeria

Corresponding author: *Peace Chidi Aliche* | ***Email:*** *peace_aliche@uniport.edu.ng*

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Abstract

Background: Pregnant women in Sub-Saharan Africa (SSA) live in settings where mining, oil extraction, informal industry and agriculture contaminate water, soil and food with toxic metals. Lead, mercury, cadmium and arsenic can cross the placenta and harm the mother and the developing fetus, yet exposure is rarely assessed in antenatal care.

Purpose: To identify the predominant heavy metals in maternal and neonatal samples in SSA, and to examine maternal-to-child transmission and the associated maternal and neonatal outcomes.

Methods: A systematic review was conducted following PRISMA 2020. Seven databases, grey literature and reference lists were searched for studies of pregnant women or mother-newborn pairs in SSA with maternal or neonatal metal measurements. Study quality was appraised with the Newcastle-Ottawa Scale, Joanna Briggs Institute checklists and AMSTAR-2, and findings were synthesised narratively.

Results: Thirty studies from 870 records were included. Lead was the most frequently reported and elevated metal; maternal blood lead ranged from 5.8 to 59.5 µg/dL. Cord-to-maternal lead ratios were 0.68 to 0.85. Mercury and arsenic showed ratios at or above 1.0 in several studies, whereas cadmium was partly retained by the placenta. Higher burdens were associated with low birth weight (11% to 32% in high-exposure groups), preterm birth, spontaneous abortion, preeclampsia, gestational hypertension and anaemia. Confidence in individual effect estimates was moderate to low, but confidence that exposure is widespread and clinically important was high.

Conclusion: Maternal-to-child transmission of toxic metals is common in SSA and is linked to outcomes that nurses and midwives manage daily. Exposure history-taking, counselling, monitoring and referral can be incorporated into antenatal nursing practice now, while prospective cohort research is urgently needed in South-East Nigeria.

Keywords: *heavy metals; maternal-to-child transmission; antenatal care; midwifery; Sub-Saharan Africa*

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1. Introduction

1.1 Background of the problem

Heavy metal exposure during pregnancy is a major but under-recognised threat to maternal and child health. Lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As) are persistent, non-biodegradable pollutants with reproductive, neurotoxic and teratogenic effects (World Health Organization [WHO], 2022). Pregnancy increases the body's demand for calcium, iron and other minerals, and the fetus is highly sensitive to toxic insult. The placenta, once thought to be a protective barrier, allows several toxic metals to reach fetal circulation, so that maternal exposure becomes fetal exposure. This process is referred to here as maternal-to-child transmission of heavy metals. The burden is concentrated in SSA. Artisanal and small-scale gold mining (ASGM), oil extraction and gas flaring, informal battery recycling, pesticide use and weak waste management contaminate drinking water, locally grown food and air (Orisakwe, 2021; Orisakwe et al., 2023). In the Niger Delta of Nigeria, maternal blood lead concentrations well above 10 µg/dL have been reported (Obi-Ezeani et al., 2019; Udom et al., 2022). In ASGM communities of northern Tanzania, total blood mercury reached 72 µg/L and about three-quarters of the 1,056 pregnant women studied exceeded the reference value (Nyanza et al., 2019). A systematic review of women of child-bearing age across SSA found weighted mean blood lead concentrations above 24 µg/dL (Bede-Ojimadu et al., 2018).

1.2 Significance to nursing

Nurses and midwives provide most antenatal care in SSA. They take the booking history, counsel on diet and behaviour, monitor blood pressure and fetal growth, and refer women with complications. Preeclampsia, gestational hypertension, anaemia, preterm birth, low birth weight and spontaneous abortion are central concerns of midwifery practice, and, as this review shows, each has been linked to maternal metal exposure. Yet environmental exposure assessment is not part of routine antenatal protocols in the region, and nurses and midwives lack evidence-based guidance on how to recognise and respond to it.

1.3 Brief review of the literature and gap

Primary studies describe lead crossing the placenta at 70% to 85% of the maternal blood concentration (Adeyemi et al., 2019; Rahman et al., 2012), methylmercury accumulating

preferentially in the fetus (Bose-O'Reilly et al., 2010), and cadmium being partly retained in placental tissue (Röllin et al., 2015). Studies from Nigeria, Tanzania, Ethiopia, Kenya and South Africa link exposure to low birth weight, preterm birth and hypertensive disorders (Dessalegn et al., 2021; Nyanza et al., 2020; Obi-Ezeani et al., 2019). However, studies differ in the metals measured, the samples taken and the outcomes defined, and metal mixtures may be more harmful than single metals (Issah et al., 2024). No previous synthesis has brought together, across SSA, the predominant metals, the efficiency of transplacental transfer and the associated maternal and neonatal outcomes, with implications for nursing practice. No included study came from Abia State, which lies next to the oil-producing Niger Delta, so evidence for South-East Nigeria is especially scarce.

1.4 Purpose statement

The purpose of this systematic review was to synthesise evidence on maternal-to-child transmission of lead, mercury, cadmium and arsenic among pregnant women in SSA. The specific objectives were (1) to identify the predominant heavy metals detected in maternal and neonatal biological samples, and (2) to examine the rates of maternal-to-child transmission and the associated maternal and neonatal outcomes. The synthesis connects three complementary dimensions of reproductive environmental health: maternal internal exposure, the element-specific behaviour of the placental interface, and outcomes relevant to maternal and neonatal clinical care. This integration offers a practice-oriented contribution beyond describing metal concentrations alone.

2. Methods

2.1 Design

A systematic review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework. The Population, Exposure, Comparison and Outcome (PECO) framework structured eligibility, extraction and synthesis. The guiding question was: What are the extent and patterns of maternal-to-child toxic metal transfer in sub-Saharan Africa, and which maternal and neonatal outcomes are associated with exposure?

2.2 Setting and participants (eligibility criteria)

Population. Pregnant women attending antenatal clinics, women at delivery, or mother-newborn pairs in SSA countries. Global comparator studies that supplied mechanistic or reference data relevant to SSA were also considered.

Exposure. Maternal heavy metal burden measured by validated laboratory methods in whole blood, serum, urine, hair, placental tissue, breast milk or cord blood. Metals of interest were lead, cadmium, mercury, arsenic, chromium, nickel, manganese and other toxic metals.

Comparison. Higher versus lower exposure, exposed versus unexposed or reference groups, different metals, or different environmental sources.

Outcomes. At least one of: maternal-to-child transmission (cord blood, placental or neonatal concentrations and ratios); maternal outcomes (preeclampsia, gestational hypertension, anaemia, spontaneous abortion); or neonatal outcomes (low birth weight, preterm birth, intrauterine growth restriction, congenital anomalies, neurodevelopmental markers).

Study designs, period and language. Primary quantitative studies (cross-sectional, cohort and case-control), systematic reviews and meta-analyses, and relevant policy or technical documents, published in English between 2009 and the final search date in 2026.

Exclusions. Studies conducted wholly outside SSA without relevant comparative data; studies that did not measure heavy metals in maternal or neonatal samples; studies reporting neither transmission nor any measurable health outcome; editorials, commentaries and letters without primary data; and records for which the full text could not be obtained.

2.3 Ethical considerations

Ethical approval was not required because the review used only published and publicly available literature. No identifiable participant data were accessed.

2.4 Data collection

Search strategy. Seven databases were searched: PubMed, Scopus, Web of Science, CINAHL, Google Scholar, African Journals Online (AJOL) and Global Health. These were chosen to cover biomedical, nursing, public health, environmental toxicology and African regional literature. Grey literature included World Health Organization (WHO) and UNICEF technical reports,

Nigerian Federal Ministry publications, university dissertations and conference proceedings. Reference lists of included studies and relevant reviews were hand-searched, and a final search update was run before manuscript preparation.

The search combined controlled vocabulary and free text for heavy metals, maternal exposure, transplacental transmission, antenatal clinics, cord blood, placental transfer, neonatal outcomes and SSA, with country-specific terms. The PubMed string was: ('heavy metal' OR 'lead' OR 'cadmium' OR 'mercury' OR 'arsenic') AND ('maternal' OR 'pregnant women' OR 'antenatal') AND ('transmission' OR 'cord blood' OR 'placental transfer' OR 'neonatal') AND ('Sub-Saharan Africa' OR 'Nigeria' OR 'Ghana' OR 'Tanzania' OR 'Kenya' OR 'Ethiopia' OR 'South Africa' OR 'Uganda').

Study selection. Records were exported to Mendeley for organisation and de-duplication. Selection followed three stages. First, two reviewers independently screened titles. Second, abstracts were independently assessed against the PECO criteria. Third, full texts were retrieved and independently assessed for population relevance, adequacy of exposure measurement, outcome reporting and design. Disagreements were resolved by discussion, with a third reviewer adjudicating unresolved cases. Reasons for exclusion at full-text stage were recorded.

Data extraction. A standardised extraction form was piloted on five studies and refined. Two reviewers extracted data independently and cross-checked entries. Items included bibliographic details; design and sample size; participant characteristics; metals, matrices, laboratory methods and concentrations; comparison groups; cord blood, placental and neonatal concentrations and ratios; maternal and neonatal outcomes; socio-demographic and environmental determinants; and quality rating.

2.5 Data analysis

Quality appraisal. Two reviewers independently appraised each study. Cohort and cross-sectional studies with a comparison structure were scored with the Newcastle-Ottawa Scale (NOS, maximum 9). Cross-sectional and prevalence studies without a comparator were appraised with the Joanna Briggs Institute (JBI) checklists (maximum 11). Systematic reviews were appraised with AMSTAR-2. Studies were classed as high quality (NOS 7 or more, or JBI 8 or more), moderate (NOS 5 to 6, or JBI 6 to 7) or low. No study was excluded on quality grounds; ratings informed the weight given to findings during interpretation.

Synthesis. Because of marked heterogeneity in metals, matrices, populations, settings and outcome definitions, meta-analysis was not performed. A narrative synthesis was organised around the four objectives and, within them, by metal, region and outcome. Where values were comparable, such as cord-to-maternal lead ratios, means and ranges were summarised descriptively. The overall certainty of evidence was assessed with the GRADE approach.

For paired maternal and umbilical cord blood measurements, the descriptive concentration ratio was defined as R_CM = C_cord / C_maternal, where concentrations refer to the same element and compatible units. Ratios below, equal to, or above 1 indicate lower, similar, or higher cord than maternal concentrations, respectively; they are not direct measures of transfer efficiency or dose. Reported odds ratios, confidence intervals and correlations were retained at study level rather than pooled across unlike designs.

3. Results

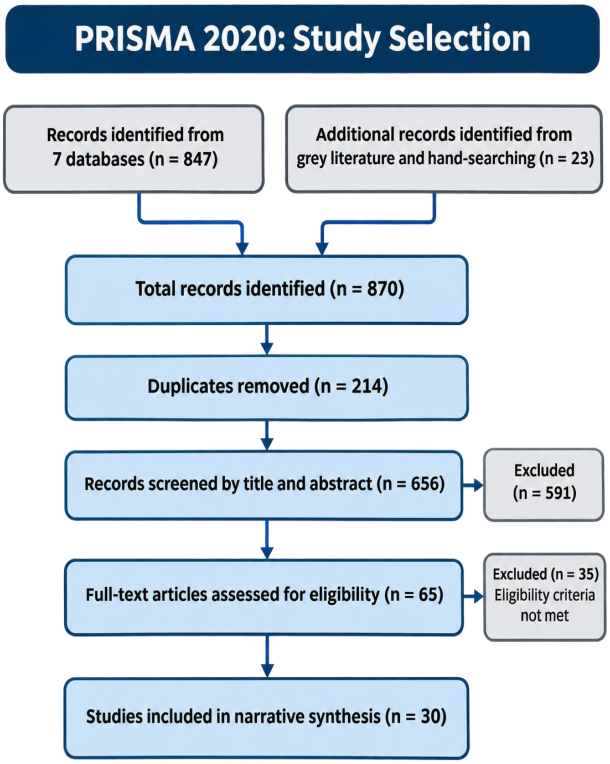
3.1 Study selection

The searches identified 847 records in databases and 23 through grey literature and hand-searching, giving 870 records. After removal of 214 duplicates, 656 records were screened by title and abstract and 591 were excluded. Sixty-five full-text articles were assessed for eligibility and 35 were excluded because they were outside SSA, did not measure metals, lacked outcome data, or were protocol papers only. Thirty studies were included in the synthesis (Table 1; PRISMA flow shown in Figure 1).

Table 1. Study identification and selection (PRISMA 2020)

Stage	Records
Identified through database searches (7 databases)	847
Identified through grey literature and hand-searching	23
Total before de-duplication	870
Duplicates removed	214
Screened by title and abstract	656
Excluded at title and abstract stage	591
Full-text articles assessed	65
Full-text articles excluded	35
Studies included	**30**

Figure 1. PRISMA 2020 flow diagram



Note. Counts reproduce the reported identification, screening, eligibility and inclusion stages; no meta-analysis was undertaken.

3.2 Characteristics of the included studies

The 30 studies spanned seven SSA countries, together with multi-country reviews and global comparators, and were published between 2009 and 2026, mostly from 2017 to 2024. Nigeria contributed the largest share, covering the South-East, the Niger Delta and South-South, and the South-West. Tanzania (n = 3), South Africa (n = 4), Ghana (n = 2), Uganda (n = 1), Kenya (n = 1) and Ethiopia (n = 1) provided the remaining country-level studies. Designs were cross-sectional (n = 15), prospective cohort (n = 6), retrospective analytical (n = 1), case-control (n = 1), systematic review or meta-analysis (n = 5) and policy or technical documents (n = 2). Sample sizes ranged from 32 mother-neonate pairs in a Ugandan pilot biomonitoring study to more than 1,000 women in Tanzanian cohorts.

Whole blood, maternal and cord, was the most common matrix (26 of 30 studies). Urine was used mainly for arsenic, hair and breast milk in six studies to reflect chronic or lactational

exposure, and placental tissue in two Nigerian studies. Laboratory methods included atomic absorption spectrometry (AAS), inductively coupled plasma optical emission spectrometry (ICP-OES), microwave plasma atomic emission spectrometry (MP-AES) and dried blood spot analysis. Twelve studies were rated high quality, sixteen moderate, and two (the WHO policy document and a narrative review) were treated as authoritative contextual references.

Figure 2. Distribution of included sources by study design

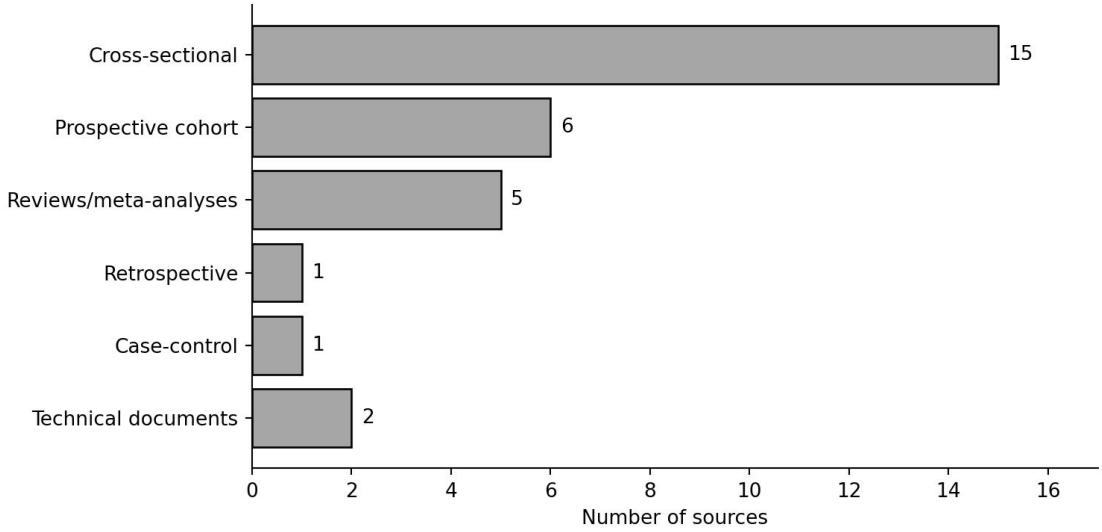


Table 2. Key primary studies reporting maternal exposure and transmission

Study	Setting	Design and sample	Metals	Main findings
Ugwuja et al. (2013)	Ebonyi, South-East Nigeria	Cross-sectional, 150 pregnant women	Pb	Mean maternal BLL 8.3 µg/dL; 67% above 5 µg/dL
Oritsemuelebi et al. (2021)	Ebonyi, South-East Nigeria	Pilot cross-sectional, 60 pairs	Multiple (incl. Pb, Hg, As, Cd)	Pb, Hg and As higher in cord blood; Cd higher in maternal blood; cord Pb inversely correlated with birth weight (r = -0.38)
Obi-Ezeani et al. (2019)	Rivers State	Prospective cohort, 200+ pairs	Pb	Maternal 14.7 and cord 10.2 µg/dL; ratio 0.69; r = 0.74; preeclampsia 18.5% vs 6.2%; LBW 24.5% vs 8.8%
Udom et al. (2022)	Niger Delta	Cross-sectional, 240 pairs	As, Pb, Cd, Hg, Cr, Ni	Pb 18.3 µg/dL (ratio 0.71); Hg ratio 1.12; Cd ratio 0.42; LBW 28%; preterm 19.2%; preeclampsia 21%
Orisakwe et al. (2021a)	Niger Delta	Cross-sectional, 180 women	Pb, Cd, As, Hg, Cr	Pb 22.6 µg/dL; over 80% above WHO reference; placental Pb 2.3 times maternal
Nwaogazie et al. (2020)	Rivers State	Cross-sectional, 120 women	Pb, Cd	Pb 19.4 µg/dL; preterm OR 2.8 (1.4 to 5.6); anaemia 64%

Study	Setting	Design and sample	Metals	Main findings
Edem et al. (2017)	Bayelsa State	Case-control, 160 subjects	Cd, Zn	Cd 3.6 vs 0.9 µg/L in controls; LBW 32%
Adeyemi et al. (2019)	Lagos	Cross-sectional, 440 pairs	Pb	Maternal 5.8 and cord 4.2 µg/dL; ratio 0.72; rs = 0.80; calcium supplement users had lower BLL
Adekunle et al. (2010)	Lagos	Cross-sectional, 214 women	Pb	Mean BLL 59.5 µg/dL (controls 27.7); rising across trimesters
Bansa et al. (2017)	Ghana mining areas	Cross-sectional, 114 pairs	Pb, Hg, Cd, As	Metals in breast milk; Pb highest
Opoku et al. (2024)	Ghana, former mining area	Community cross-sectional	Pb, Cd, As, Hg, Cr	Soil Pb 1,240 mg/kg; maternal BLL 9.7 µg/dL; more LBW and preterm births than non-mining areas
Nyanza et al. (2019)	Northern Tanzania (ASGM)	Cross-sectional, 1,056 women	As, Hg	T-Hg up to 72 µg/L; T-As up to 213 µg/L; 75% above reference; over 50% adverse outcomes
Nyanza et al. (2020)	Northern Tanzania (ASGM)	Prospective cohort, 961 women	As, Hg	Dose-response with spontaneous abortion, stillbirth, preterm birth, LBW and anomalies
Thomas et al. (2024)	North-Western Tanzania	Cross-sectional	Pb	BLL above 5 µg/dL; geophagy and ASGM independently raised BLL
Udom et al. (2025)	Bushenyi, Uganda	Biomonitoring, 32 pairs	As, Pb, Cr, Ni and others	Maternal above cord; Pb transfer 50.51%
Muinde et al. (2020)	Nairobi, Kenya	Cross-sectional, 96 pairs	Pb, Cd, Hg, As	Pb 8.6 µg/dL (r = 0.67); Hg r = 0.71; LBW 22%
Dessalegn et al. (2021)	Addis Ababa, Ethiopia	Prospective cohort, 312 women	Pb, Cd, As	Pb ratio 0.68; Cd 0.45; As cord above maternal in 62%; LBW OR 2.1; preterm OR 1.8
Röllin et al. (2009)	South Africa, 7 sites	Multi-site cross-sectional	Cd, Hg, Pb, Mn and others	Coastal Hg median 1.78 µg/L; metals varied by site
Röllin et al. (2015)	KwaZulu-Natal and Western Cape	Cohort, 641 maternal and 317 cord samples	Cd	Cord Cd 0.27 vs maternal 0.25 µg/L; LBW 11%
Mahlalela et al. (2021)	Limpopo, South Africa	Retrospective, 220 records	Pb, Cr, Mn, As	Mean BLL 6.4 µg/dL; gestational hypertension OR 2.4; anaemia 72%
Mathee et al. (2021)	Gauteng, South Africa	Cross-sectional, lactating mothers	Pb, Cd, Hg, As	Pb and Cd in breast milk above WHO thresholds in most samples
Vigeh et al. (2020)	Japan and Iran (comparator)	Prospective cohort, 600+	Pb, Cd, Hg	Low-level Pb associated with 2.1-fold risk of spontaneous abortion

Study	Setting	Design and sample	Metals	Main findings
Rahman et al. (2012)	Kuwait (comparator)	Prospective cohort	Pb	Maternal-cord r = 0.82; ratio 0.70 to 0.85

BLL, blood lead level; LBW, low birth weight; ASGM, artisanal and small-scale gold mining; T-Hg, total mercury; T-As, total arsenic. Systematic reviews and policy documents (Bede-Ojimadu et al., 2018; Orisakwe, 2021; Orisakwe et al., 2023; Orisakwe et al., 2024; Issah et al., 2024; Bose-O'Reilly et al., 2010; WHO, 2022) are discussed in the text.

3.3 Primary findings: predominant metals in maternal and neonatal samples

Lead, cadmium, mercury and arsenic were the four principal metals across the 30 studies, with lead the most frequently measured and most frequently elevated. Chromium, nickel, manganese, zinc (as an indicator of cadmium-related displacement), aluminium and antimony were reported in selected studies.

Lead. Lead was almost universally detected above the 5 µg/dL reference value used in the included studies. In South-East Nigeria, Ugwuja et al. (2013) found a mean maternal blood lead level (BLL) of 8.3 µg/dL, with 67% of 150 women above 5 µg/dL. In the Niger Delta, mean values were 14.7 µg/dL in Rivers State (Obi-Ezeani et al., 2019), 18.3 µg/dL across Bayelsa, Rivers and Delta States (Udom et al., 2026) and 22.6 µg/dL in oil-producing communities, where over 80% of women exceeded the reference value (Orisakwe et al., 2021a). In Lagos, Adeyemi et al. (2019) reported a median of 5.8 µg/dL in 440 women, whereas Adekunle et al. (2010) reported a mean of 59.5 µg/dL, one of the highest values in the SSA literature. The systematic review by Bede-Ojimadu et al. (2018) pooled 15 studies of more than 2,000 women and calculated a weighted mean BLL of 24.73 µg/dL, rising to 26.24 µg/dL in pregnant women. Elsewhere, mean BLLs exceeded 5 µg/dL in North-Western Tanzania, particularly among women involved in ASGM (Thomas et al., 2024); averaged 6.4 µg/dL in Limpopo, South Africa (Mahlalela et al., 2021); and were 7.2 µg/dL in Addis Ababa, 8.6 µg/dL in Nairobi and 9.7 µg/dL near former Ghanaian mines.

Mercury. Mercury was the second most commonly elevated metal. In Geita, Tanzania, total blood mercury reached 72 µg/L and about three-quarters of 1,056 women exceeded the reference value (Nyanza et al., 2019), placing these communities among the most mercury-burdened pregnant populations reported. Median mercury was 1.78 µg/L at a South African coastal site, consistent with methylmercury exposure through seafood (Röllin et al., 2009). In Niger Delta

mother-neonate pairs, mercury concentrations averaged 6.8 µg/L (Udom et al., 2022). Breast milk data confirm a continuing postnatal route (Orisakwe et al., 2024).

Cadmium. Edem et al. (2017) found mean maternal cadmium of 3.6 µg/L in pregnant women in Bayelsa State versus 0.9 µg/L in controls. Niger Delta cohorts reported 3.2 to 4.1 µg/L (Udom et al., 2026; Orisakwe et al., 2021a), and Nigerian breast milk had the highest mean cadmium among SSA studies in a meta-analysis (29 ± 1.3 µg/L in mature milk; Orisakwe et al., 2024). Cadmium was one of the most frequently co-detected metals alongside lead and mercury in mixture analyses (Issah et al., 2024).

Arsenic. Arsenic was most prominent in East African studies. Urinary total arsenic reached 213 µg/L among women in Tanzanian ASGM areas (Nyanza et al., 2019), with a median of 38.2 µg/L in the follow-up cohort (Nyanza et al., 2020). Niger Delta reviews attribute raised arsenic to petroleum-related contamination, pesticide use and poor waste management (Orisakwe et al., 2021a, 2023).

3.4 Primary findings: maternal-to-child transmission

Maternal and neonatal biological measurements provided evidence of transplacental exposure to the four principal metals. Transfer patterns differed by element and matrix (Table 3). Cord-to-maternal concentration ratios describe relative measured concentrations rather than the percentage of the maternal absorbed dose delivered to the fetus.

Table 3. Cord-to-maternal transfer by metal

Metal	Evidence	Pattern
Lead	Ratios of 0.72 (Lagos, n = 440), 0.69 (Rivers), 0.71 (Niger Delta), 0.68 (Addis Ababa); correlations r = 0.67 to 0.80; r = 0.82 and ratio 0.70 to 0.85 in Kuwait; transfer 50.51% in a small Ugandan sample	Efficient, predictable transfer; roughly 50% to 85% of maternal burden reaches cord blood
Mercury	Ratio 1.12 (Niger Delta); r = 0.71 (Nairobi); cord above maternal in Ebonyi; ratio above 1.0 in the global methylmercury review	Preferential fetal accumulation
Cadmium	Ratios 0.42 (Niger Delta) and 0.45 (Addis Ababa); cord 0.27 vs maternal 0.25 µg/L in South Africa; maternal above cord in Ebonyi	Partial placental barrier, with placental accumulation
Arsenic	Cord above maternal in 62% of Ethiopian participants; cord above maternal in Ebonyi	Active transfer at higher exposure

Lead. Adeyemi et al. (2019), the largest paired study in Nigeria, found a Spearman correlation of 0.80 between maternal and cord lead and a ratio of 0.72, showing that nearly three-quarters of

maternal blood lead is reflected in cord blood. Obi-Ezeani et al. (2019) found r = 0.74 and a ratio of 0.69. A fetus whose mother has a BLL of 22 µg/dL, as reported in the Niger Delta, would therefore be expected to have a cord BLL of roughly 15 to 19 µg/dL at birth. Maternal BLL is thus a reliable surrogate for fetal exposure.

Interpretive synthesis: The repeated maternal–cord lead associations across Nigerian and comparator studies indicate that maternal blood lead is informative for fetal exposure assessment. At the same time, differences in sampling time, laboratory method and population exposure distribution should be considered when interpreting an individual mother–infant pair. This reinforces the clinical value of exposure history alongside laboratory testing.

Mercury and arsenic. Mercury cord-to-maternal ratios above 1.0 indicate that fetal concentrations can exceed those of the mother, because methylmercury is actively transported across the placenta (Udom et al., 2026; Bose-O'Reilly et al., 2010). Arsenic showed a similar pattern in Ethiopia, where cord arsenic exceeded maternal in 62% of women (Dessalegn et al., 2021). Fetal burden for these metals may therefore be underestimated when inferred from maternal blood alone.

Cadmium. Cadmium transfer was partial (ratios 0.42 to 0.50), but accumulation in the placenta is associated with disruption of the syncytiotrophoblast and impaired uteroplacental blood flow, offering a route to growth restriction independent of transfer. Edem et al. (2017) additionally showed that cadmium displaces zinc, linking maternal cadmium burden to fetal zinc deficiency.

3.5 Secondary findings: maternal and neonatal outcomes

Neonatal outcomes. Low birth weight (under 2,500 g) was the most consistently reported adverse neonatal outcome, ranging from 11% to 32% in high-exposure groups: 28% in the Niger Delta (Udom et al., 2026), 32% in the high-cadmium group in Bayelsa (Edem et al., 2017), 24.5% versus 8.8% by lead exposure in Rivers State (Obi-Ezeani et al., 2019), 22% in Nairobi (Muinde et al., 2020) and 11% in South Africa (Röllin et al., 2015). Dessalegn et al. (2021) reported an odds ratio of 2.1 (95% CI 1.3 to 3.6) for low birth weight with high lead exposure, and 1.8 (95% CI 1.1 to 3.0) for preterm birth with high arsenic exposure. Preterm birth was 19.2% in the Niger Delta cohort and carried an odds ratio of 2.8 (95% CI 1.4 to 5.6) with high lead and cadmium in Rivers State (Nwaogazie et al., 2020). In Tanzanian ASGM communities, more than half of women experienced a composite adverse outcome (spontaneous abortion, stillbirth, preterm birth, low birth weight or visible congenital anomaly), and the prospective

cohort showed that arsenic and mercury independently predicted these outcomes in a dose-dependent way (Nyanza et al., 2019, 2020). Even lead levels below action thresholds were associated with a 2.1-fold higher risk of spontaneous abortion in the comparator cohort (Vigeh et al., 2020). Cord lead was inversely correlated with birth weight (r = -0.38) in the Ebonyi pilot (Oritsemuelebi et al., 2021). Metal mixtures were linked to greater combined risk than single metals (Issah et al., 2024). Across the reported studies, the low-birth-weight percentages are study-specific observations rather than a pooled prevalence. In Rivers State, the 24.5% versus 8.8% contrast corresponds to a 15.7-percentage-point absolute difference and approximately 2.8 times the observed proportion in the higher-exposure group. This comparison communicates the potential clinical importance of the reported association while preserving the study-specific nature of the evidence.

Maternal outcomes. Preeclampsia occurred in 18.5% of women with high BLL versus 6.2% with low BLL in Rivers State (Obi-Ezeani et al., 2019), and in 21% of the Niger Delta cohort (Udom et al., 2022). Gestational hypertension had an odds ratio of 2.4 in Limpopo (Mahlalela et al., 2021), and a positive BLL-hypertension association was found across SSA studies (Bede-Ojimadu et al., 2018). Anaemia was common among exposed women, at 64% in Rivers State and 72% in Limpopo, consistent with lead interference with haem synthesis. Reviews from the Niger Delta additionally describe reproductive failure, placental damage and perinatal mortality (Orisakwe, 2021; Orisakwe et al., 2023).

Postnatal transmission. Breast milk studies from Ghana, South Africa and a meta-analysis across SSA show that lead, cadmium, mercury and arsenic are transferred postnatally, with lead and cadmium exceeding WHO provisional tolerable intake thresholds in most samples in Gauteng (Bansa et al., 2017; Mathee et al., 2021; Orisakwe et al., 2024). Prenatal and lactational exposure are therefore cumulative.

3.6 Quality of the evidence

Twelve studies (40%) were rated high quality, including the Tanzanian cohorts (Nyanza et al., 2019, 2020), the South African cohort (Röllin et al., 2015), the Nigerian studies by Obi-Ezeani et al. (2019), Adeyemi et al. (2019) and Udom et al. (2022), and several systematic reviews. Sixteen studies (53%) were of moderate quality and two (7%) were authoritative reference documents. Common limitations were small samples (as few as 32 pairs), cross-sectional designs precluding causal inference, a single blood sample at booking or delivery, incomplete multi-metal assessment, limited adjustment for gestational age, nutrition, parity and socio-economic

status, and heterogeneity in laboratory methods, with less sensitive techniques risking underestimation at low concentrations. Selective reporting of significant findings was suspected in several cross-sectional studies. Publication bias could not be tested formally because the synthesis was narrative, although grey literature and AJOL searches reduced the risk of missing regional work. Using GRADE, certainty in specific metal-outcome effect estimates was moderate to low, mainly because most evidence was cross-sectional, settings were heterogeneous and results for cadmium outcomes were inconsistent. Certainty in the overall finding that maternal heavy metal exposure is widespread and clinically consequential across SSA was high, because the direction of evidence was consistent across diverse settings and methods.

4. Discussion

4.1 Interpretation of findings

This review confirms that toxic metal exposure is widespread among pregnant women in SSA and that all four principal metals are transmitted to the fetus. Lead was the most consistently elevated metal, and the cord-to-maternal ratios of 0.68 to 0.85 reported from Lagos, Rivers State, the Niger Delta and Addis Ababa show that a mother's blood lead is a dependable indicator of her baby's exposure (Adeyemi et al., 2019; Dessalegn et al., 2021; Obi-Ezeani et al., 2019; Udom et al., 2026). The WHO position is that no level of blood lead is known to be without harm (WHO, 2022). The 5 µg/dL reference value used in the included studies has since been lowered by the United States Centers for Disease Control and Prevention to 3.5 µg/dL, so even the lower values reported from Lagos, Addis Ababa and Nairobi describe exposure that remains of concern.

The pattern for mercury and arsenic differs in an important way. Cord concentrations equal to or higher than maternal concentrations indicate active placental transport, most clearly for methylmercury (Bose-O'Reilly et al., 2010; Udom et al., 2026). Fetal exposure to these metals may therefore be underestimated when it is inferred from maternal blood alone. The extreme mercury and arsenic values found in Tanzanian mining communities, together with a dose-response relationship with spontaneous abortion, stillbirth, preterm birth, low birth weight and congenital anomalies, make a strong case that exposure at this scale is clinically important (Nyanza et al., 2019, 2020). Cadmium behaves differently. Its partial retention by the placenta limits transfer, but placental accumulation and displacement of zinc offer a plausible route to

growth restriction independent of how much reaches the fetus (Edem et al., 2017; Röllin et al., 2015).

The consistency of the outcome findings across very different settings strengthens the conclusion that these exposures matter. Low birth weight was reported from 11% to 32% in high-exposure groups, and preeclampsia was roughly three times as frequent in women with high blood lead as in those with low blood lead in Rivers State (Obi-Ezeani et al., 2019). Because most included studies were cross-sectional, these associations cannot prove causation, but they are biologically plausible and the direction of evidence is the same in studies from Nigeria, Tanzania, Ethiopia, Kenya and South Africa.

4.2 Comparison with existing literature

The transfer ratios found here agree with studies from outside SSA. Rahman et al. (2012) reported a maternal-cord correlation of 0.82 and ratios of 0.70 to 0.85 for lead in Kuwait, matching the African values. The finding that lead below conventional action thresholds was associated with a 2.1-fold higher risk of spontaneous abortion in Japan and Iran (Vigeh et al., 2020) suggests that the lower SSA values are not benign. The weighted mean maternal blood lead of 24.73 µg/dL pooled by Bede-Ojimadu et al. (2018) is far higher than values in most high-income countries, and the review by Orisakwe et al. (2023) shows that metal contamination of the Niger Delta environment is pervasive. Evidence that mixtures carry greater combined risk than single metals (Issah et al., 2024) supports the observation that women in mining and oil-producing areas are exposed to several metals at once. The postnatal findings, in which breast milk in Ghana, South Africa and across SSA contained lead, cadmium, mercury and arsenic (Bansa et al., 2017; Mathee et al., 2021; Orisakwe et al., 2024), show that prenatal exposure continues after birth.

4.3 Implications for nursing practice

This is where the findings are most useful to nurses and midwives. The outcomes linked to metal exposure are the ones that antenatal and labour wards already manage every day, and nurses and midwives are the professionals who see women earliest and most often. Five actions can begin within existing services (Table 4).

A feasible implementation pathway begins with brief exposure questions at booking, continues with culturally appropriate dietary and occupational counselling, and links women with substantial exposure

concerns to existing obstetric surveillance and environmental health referral services. Integrating these activities into established antenatal encounters can strengthen preventive care without creating a separate clinical pathway for every toxic element.

Exposure history at booking. A short environmental history can be added to the booking interview. It asks about residence near mining, oil facilities, dumpsites or industrial areas; work in battery repair, welding, automobile workshops, paint, tanning, scrap metal or gold processing; clay (nzu) eating; herbal preparations; the main source of drinking water; and frequency of fish consumption. Women who report risk factors can be flagged. The history costs nothing and generates local data.

Counselling. Calcium, iron and zinc compete with lead and cadmium for absorption, and calcium supplement use was associated with lower blood lead in Lagos (Adeyemi et al., 2019). Midwives can reinforce adequate calcium intake in line with national guidance, ensure iron and folic acid are taken, and encourage zinc-containing foods. Advice on safer water and food, and respectful, non-stigmatising education about clay eating and herbal products, should be offered, recognising that poor households often have limited choices.

Monitoring and referral. Women with identified exposure merit attentive monitoring for hypertension, proteinuria, anaemia and fetal growth, given the associations documented with preeclampsia, gestational hypertension, low birth weight and preterm birth. Where blood lead measurement is available, a pilot programme for women with risk factors, with a referral pathway to toxicology or environmental health services, is justified. A single booking measurement may underestimate exposure later in pregnancy, because lead rose across trimesters in one high-exposure Lagos cohort (Adekunle et al., 2010).

Postnatal care. Breast milk contained measurable metals in several studies, but breastfeeding has major protective benefits for infants, and these findings are not a reason to discourage it. Midwives should continue to support breastfeeding while helping mothers reduce ongoing exposure. Birth weight and gestational age should be recorded carefully, and infants of highly exposed mothers can be flagged for developmental follow-up.

Education and advocacy. Environmental health content is rarely emphasised in nursing and midwifery curricula in the region. Training in sources of exposure and counselling skills, and advocacy by professional bodies for including exposure enquiry in antenatal guidelines, would turn evidence into routine practice.

Table 4. Practical actions for antenatal nurses and midwives

Contact point	Action supported by this review
Booking visit	Environmental exposure history (residence, occupation, water, diet, pica, herbal use); flag women at risk
Antenatal counselling	Dietary calcium, iron and zinc; safer water and food; culturally sensitive advice on pica and herbal products
Routine monitoring	Closer attention to blood pressure, proteinuria, anaemia and fetal growth in flagged women
Referral	Pathway to toxicology or environmental health services where blood lead screening is available
Delivery and postnatal	Record birth weight and gestational age; support breastfeeding; flag infants for developmental follow-up
Service level	Contribute data to pilot biomonitoring; advocate for inclusion in antenatal guidelines and insurance cover

4.4 Limitations

Several limitations should be acknowledged. First, restriction to English-language publications may have excluded relevant work in French, Portuguese or local languages. Second, heterogeneity in design, metals, sampling matrices, laboratory methods and outcome definitions prevented meta-analysis, so quantitative comparisons are approximate. Third, most studies were cross-sectional and often relied on a single blood sample, which limits causal inference. Fourth, units and reference values differed between studies (µg/dL and µg/L, and different matrices), so cross-study comparisons should be made cautiously. Fifth, some very high values, such as the mean blood lead of 59.5 µg/dL in one Lagos study (Adekunle et al., 2010), may reflect local conditions or measurement differences and should not be taken as representative. Finally, no included study was conducted in Abia State, so application to South-East Nigeria rests on inference from neighbouring areas.

4.5 Recommendations for future research

A priority for subsequent research is a prospective maternal–newborn biomonitoring cohort in South-East Nigeria, with repeated maternal measurements and paired delivery-time cord samples. This design could relate metal-specific and combined exposures to gestational hypertension, maternal anaemia, fetal growth, gestational age and neonatal anthropometry. Complementary implementation research could assess the feasibility of environmental history-taking, targeted testing, referral and postnatal developmental follow-up in antenatal services.

5. Conclusion

Thirty studies show that pregnant women in Sub-Saharan Africa are exposed to lead, mercury, cadmium and arsenic, that all four metals cross the placenta, and that higher maternal burdens are associated with low birth weight, preterm birth, spontaneous abortion, preeclampsia, gestational hypertension and anaemia. Lead transfers predictably at about 70% to 85% of the maternal level, mercury and arsenic can accumulate preferentially in the fetus, and cadmium is partly retained in the placenta.

Antenatal nurses and midwives are best placed to act on this evidence. Exposure history-taking, nutritional and behavioural counselling, close monitoring, supportive breastfeeding care and referral can begin now, and a prospective cohort in South-East Nigeria would supply the local evidence on which guidelines and policy can be built.

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