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Sources, Patterns and Modifying Factors of Cumulative Toxicant Exposure among Pregnant and Lactating Women in the Niger Delta and Sub-Saharan Africa: Implications for Nursing and Midwifery Practice

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Abstract

Background: Women in the Niger Delta region of Nigeria are exposed to a mixture of toxicants from oil spills, gas flaring and artisanal refining, while women elsewhere in Sub-Saharan Africa (SSA) face lead, cadmium and household air pollution. How these exposures arise, how they combine and what makes some women more vulnerable than others is poorly organised in the literature, which limits what nurses and midwives can do about it.

Objective: To synthesise the types, sources and patterns of cumulative environmental and occupational toxicant exposure reported among pregnant and lactating women in SSA, with emphasis on the Niger Delta, and the factors that modify exposure and vulnerability.

Methods: A systematic review following PRISMA 2020 searched PubMed, Scopus, Web of Science, CINAHL, Global Health, Google Scholar, African Journals Online and grey literature (January 2000 to May 2026). Eligibility was defined using the PECO framework. Two reviewers independently screened studies, extracted data and appraised quality with JBI checklists and the Newcastle–Ottawa Scale. Findings on exposure patterns and effect modifiers were synthesised narratively.

Results: Of 1,898 records, 30 studies were included (12 from Nigeria, two from the Democratic Republic of Congo, two from South Africa, one from Ghana and 13 SSA-wide or global syntheses); 11 were of high, 14 of moderate and five of low quality. Exposure was chronic, multi-route and multi-toxicant. In the Niger Delta it arose from oil spills, gas flaring and contaminated water, soil and food, and involved lead, cadmium, polycyclic aromatic hydrocarbons, volatile organic compounds and particulate matter. In the Democratic Republic of Congo it arose from lead in mining dust and geophagy, and in Ghana and East and Southern Africa from biomass cooking smoke. Biomarker studies found elevated blood lead and cadmium that rose with years of residence, closeness to flares and, modestly, with advancing pregnancy, and metals were detectable in breast milk. Nineteen studies identified effect modifiers: duration and intensity of exposure, trimester, season, occupation, poverty, rural residence, cooking practice and poor nutrition.

Conclusions: Pregnant and lactating women in the Niger Delta and SSA carry cumulative toxicant burdens that are shaped as much by social circumstances, occupation and daily practices as by proximity to pollution. Nurses and midwives can identify high-exposure women through structured exposure histories, counsel on modifiable routes, support breastfeeding mothers and advocate for exposure reduction. Individual-level, longitudinal exposure mixture studies are needed.

Keywords: *cumulative exposure; exposome; heavy metals; gas flaring; household air pollution; pregnancy; lactation; Niger Delta; Sub-Saharan Africa; nursing; midwifery*

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1. Introduction

The central analytical proposition of this review is that cumulative exposure is produced by the intersection of environmental contamination and patterned daily activities. A woman may encounter petroleum-related emissions in outdoor air, combustion products in the household, and metals or hydrocarbons through locally sourced water and food. These pathways are not interchangeable: they differ in frequency, intensity, biological uptake and potential for prevention. A source–pathway–person framework therefore provides a more useful basis for maternal assessment than a list of pollutants considered independently. This review distinguishes three related concepts: co-exposure, meaning contact with multiple toxicants; cumulative exposure, meaning exposure accumulated across time and pathways; and susceptibility, meaning the physiological and social conditions that may modify the effect of a given exposure. Keeping these concepts distinct makes the synthesis more clinically interpretable while preserving its exposome orientation. Pregnancy and lactation are periods of heightened biological vulnerability. Maternal blood volume expands, fat and bone stores are remodelled, and nutrients and, with them, contaminants are transferred to the fetus across the placenta and later to the infant in breast milk. Exposure to environmental toxicants at these times therefore has consequences for two generations (Robinson et al., 2015). In high-income settings exposure is usually episodic and low-level. In many parts of Sub-Saharan Africa it is chronic, begins early in life and arises from several sources at once. Nowhere is this clearer than in the Niger Delta of Nigeria. More than six decades of oil exploration, recurrent oil spills, continuous gas flaring and unregulated artisanal refining have contaminated air, water, soil and the food chain with lead, cadmium, mercury, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and particulate matter (UNEP, 2011; Ordinioha & Brisibe, 2013; Orisakwe et al., 2021). The inhabitants of many communities depend on local fishing, farming and small trading, so the same environment that harms them is also their livelihood. Elsewhere in SSA, other combinations occur: lead from mining and from geophagy in the Democratic Republic of Congo (DRC), cadmium and trace mineral disturbances in South Africa, and smoke from biomass cooking fuel across West, East and Southern Africa. The exposome concept, which describes the totality of environmental exposures from conception onwards, offers a useful way to think about these circumstances (Robinson et al., 2015). It shifts attention from single pollutants to the pattern of exposures that a woman accumulates through where she lives, what she eats and drinks, how she cooks and what work she does. Studies of single toxicants cannot show how these exposures combine, and mixture research from Africa is still scarce (Güil-Oumrait et al., 2024).

Previous research has tended to treat exposure and outcome separately. Exposure studies describe pollutant levels in air, water, soil or blood, while clinical studies describe outcomes in women without measuring what they were exposed to. Fewer have linked the two, and fewer still have

asked how exposure is distributed within a population, why some women carry more than others and what that means for the care they receive. These are the questions that matter to a nurse deciding whom to counsel and what to ask. For nursing and midwifery, understanding exposure patterns is a practical matter. Nurses and midwives conduct the booking history, see women repeatedly through pregnancy and lactation and work in the communities concerned. Yet environmental exposure history is rarely part of routine care, and no review has organised the African evidence on exposure sources and modifiers in a form that supports it. This article, which reports objectives 1 and 3 of a systematic review, aims to fill that gap. It addresses two questions: (1) what are the types, sources and patterns of cumulative toxicant exposure among pregnant and lactating women in SSA, particularly the Niger Delta; and (2) how do exposure timing, intensity, duration and socio-demographic and occupational factors alter exposure and vulnerability? A companion article reports associations with cardio-metabolic outcomes.

2. Methods

2.1 Design, protocol and reporting

The unit of synthesis in this article is the reported exposure pathway or modifier, rather than an estimated pooled clinical effect. Findings from primary investigations are interpreted alongside regional and global syntheses to explain the consistency of exposure pathways across contexts. The clinical outcome requirement belongs to the parent review; this article extracts the exposure-related evidence relevant to its two stated questions. The study is a systematic review conducted to a protocol developed with PRISMA-P (Moher et al., 2015), registered prospectively with PROSPERO and reported according to PRISMA 2020 (Page et al., 2021). The present article draws on the review's first and third objectives.

2.2 Eligibility criteria

Eligibility followed the PECO framework (Table 1). The population was pregnant women at any trimester and lactating women up to 12 months postpartum, residing in SSA, with priority to the Niger Delta. Exposure was cumulative environmental or occupational toxicant exposure (lead, cadmium, mercury, arsenic, PAHs, VOCs, particulate matter) from oil spills, gas flaring, artisanal refining, contaminated water, soil or food, mining or biomass fuel; biomarker, environmental sampling and self-reported measures were accepted, with biomarkers prioritised. Comparison was between higher and lower exposure or between exposed and less exposed groups. Studies had to report a cardio-metabolic outcome, which is the review's overall outcome focus, although this article uses those studies for their exposure and modifier data. Quantitative, qualitative and mixed-methods studies and systematic reviews published in English from January 2000 to May 2026 were

eligible. Studies outside SSA, studies of other populations, studies without toxicant assessment and non-empirical papers were excluded.

Table 1. PECO framework

Element	Definition
Population	Pregnant women (any trimester) and lactating women (to 12 months postpartum) in SSA; priority to the Niger Delta.
Exposure	Cumulative environmental or occupational toxicants (metals, PAHs, VOCs, particulate matter) from oil and gas activity, contaminated media, mining or biomass fuel.
Comparison	Higher versus lower exposure, exposure–response associations, or exposed versus less exposed groups.
Outcome	Gestational hypertension, pre-eclampsia, gestational diabetes and related metabolic outcomes (review-level outcomes); exposure and modifier data extracted for this article.

2.3 Search, selection and data extraction

PubMed, Web of Science, Scopus, CINAHL, Google Scholar, African Journals Online and Global Health were searched, together with grey literature (WHO and UNEP reports, Nigerian federal publications, theses and conference proceedings); the last search was in May 2026. The strategy combined controlled vocabulary and free-text terms for pregnancy and lactation, toxicants and oil pollution, cumulative exposure, cardio-metabolic outcomes and geography. The databases yielded 1,856 records (PubMed 612, Scopus 478, Web of Science 289, Google Scholar 214, AJOL 98, CINAHL and Global Health 165) and other sources a further 42. After deduplication, two reviewers independently screened titles, abstracts and full texts, with a third resolving disagreements. A piloted extraction form captured study design and setting, population characteristics, exposure type, source, duration and measurement, and findings; two reviewers extracted data independently and resolved discrepancies by consensus.

2.4 Quality appraisal and synthesis

For narrative integration, evidence was grouped by environmental source (oil and gas activity, mining, household fuel and contaminated media), exposure route (inhalation, ingestion and dermal contact), measurement approach (biomarker, environmental measure or proxy), and modifier (time, place, occupation, socioeconomic conditions and pregnancy stage). This classification allows recurring patterns to be identified without treating qualitatively different measurements as equivalent. It also distinguishes evidence of exposure from evidence of a biological or clinical consequence. Quality was appraised independently by two reviewers using JBI checklists (cross-sectional, cohort, qualitative, mixed-methods and review designs) and the Newcastle–Ottawa Scale (case-control and cohort studies). No study was excluded on quality alone; lower-quality studies were given less interpretive weight. Because exposure assessment, mixtures and designs differed too much for pooling, exposure and modifier findings were synthesised narratively in two domains: patterns of cumulative exposure, and contextual and modifying factors.

3. Results

3.1 Study selection and characteristics

The searches identified 1,898 records. After 412 duplicates were removed, 1,486 records were screened by title (967 excluded) and 519 by abstract (332 excluded). Of 187 full texts assessed, 157 were excluded (no cardio-metabolic outcome data, 52; outside SSA, 39; no toxicant assessment, 31; non-pregnant or non-lactating populations, 18; insufficient detail, 11; duplicate datasets, 6), leaving 30 studies (Figure 1).

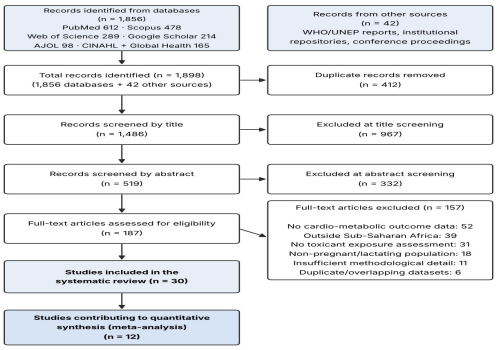


Figure 1. PRISMA 2020 flow diagram

Twelve of the 30 studies came from Nigeria, mostly from Rivers, Bayelsa, Delta and Edo States. Two case-control studies came from the DRC, two studies from South Africa and one from Ghana; 13 were SSA-wide or global syntheses with African data (Table 2). Eleven studies were rated high quality, 14 moderate and five low. Main sources of bias were inadequate adjustment for confounders (15 studies), self-reported or area-based exposure measures (12), non-representative sampling (9) and incomplete reporting (6). The studies are listed in Table 3.

Table 2. Included studies by origin and principal exposure

Origin	Studies (n)	Principal exposures
Nigeria (predominantly Niger Delta)	12	Oil pollution, gas flaring, lead, cadmium, crude oil pollutants, artisanal refining
Democratic Republic of Congo	2	Lead (blood, urine); geophagy; mining and dust
South Africa	2	Cadmium; trace minerals
Ghana	1	Household air pollution (biomass fuel)
SSA-wide syntheses	6	Lead; household air pollution; environmental risk factors
Global syntheses with African data	7	Lead, cadmium, air pollution, biomass fuel, oil and gas development
Total	30	

Table 3. Characteristics of the 30 included studies

#	Study	Setting	Design / sample	Exposure	Outcomes and key findings	Quality
1	Oghenetega et al., 2022	Nigeria (Rivers, Delta)	Prospective cohort; n = 1,418	Oil pollution proximity; gas flaring	PIH; adverse maternal outcomes. Higher PROM (ARR 1.96) and PPH (ARR 2.12) in high-exposure areas; PIH association attenuated after adjustment	High
2	Oghenetega et al., 2020b	Nigeria (Niger Delta)	Qualitative; n = 39	Oil spillage; gas flaring	Perceived links between pollution and hypertensive disorders/GDM; limited access to water and care	Moderate–High
3	Okwuchukwu et al., 2024	Nigeria (Bonny Island)	Cross-sectional; n = 120	Gas flaring	Altered sodium/potassium; possible hypertension risk	Moderate
4	Uvoh et al., 2021	Nigeria (Bayelsa)	Cross-sectional; ~300 (200 pregnant)	Lead, cadmium; gas flaring	Elevated Pb/Cd with longer exposure; oxidative stress and hypertension risk	Moderate
5	Oghenetega et al., 2020a	Nigeria (Niger Delta)	Systematic review	Oil spills; gas flaring	Increased risk of hypertensive disorders and GDM via multiple pathways	Moderate–High
6	Orisakwe et al., 2021	Nigeria (Niger Delta)	Narrative review	Metals, PAHs, VOCs	Endocrine disruption and inflammation pathways to hypertension and GDM	Moderate–High
7	Obadia et al., 2018	DRC (Lubumbashi)	Case-control; n = 79 (40 cases)	Blood lead; geophagy	Higher Pb in pre-eclampsia (6.66 vs 5.08 µg/dL; OR 6.1)	Moderate–High
8	Elongi Moyene et al., 2016	DRC (Kinshasa)	Case-control; n ≈ 176	Urinary toxic metals (Pb)	Higher excretion in pre-eclampsia ($p < 0.001$); higher in dry season	Moderate–High
9	Bede-Ojimadu et al., 2018	SSA-wide	Systematic review; 15 papers	Blood lead	High blood lead levels associated with pre-eclampsia/hypertension	High
10	Maternal lead CRA, 2026	SSA-wide	Comparative risk assessment	Maternal lead	Lead contributes to pre-eclampsia burden	Moderate–High
11	Ikechukwu et al., 2012	Nigeria (Edo)	Observational; 59 cases, 150 controls	Blood lead	Higher Pb and lower Ca/P in pre-eclampsia	Moderate
12	Emokpae et al., 2025	Nigeria (south)	Observational; n = 85 + newborns	Crude oil pollutants	Thyroid and metabolic hormone disruption	Moderate
13	Nriagu et al., 2016	Nigeria (Niger Delta)	Cross-sectional community survey	Oil pollution; gas flaring	More hypertension symptoms near flares	Moderate
14	Rollin et al., 2015	South Africa	Observational	Cadmium	Cd exposure linked to pre-eclampsia risk	Moderate
15	Rosen et al., 2018	Global (incl. SSA)	Systematic review; 28 studies	Metals; air pollution	Suggestive associations (Cd, PM) with pre-eclampsia	High
16	Jikamo et al., 2023	SSA-wide	Systematic review/meta-analysis	Various incl. environmental	Incidence and risk factors of pre-eclampsia	High
17	Li et al., 2023	Global (incl. Africa)	Meta-analysis; 17 studies (n = 10,373)	Cadmium	Positive association with pre-eclampsia (SMD 0.27)	High
18	Asare et al., 2022	Nigeria (Ebonyi)	Pilot observational; maternal–cord pairs	Toxic and essential metals	Toxic metals linked to birth parameters (indirect cardio-metabolic)	Moderate
19	Ndlovu et al., 2025	SSA-wide	Systematic review; 40 studies	Indoor air pollution (biomass, PM)	Consistent associations with gestational hypertension and GDM	High
20	Maduray & Moodley	South Africa	Case-control; ~66	Cd, Mn	Lower Mn and higher Cd linked to pre-eclampsia	Moderate
21	Zhong et al., 2022	Global (incl. SSA)	Systematic review/meta-analysis	Blood lead	Associations with pre-eclampsia	High
22	Kaali et al.	Ghana	Cohort	Household air pollution	Cardiovascular/metabolic stress markers	Moderate–High
23	Muthelo et al., 2026	SSA-wide	Scoping review	Household air pollution	Links to gestational hypertension	Moderate–High
24	Agrawal et al., 2014	Global (SSA relevance)	Review	Biomass/solid fuel	Positive associations with gestational hypertension	Moderate–High
25	Vigeh et al., 2011	Various	Review	Lead	Links to pregnancy-induced hypertension	Moderate–High
26	Ngbala-Okpabi et al.,	Nigeria (Niger	Observational	Crude oil polluted	Preterm birth, maternal anaemia;	Moderate

#	Study	Setting	Design / sample	Exposure	Outcomes and key findings	Quality
	2024	Delta)		environment	increased risk in polluted areas	
27	Maduka & Tobin-West, 2017	Nigeria (Niger Delta)	Observational community study	Gas flaring	Higher probability of hypertension in host communities	Moderate
28	Latifi et al., 2025	Oil and gas settings	Review/observational	Oil and gas development	Increased hypertensive disorders	Moderate
29	Gajewska et al., 2021	Global	Review	Lead	Raised lead associated with gestational hypertension and pre-eclampsia	Moderate–High
30	Additional SSA meta-analyses	SSA-wide	Systematic reviews	Environmental factors	Risk-factor associations with pre-eclampsia	High

PIH, pregnancy-induced hypertension; PROM, premature rupture of membranes; PPH, postpartum haemorrhage; ARR, adjusted risk ratio; SMD, standardised mean difference; CRA, comparative risk assessment; Pb, lead; Cd, cadmium; Mn, manganese; PM, particulate matter.

3.2 Types, sources and patterns of cumulative exposure

The most informative feature of this regional comparison is the overlap between source and route. Oil and gas operations can affect ambient air and surrounding water or food systems; household combustion adds an indoor inhalation route; and occupational activities can extend both contact duration and frequency. Consequently, women who share a geographical location may still have markedly different exposure profiles according to livelihood, cooking arrangements, water source and food practices. This within-community variation provides a direct rationale for individual exposure histories during antenatal care. Across all regions, exposure was chronic, multi-route and multi-toxicant rather than a single event (Figure 2). Four groups of toxicants recurred: heavy metals (lead and cadmium most often, with mercury and arsenic reported less), PAHs, VOCs and particulate matter. Their sources, routes and the studies that reported them are summarised in Table 4.

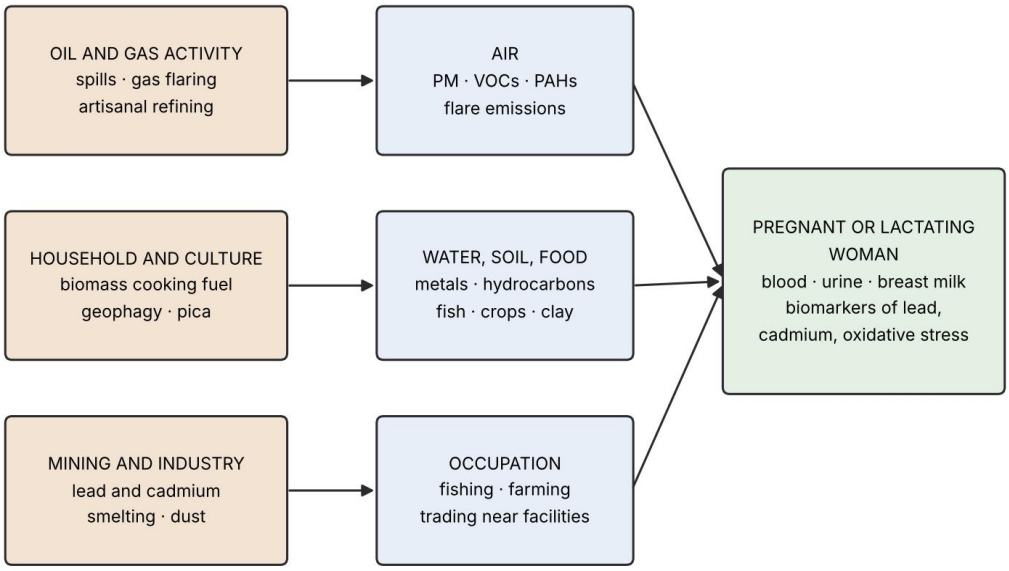


Figure 2. Sources and routes of cumulative toxicant exposure among pregnant and lactating women in SSA

Table 4. Toxicants, sources and routes of exposure by region

Region	Principal toxicants	Sources and routes	Representative evidence
Niger Delta, Nigeria	Lead, cadmium, PAHs, VOCs, PM; mercury	Oil spills, gas flaring, artisanal refining; inhalation of flare emissions; ingestion of seafood, crops and water; dermal contact with polluted water	Oghenetega et al., 2022; Uvoh et al., 2021; Okwuchukwu et al., 2024; Orisakwe et al., 2021; Maduka & Tobin-West, 2017
Other Nigeria (Edo, Ebonyi, south)	Lead; metals; crude oil pollutants	Environmental and dietary contamination; crude oil pollution	Ikechukwu et al., 2012; Asare et al., 2022; Emokpae et al., 2025
DR Congo	Lead and other toxic metals	Mining and industrial pollution; geophagy; dust	Obadia et al., 2018; Elongi Moyene et al., 2016
South Africa	Cadmium; trace minerals	Environmental contamination; diet	Rollin et al., 2015; Maduray & Moodley
Ghana and wider West/East/Southern Africa	PM, VOCs, carbon-based pollutants	Biomass cooking fuel and household air pollution	Kaali et al.; Ndlovu et al., 2025; Muthelo et al., 2026; Agrawal et al., 2014

Niger Delta and Nigeria

Twelve Nigerian studies described a landscape in which women are simultaneously exposed through air, water and food. In the prospective cohort of 1,418 pregnant women in Rivers and Delta States, residential proximity to oil-polluted land and active flare sites defined exposure, and women in high-exposure communities had concurrent contact with crude oil derivatives, VOCs and particulate matter (Oghenetega et al., 2022). The companion qualitative study, which interviewed 39 pregnant women and health providers, found that mothers experienced exposure as continuous and intergenerational: they had lived with it since childhood, expected to continue to do so and could not readily avoid it because of dependence on local water and food (Oghenetega et al., 2020b).

Biomarker studies confirmed that these exposures reach the body. In Bayelsa State, blood lead and cadmium were significantly raised among about 200 pregnant women near gas-flaring sites (Uvoh et al., 2021). On Bonny Island in Rivers State, a cross-sectional study of 120 pregnant women found disturbed sodium and potassium balance attributable to chronic flaring, suggesting broader systemic absorption (Okwuchukwu et al., 2024). Raised blood lead was also reported among pregnant women in Edo State (Ikechukwu et al., 2012), and crude oil pollutant exposure was associated with altered maternal and neonatal hormone profiles in southern Nigeria (Emokpae et al., 2025). A pilot study of maternal–cord blood pairs in Ebonyi State measured toxic and essential metals together (Asare et al., 2022). A more recent study of maternal and cord blood in the Niger Delta examined potentially toxic elements at both sites (Udom et al., 2026).

Lactation is part of the same exposure picture. Heavy metals were measured in the breast milk of lactating mothers in Bayelsa State, with different concentrations among mothers who had or had not had gestational diabetes (Philip-Slaboh et al., 2023). This shows that the maternal body burden persists after delivery and may reach the infant. Community-level surveys added that gas-flaring host communities had higher exposure intensity and poorer maternal health indicators than non-host

communities (Maduka & Tobin-West, 2017; Nriagu et al., 2016; Ngbala-Okpabi et al., 2024), and that artisanal refining and frequent spills amplified exposure in rural oil-producing communities. Orisakwe et al. (2021) mapped the pathways in detail as inhalation of flared gases, ingestion of contaminated seafood and crops, and dermal contact with polluted water.

Central Africa

In the DRC, lead was the dominant exposure, arising from mining and industrial pollution and from geophagy, the culturally embedded consumption of soil or clay during pregnancy. In a hospital-based case-control study in Lubumbashi, geometric mean blood lead was 6.66 µg/dL in preeclamptic women and 5.08 µg/dL in controls, and geophagy contributed to the burden (Obadia et al., 2018). In Kinshasa, urinary excretion of lead and other toxic metals was markedly higher in preeclamptic women and higher still in the dry season (Elongi Moyene et al., 2016). These studies show how a cultural practice can become a major exposure route when the soil itself is contaminated.

Southern and West Africa and wider syntheses

South African studies identified cadmium and altered trace mineral status (lower manganese, higher cadmium) as key exposures, linked to environmental contamination and diet (Rollin et al., 2015; Maduray & Moodley). In Ghana, household air pollution from biomass cooking was the dominant chronic exposure during pregnancy (Kaali et al.). SSA-wide and global syntheses confirmed that lead, cadmium and particulate matter from biomass and mining are pervasive on the continent and that women in low-resource settings, especially in rural and low-income groups, have higher body burdens than global averages (Bede-Ojimadu et al., 2018; Rosen et al., 2018; Ndlovu et al., 2025; Muthelo et al., 2026; Agrawal et al., 2014).

Overall pattern

Three features of the exposure pattern stand out. First, it is cumulative: women in the Niger Delta are exposed to metals, hydrocarbons and particles together, and those who also cook with biomass fuel add a further layer. Second, it is long-standing: it begins before conception and extends through lactation. Third, it is structured by social circumstances: the routes involved (local water, locally caught fish, locally grown crops, soil, indoor cooking) are the routes through which poor households live.

3.3 Contextual and modifying factors

The modifiers can be organised into three clinically useful levels. Source-related modifiers include distance from flares, residence duration and seasonal conditions. Behavioural and livelihood modifiers include occupation, geophagy, fuel choice, ventilation and reliance on local food or water. Host-related modifiers include pregnancy stage, nutritional status and pre-existing metabolic

conditions. This classification clarifies which factors require environmental action, which may be addressed through counselling, and which warrant closer clinical assessment. Importantly, a modifier may alter exposure opportunity, biological uptake or vulnerability to effects; these are distinct processes. For example, residence near a flare primarily indicates potential contact, whereas nutritional status may influence susceptibility. In practice, the presence of several modifiers should prompt a more detailed history rather than be interpreted as a validated numerical risk score. Nineteen of the 30 studies addressed factors that modify exposure or vulnerability, and ten of these were from Nigeria (Table 5).

Table 5. Factors modifying exposure and vulnerability

Factor	Findings	Representative evidence
Duration of residence	Blood lead and cadmium rose with years lived in gas-flaring communities; higher risks in women with longer residence	Uvoh et al., 2021; Oghenetega et al., 2022
Proximity and intensity	Exposure gradient with distance from spills and flares; more pronounced electrolyte disturbance closer to flares	Oghenetega et al., 2022; Okwuchukwu et al., 2024
Trimester	Modestly higher metal levels in the third trimester, possibly from greater blood volume and fat mobilisation	Uvoh et al., 2021
Season	Higher urinary lead in the dry season, when dust and geophagy intensify	Elongi Moyene et al., 2016
Cultural practice	Geophagy markedly raised blood lead	Obadia et al., 2018
Occupation	Fishing, farming and trading near oil facilities added exposure through several routes	Oghenetega et al., 2020b; Nriagu et al., 2016
Poverty, rurality, education	Higher lead and cadmium burdens in rural, low-income and less-educated women; limited access to clean water and antenatal care	Bede-Ojimadu et al., 2018; Oghenetega et al., 2020b
Cooking practice	Exposure varied with fuel, ventilation and hours of indoor cooking, and was highest in pregnancy when women spent more time cooking	Kaali et al.; Ndlovu et al., 2025; Agrawal et al., 2014
Nutrition	Low calcium intake and poor nutritional buffering increased susceptibility to lead and cadmium	Ikechukwu et al., 2012; Rosen et al., 2018; Zhong et al., 2022
Pre-existing metabolic status	Differences in breast milk metals by history of gestational diabetes	Philip-Slaboh et al., 2023

Duration, intensity and timing. In the Niger Delta cohort, an exposure gradient was evident, with women in high oil-pollution areas at greater risk than those in low-exposure areas, and the effect was stronger in women with longer residence (Oghenetega et al., 2022). In Bayelsa, biomarker levels rose with years of residence, with a modest further rise in the third trimester, which suggests both a chronic cumulative burden and a pregnancy-specific increase in internal dose (Uvoh et al., 2021). On Bonny Island, women living closer to flare sites had more pronounced electrolyte disturbance, indicating that intensity matters (Okwuchukwu et al., 2024).

Occupation, poverty and access. Women who fished, farmed or traded close to oil facilities faced compounded exposure through air, water and food. The qualitative study described limited access to clean water and antenatal care as amplifiers of risk (Oghenetega et al., 2020b), and community studies showed that host communities experienced both higher exposure and poorer maternal health

than non-host communities (Nriagu et al., 2016; Ngbala-Okpabi et al., 2024). Syntheses across SSA found that blood lead was consistently higher in rural and low-income groups (Bede-Ojimadu et al., 2018).

Season, culture and household practice. In the DRC, the dry season and geophagy intensified exposure (Elongi Moyene et al., 2016; Obadia et al., 2018). In Ghana, exposure to household air pollution varied with cooking practice, ventilation and season, and reviews noted that it is greatest in pregnancy, when women spend more time cooking (Kaali et al.; Ndlovu et al., 2025; Muthelo et al., 2026; Agrawal et al., 2014).

Nutritional buffering. Several syntheses and primary studies identified low calcium intake and poor nutritional status as increasing susceptibility to lead and cadmium toxicity (Ikechukwu et al., 2012; Rosen et al., 2018; Li et al., 2023; Zhong et al., 2022). This is the one modifier that nurses and midwives can influence directly through counselling.

3.4 Methodological quality of the exposure evidence

The strength of conclusions about exposure depends on how exposure was measured, so the quality of the evidence deserves separate attention. The strongest primary evidence came from the prospective Niger Delta cohort, which classified exposure by residence in high or low oil-pollution areas, followed participants forward and adjusted for confounders (Oghenetega et al., 2022), and from the qualitative study, which scored well on JBI criteria for richness of data and coherence of interpretation (Oghenetega et al., 2020b). The biomarker and cross-sectional studies from Bayelsa and Rivers States measured lead, cadmium and electrolytes directly and described laboratory methods clearly, but they had small to moderate samples, no individual-level cumulative exposure score and limited adjustment for diet, body mass index and socio-economic status (Uvoh et al., 2021; Okwuchukwu et al., 2024). The DRC case-control studies were of moderate to high quality, with good case definition and biological measurement of exposure, but were hospital-based and incompletely adjusted for nutrition and co-exposures (Obadia et al., 2018; Elongi Moyene et al., 2016). SSA-wide and global syntheses were mostly of high quality, with comprehensive searches and clear inclusion criteria, although some had substantial heterogeneity or did not formally appraise their primary studies. Cross-sectional and cohort studies from South Africa and Ghana were mostly of moderate quality, with reliance on self-reported biomass use and loss to follow-up as the commonest weaknesses. Table 7 summarises the pattern and what it means for the exposure findings.

Table 7. Quality of the exposure evidence by region and design

Region / design	Typical strengths	Typical weaknesses	Implication for exposure findings
Niger Delta cohort and qualitative study	Prospective design; adjustment; rich narrative data	Area-based exposure classification	Reliable on gradient and context; less so on dose
Niger Delta biomarker and cross-sectional studies	Direct measurement of metals and electrolytes	Small samples; limited confounder control; no mixture score	Consistent signal of elevated burden; magnitude uncertain
DRC case-control studies	Biological exposure measures; clear case definitions	Hospital-based sampling; incomplete adjustment	Strong evidence for lead; limited generalisability
South Africa and Ghana studies	Relevant local exposures	Self-reported fuel use; loss to follow-up	Moderate confidence in source patterns
SSA-wide and global syntheses	Comprehensive searches; clear criteria	Heterogeneity; incomplete appraisal of primary studies	Confirm that burdens are widespread and higher in poor rural groups

3.5 Summary of the findings

Taken together, the findings answer the two review questions as follows (Table 8). Exposure among pregnant and lactating women in SSA is chronic, multi-toxicant and multi-route, with regionally distinct sources. Its intensity is set by how long and how close a woman lives to a source, and by her occupation, income, household energy, diet and cultural practices. The evidence is most plentiful and most context-specific for the Niger Delta, most precise for lead in the DRC and most consistent for household air pollution across the wider continent, but in all settings it relies mainly on single-toxicant or proxy measures rather than on true mixture assessment.

Table 8. Summary of findings on exposure patterns and modifying factors

Question	Main finding	Confidence
What are the main toxicants?	Lead and cadmium most often; PAHs, VOCs and particulate matter from flaring, spills and biomass fuel; mercury and arsenic less often	Moderate: consistent across many studies
What are the main sources?	Oil spills, gas flaring and artisanal refining (Niger Delta); mining dust and geophagy (DRC); biomass cooking fuel (Ghana and wider SSA); diet and environmental contamination (South Africa)	Moderate
Is exposure cumulative and long-standing?	Yes: multi-route, lifelong and continuing through lactation; metals detectable in blood and breast milk	Moderate; limited longitudinal data
Which factors raise exposure?	Longer residence, closeness to sources, occupation near oil facilities, dry season, geophagy, indoor cooking	Moderate for Niger Delta and DRC
Who is most vulnerable?	Rural, low-income and less-educated women with poor access to clean water, care and nutrition; women in late pregnancy	Moderate; mostly observational

Key points for practice

1. Exposure to toxicants among pregnant and lactating women in affected areas is usually cumulative and long-standing, not occasional.
2. Where a woman lives, how she cooks, what she eats and drinks, and how she earns a living can be asked about at booking and shape her level of exposure.
3. Women who are poor, rural and poorly nourished are most vulnerable, and adequate calcium intake may reduce susceptibility to lead and cadmium.

4. Breastfeeding is still recommended; maternal nutrition, exposure reduction and follow-up are the appropriate responses to metals found in breast milk.

4. Discussion

4.1 What the evidence shows

The synthesis advances a practical exposure-chain interpretation: pollution sources determine which toxicants are available; environmental and household conditions determine routes of contact; occupation and daily routines shape frequency and duration; and maternal physiology and nutrition influence internal burden and susceptibility. This chain is particularly useful for nursing and midwifery because it translates environmental epidemiology into questions that can be asked at booking, reviewed during follow-up and used to guide referrals. This review found that pregnant and lactating women in the Niger Delta and elsewhere in SSA experience cumulative, multi-route exposure to metals, hydrocarbons and particles, and that the pattern differs by region but is consistently shaped by poverty, occupation and everyday practices. The Niger Delta emerges as the setting with the most complex exposure mixture, in which oil spills, gas flaring, contaminated food and water and, for many women, biomass cooking overlap. In the DRC the exposure is simpler but intense and is tied to a cultural practice. In both, the routes are those of ordinary daily life, so exposure cannot be avoided by individual choice alone. These findings support the exposome concept (Robinson et al., 2015). Women do not experience one pollutant at a time; they experience the accumulated pattern, and the studies that measured single metals in blood almost certainly underestimate what is present. The scarcity of mixture studies is therefore not a minor gap but a core limit on what can be said about total burden and about synergistic effects.

4.2 Why pregnancy and lactation matter

An exposure-informed continuum of care should therefore begin at antenatal booking, continue through trimester-specific review and extend into postnatal follow-up. Reassessment matters because work patterns, dietary practices, water access and household fuel use can change during pregnancy and after birth. For lactating women, the appropriate clinical response is to reduce avoidable exposure while supporting breastfeeding and assessing any specific concerns through established clinical pathways. Pregnancy changes how toxicants are handled. Expanding blood volume and mobilisation of bone and fat stores can release previously accumulated metals, which may explain the third-trimester rise in lead and cadmium reported in Bayelsa. The placenta and breast milk then act as routes to the child. The finding of heavy metals in breast milk, particularly in mothers with a history of gestational diabetes, is notable because it suggests that metabolic health and toxicant burden may interact (Philip-Slaboh et al., 2023). It does not, however, argue against

breastfeeding, which remains the recommended feeding practice; it argues for better maternal nutrition, exposure reduction and monitoring.

4.3 Differences between regions

The cross-regional evidence also supports context-specific prioritisation. In oil-producing communities, questions about flare proximity, spills, livelihood and local water or seafood are particularly informative. In mining areas, dust, occupational contact and soil consumption merit emphasis. In settings dominated by household combustion, fuel type, cooking location and ventilation are especially relevant. A common exposure-history framework can therefore be implemented with locally tailored prompts rather than a uniform checklist that overlooks regional realities. Differences between regions probably reflect real differences in exposure source and differences in how exposure was measured. The DRC studies used individual blood and urinary biomarkers, whereas many Niger Delta studies relied on residence-based or area-based proxies and community surveys. This makes direct comparison of the magnitude of exposure difficult, but the qualitative similarities are clear: in each setting, exposure is cumulative, tied to the local economy and heaviest in poor rural households.

4.4 Strengths and limitations

Strengths of the review include its registered protocol, comprehensive search with grey literature, dual independent screening, extraction and appraisal, the integration of biomarker, community and qualitative evidence, and its primary focus on the Niger Delta. Limitations should be noted. Only 12 of the 30 studies were from Nigeria and many assessed exposure by area-based proxy rather than individual measurement. Mixture analysis was rare, and longitudinal studies that follow women before conception through lactation were scarce, so changes in exposure over time are inferred largely from cross-sectional comparisons. Confounding was common (15 studies), and some studies were hospital-based. Language and publication bias are possible, and the included syntheses may overlap with some primary studies. Finally, the review's inclusion criteria required a cardio-metabolic outcome, so studies describing exposure alone in pregnant women, without such an outcome, were not captured and the overall picture of exposure may be incomplete.

4.5 Exposure, inequality and the policy context

This finding has an important equity dimension: exposure-reduction advice is only actionable when safer alternatives are accessible. Asking women to change water sources, household fuels or livelihoods without addressing affordability and availability risks shifting responsibility from environmental systems to individuals. The clinical and policy responses should therefore operate together, with nurses and midwives documenting patterns of exposure and service managers using aggregated, non-identifiable information to inform local prevention priorities. The modifiers

identified in this review (poverty, rurality, low education, dependence on local water and food, and limited access to antenatal care) are the markers of social disadvantage. This means that the burden of toxicant exposure falls on women who have least power to avoid it, and that exposure and inequality reinforce each other. Women in host communities live next to the infrastructure that generates the pollution but may receive few of the benefits of the industry, and the qualitative evidence suggests that they are well aware of this (Oghenetega et al., 2020b). Environmental pollution in the Niger Delta is therefore best understood as a social determinant of maternal health, and not only as an environmental hazard. This view connects the findings to global commitments on maternal health, reducing inequalities, responsible production and climate action, which are covered by Sustainable Development Goals 3.1, 10, 12 and 13. It also means that clinical responses, while necessary, are not sufficient. Exposure-informed nursing care can identify and support women, but only regulation of gas flaring, spill response and remediation, protection of water sources and access to clean household energy can reduce the exposure itself. The role of nurses and midwives is to provide the evidence from the clinic and the community that makes the case for such action.

4.6 Directions for future research

Several research priorities follow. Prospective cohorts should measure exposure at the individual level with repeated biomarkers, from before conception through lactation, and use mixture methods to estimate joint effects. Studies should measure the same toxicants in several media (blood, urine, cord blood, breast milk, water, food and household air) in the same women, so that sources and routes can be linked to body burden. Studies should be designed to separate seasonal, occupational and nutritional modifiers. Intervention research should test whether water treatment, cookstove programmes, nutritional supplementation or nursing-led counselling change exposure and health outcomes. Finally, qualitative and participatory methods should be used to understand how women perceive and manage exposure, so that interventions are designed with, and not for, them.

4.7 Comparison with the wider literature

The distinctive contribution of this article is the explicit synthesis of modifiers rather than the mere enumeration of toxicants. By bringing together residence, proximity, duration, season, household energy, occupation, culture and nutrition, it identifies an actionable structure for assessing exposure at the point of maternal care. The findings also support research designs that evaluate mixtures and trajectories rather than isolated exposure measurements at one time point. The pattern of exposure found here is consistent with the broader literature on environmental contaminants in pregnancy. International syntheses have reported that lead, cadmium and air pollutants are measurable in pregnant women worldwide, and that levels are higher in low-resource settings (Rosen et al., 2018; Zhong et al., 2022; Li et al., 2023). Reviews of household air pollution have likewise shown that

reliance on biomass and solid fuel is a major and avoidable source of exposure for women of reproductive age (Agrawal et al., 2014; Ndlovu et al., 2025). What this review adds is a regional picture in which these generic sources are combined with oil and gas activity, mining and cultural practices such as geophagy, and a focus on the modifiers that make some women more exposed than others. It also adds an emphasis on lactation. Much of the earlier literature stops at delivery, yet the Niger Delta evidence indicates that maternal body burden continues to matter in the postnatal period, both for the mother and, through breast milk, for the infant. This extends the concern of maternal health services beyond the antenatal period, and it is directly relevant to the postnatal and community nurses who follow mothers after birth. Because the number of studies on lactation in the review was small, this is an area where new primary research would be especially valuable.

5. Implications for Nursing and Midwifery Practice

The exposure patterns described above have direct implications for the professionals who deliver most maternal care in affected areas.

5.1 Take an exposure history

Implementation can be streamlined by using a brief initial screen for residence near major pollution sources, water and food sources, household fuel, occupation and geophagy, followed by a more detailed assessment when multiple exposure pathways are identified. Responses should be documented consistently, updated at subsequent visits and interpreted alongside routine obstetric findings. The screening questions identify potential exposure and do not substitute for laboratory confirmation when such testing is clinically indicated and available. Because exposure is determined by where a woman lives, what she eats and drinks, how she cooks and what she does for a living, much of it can be elicited by simple questions at the booking visit. Table 6 sets out a framework drawn from the exposure and modifier evidence. A woman who lives near a flare, depends on untreated water, cooks indoors with wood or kerosene, eats clay or earth and works in fishing or farming close to oil facilities has several overlapping risk factors and merits closer follow-up. Recording the answers in the antenatal record would, over time, give clinics a picture of the exposure profile of their catchment area.

Table 6. Exposure history framework for the booking visit and follow-up

Domain	Questions to ask	Why it matters
Residence	How far is your home from a gas flare, spill site or refining camp? How many years have you lived here? Any recent spill?	Exposure rises with proximity and duration
Occupation	Do you fish, farm, trade or work with petroleum products near oil facilities? For how many hours?	Adds exposure by several routes
Cooking and household energy	What fuel do you use? Do you cook indoors? How long each day? Is the room ventilated?	Biomass smoke is a major source of particulate matter and VOCs
Water and food	Where does your drinking water come from and is it	Ingestion route for metals and hydrocarbons

Domain	Questions to ask	Why it matters
	treated? How much local fish, seafood and locally grown produce do you eat?	
Soil and clay eating	Do you eat soil or clay? Has this changed in the dry season?	Major lead source in the DRC studies
Diet and nutrition	How often do you eat calcium-rich foods, vegetables and fruit? Are you taking calcium and iron?	Nutritional status modifies susceptibility
Infant feeding plans	Are you breastfeeding or planning to? Do you have concerns?	Metals detectable in breast milk

5.2 Counsel on modifiable routes

Counselling should distinguish microbial safety from chemical contamination. Boiling water can reduce microbial hazards but does not remove dissolved metals or petroleum-derived chemical contaminants; advice about drinking water should therefore reflect locally established water-quality information and the suitability of any treatment method. Similarly, improved ventilation may reduce smoke accumulation but does not replace cleaner fuel or source-level pollution control. These distinctions make practical guidance more precise and prevent women from relying on measures that do not address the relevant contaminant. Counselling should be practical and respectful of constraints, because many women cannot change where they live or what work they do. Within those limits, nurses and midwives can advise on household water treatment and filtration, safer food preparation, improved cookstoves, cooking outdoors or with better ventilation, cleaner fuels where affordable, and reduced soil eating where this is culturally appropriate and a safe alternative can be offered. Nutritional counselling should promote calcium-rich foods and antioxidant-rich diets, which may reduce susceptibility to lead and cadmium.

5.3 Support lactating mothers

Postnatal and community nurses should reassure mothers that breastfeeding remains beneficial, support exclusive breastfeeding with adequate maternal nutrition, and refer high-exposure mothers for monitoring where services exist. They should be alert to mothers with a history of gestational diabetes, in whom breast milk metals differed in the available evidence.

5.4 Work at community level

Community health nurses and midwives are well placed to run education in local languages, to work with traditional leaders, women’s groups and faith-based organisations, and to include women in designing exposure-reduction strategies that are culturally acceptable and economically realistic. The qualitative evidence suggests that women already understand the link between pollution and their health; what they lack is access to water, fuel, care and information.

5.5 Education, advocacy and research

A feasible service-level improvement is a short environmental exposure module incorporated into existing maternal health training, supported by a one-page booking prompt and referral guidance. Evaluation could examine completion of exposure histories, uptake of counselling, appropriate referrals and women's reported ability to adopt feasible exposure-reduction practices. Such implementation indicators would connect the review's recommendations to measurable improvements in service delivery. Environmental reproductive health should be part of nursing and midwifery curricula and in-service training in the Niger Delta. Professional associations can bring the exposure data that nurses collect to environmental regulators and local government, giving frontline observations a place in policy. Finally, nurse- and midwife-led studies of exposure-informed antenatal care and of household interventions would fill an important evidence gap.

5.6 An illustrative practice scenario

A midwife at a primary health centre in a Niger Delta community books a 27-year-old woman at 12 weeks of gestation in her third pregnancy. Using the exposure history, she learns that the woman has lived for 15 years about one kilometre from an active flare, draws water from a borehole that is not treated, cooks indoors on firewood for several hours a day, sells smoked fish at a market near the terminal and has begun eating clay since early pregnancy. Her diet contains little dairy or green vegetables. The midwife recognises several overlapping modifiers: long residence and close proximity, an untreated water source, indoor biomass cooking, an occupational contact, geophagy and low calcium intake. She does not attempt to remove them all at once. She records the history, arranges blood pressure and urinalysis at every visit, schedules glucose screening in line with national protocol and explains the danger signs of pre-eclampsia. She advises on boiling or filtering water, on cooking outdoors or opening ventilation, on a locally available calcium-rich food, and discusses alternatives to clay in a non-judgemental way. She explains that breastfeeding after delivery is encouraged and links the woman to the community health extension worker for follow-up. The clinic adds the woman's exposure profile to its register and, over time, the data show that many booked women share the same risks, which the head of unit uses to support a request to the local government for a water point. The scenario shows how clinical care, counselling and advocacy can be combined within a single booking visit.

5.7 Barriers and enablers

Several barriers may limit the adoption of exposure-informed care. Nurses and midwives may not have received training in environmental health, and booking visits are short and busy. Equipment for measuring blood pressure and glucose may be unavailable or poorly maintained. Biomonitoring of metals is not available in most primary care settings, so decisions must rely on history and

clinical surveillance. Women may be reluctant to discuss practices such as geophagy for fear of criticism, and advice on cooking fuel or water treatment is meaningless if alternatives are unaffordable. Enablers include short structured tools that fit into existing booking forms, training that links exposure to practical advice, supportive supervision, partnerships with community leaders and environmental agencies, and recognition of exposure-related risk in national maternal health guidelines. Given the limited evidence for what works, early adopters should evaluate their own practice and report their experience.

6. Recommendations

1. **Practice:** adopt a structured exposure history at booking and follow-up in antenatal clinics in oil-producing and mining communities, and record it in antenatal notes.
2. **Education:** include environmental reproductive health in pre-service and in-service training for nurses and midwives.
3. **Community:** deliver locally adapted counselling on water, cooking, soil eating and nutrition, in partnership with community leaders and women's groups.
4. **Policy:** enforce gas flare-out deadlines, spill remediation and buffer zones, support access to clean water and cleaner household energy, and establish routine environmental and biomonitoring surveillance in high-risk communities.
5. **Research:** conduct prospective studies with individual biomarkers and mixture analysis from pre-conception through lactation; evaluate household and nursing interventions; and combine biomarker data with women's own accounts of exposure.

In more detail, the recommendations for nursing and midwifery services are as follows. At the clinic level, an exposure history should be added to the booking form and revisited at the second and third trimester visits, so that changes in occupation, water source or cooking practice are noted. Blood pressure, urine protein and glucose surveillance should follow national protocols with extra vigilance for women with several risk factors. At the community level, nurses and midwives should work with traditional leaders and women's groups to deliver education in local languages, demonstrate water filtration and improved cookstoves, and promote locally available calcium-rich foods. At the service level, managers should provide training, job aids and supportive supervision, ensure that blood pressure and glucose equipment are functioning, and set up simple registers that allow exposure profiles to be summarised. At the professional level, nursing and midwifery councils and associations should include environmental health competencies in curricula and continuing education, and should make nursing observations available to regulators and to researchers.

7. Conclusion

The review's central practice implication is that cumulative exposure can be approached systematically even where comprehensive toxicant testing is unavailable. A structured source–route–modifier history, paired with routine maternal assessment and community-level advocacy, provides a realistic framework for identifying women who may benefit from targeted advice and follow-up. The resulting model connects environmental prevention, maternal clinical care and social determinants of health without reducing complex exposures to a single pollutant or a single behaviour. Pregnant and lactating women in the Niger Delta and across Sub-Saharan Africa live with cumulative, multi-route toxicant exposure that is shaped by oil and gas activity, mining, household energy, soil eating and, above all, by poverty and limited access to clean water and care. Nurses and midwives cannot remove these exposures alone, but they are the health workers who know the women and see them most often. By taking exposure histories, counselling on modifiable routes, supporting breastfeeding mothers and speaking for their communities, they can make exposure visible, reduce what can be reduced and strengthen the case for structural change.

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