

Changes in maternal health services utilization after industrial mine openings in 23 sub-Saharan African countries

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Abstract

Background

Large-scale mining operations can profoundly shape maternal health through multiple pathways, creating both risks and opportunities for equitable access to maternal health services. While mining-driven population mobility and economic transformation may increase vulnerabilities, including HIV transmission, mining investments can also strengthen healthcare infrastructure and service utilization. This study assesses changes in maternal health service utilization and equity following mine openings across sub-Saharan Africa (SSA).

Methods

Repeated cross-sectional data from the Demographic Health Surveys in 23 SSA countries between 1986 and 2023 were used. A difference-in-differences approach was applied, comparing areas close to mines (0–10 km) and comparison areas (10–50 km) over time before and after mine openings. Logistic regression models were used to determine the effect of mine openings on the number of antenatal care (ANC) contacts, HIV testing during ANC, facility-based births and skilled birth attendance.

Results

Among 390,486 pregnancies, women living in mining communities were more likely to attend 4 or more ANC visits than women in comparison areas, accounting for baseline differences and overall temporal trends (adjusted odds ratio (aOR): 1.76; 95% confidence interval (CI): 1.27–2.44). Both, ANC (aOR: 1.51, 95% CI: 1.09–2.08) and child births (aOR: 1.62, 95% CI: 1.27–2.05) were more often attended by a professional healthcare provider. However, these improvements were only seen among the wealthier households. Overall, no significant changes in HIV testing were observed.

Conclusion

Mining contexts present both opportunities and challenges for equitable maternal healthcare. Mine openings were associated with improved ANC utilization and more professionalized maternal care, but these benefits were largely confined to wealthier households. No effects on HIV testing were observed despite elevated risks in mining settings, underscoring the need to strengthen testing among pregnant women. These findings highlight the need to ensure that industrial development contributes to equitable improvements in maternal health services across SSA.

Background

Between 2000 and 2020, sub-Saharan Africa (SSA) achieved a 33% reduction in maternal mortality (1). Despite this progress, SSA disproportionately accounted for approximately 70% of maternal deaths worldwide in 2020 (1). Adequate maternal health services (MHS) are critical for preventing these deaths by enabling early detection of pregnancy complications, providing interventions to reduce mother-to-child transmission of infections, such as human immunodeficiency virus (HIV), and ensuring effective management of complications during and after birth (2, 3).

A crucial element of MHS is the provision of antenatal care (ANC) contacts throughout the pregnancy. Recognizing their importance in improving maternal health, the World Health Organization (WHO) increased the number of recommended ANC contacts from 4 to 8 in 2016 (4). However, between 2018 and 2023, only 9% of women in SSA met this target (5). Similarly, the presence of skilled healthcare professionals during birth is a crucial element to achieve Sustainable Development Goal (SDG) 3 Targets 3.1 and 3.2, which aim to reduce global maternal mortality and end preventable deaths of newborns and children under 5 years of age by 2030 (6). Yet, recent estimates indicate that more than a third of births are still not attended by skilled health personnel (7, 8). While differences exist across SSA countries, the utilization of ANC and skilled birth assistance services is largely shaped by socio-economic factors. Women from higher socio-economic backgrounds consistently demonstrate better use of MHS, while those from poorer households in remote and rural areas face multiple barriers, including inadequate health infrastructure, shortages of skilled providers, insufficient quality of care, and limited access to essential medicines (9–11).

Natural resource extraction in sub-Saharan Africa is deeply intertwined with processes of globalization, connecting mineral-rich regions to global commodity markets, international investment flows, and transnational supply chains. The abundance of natural resources in low- and middle-income countries offers the private sector an opportunity to contribute to economic growth and societal development (12, 13). However, there is limited evidence on whether the health benefits associated with mining-related development are distributed equitably across socio-economic groups and communities. This is particularly relevant in Africa, which holds more than 30% of the world's mineral reserves and over 60 different metals (14). As the global transition towards low-carbon energy systems accelerates, the strategic importance of Africa's mineral resources is likely to increase further (15, 16). Renewable energy technologies, including wind, solar, and hydrogen systems, are considerably more material-intensive than conventional fossil-fuel-based energy systems, driving rapidly growing demand for critical minerals and metals (17–19).

In the context of SSA, the establishment of large mining projects often triggers socio-economic changes that influence maternal health in complex, multifaceted ways (20–22). For example, limited employment opportunities and other socio-economic disadvantages increase the vulnerability of women of reproductive age to engage in transactional sex and unsafe practices, heightening their risk of HIV transmission (23, 24). At the same time, mining companies are often reported to invest in healthcare and other public infrastructure and services (25–28). These investments include establishing and upgrading health facilities, donating medical equipment, and engaging in community health initiatives, some of

which promote maternal health and HIV/AIDS services. Furthermore, road infrastructure improvements and potential increases in household wealth may reduce barriers to access maternal health facilities (29, 30). While access to healthcare remains a complex and multifaceted issue, these changes could result in improved infrastructure and service availability (31).

Previous studies have focused solely on individual case studies; thus, the current understanding of the impact of mine openings on maternal health service (MHS) utilization and the equitable distribution of these benefits across SSA remains limited. Therefore, this study aimed to assess changes in MHS utilization, including antenatal care (ANC), HIV testing, and skilled birth attendance, following mine openings across SSA, and to examine whether these changes differed by socio-economic status, using the largest available maternal health and mine-opening datasets.

Methods

Study design

This study employed a quasi-experimental difference-in-difference design to assess how the transition from pre-mining to the operational phase of industrial mines affected MHS utilization, including ANC contacts, HIV testing and skilled birth attendance. Pseudo-panels were created around the mining sites, utilizing regionally representative data from repeated cross-sectional household surveys. Trends in outcomes from the pre-mining to the operational phase were compared between populations living close to the mine (0–10 km radius) and those in the comparison areas (10–50 km radius).

Data sources

Mining data

Data on industrial mining projects in SSA were retrieved from the Standard&Poor's Global Market Intelligence dashboard on 23 October 2023, including details about location, commodity and operational status, opening and closing dates of mines since 1980 (32). The accuracy of mining information was verified for a subset of mines included in a larger research initiative (33).

The mining phases are dichotomized into a pre-mining phase (> 3 years before mine opening) and an operational phase (after mine opening). The three years prior to mine opening were classified as the construction phase, which typically involves rapid demographic changes that may bias estimates of community-level effects (34). Therefore, data from this period were excluded. The three year duration reflects average construction timelines reported in grey literature and mining project documents (35).

Demographic and Health Survey (DHS) data

Demographic and Health Surveys (DHS) are nationally and regionally representative, cross-sectional surveys funded by the United States Agency for International Development (USAID) that provide

household- and individual-level data. The standardized questionnaires collect information on household characteristics, maternal and reproductive health, and HIV-related indicators, enabling cross-national and temporal comparisons (36). DHS include georeferenced cluster locations collected using Global Position System (GPS) data. To protect confidentiality, DHS displaces cluster coordinates up to 2 km in urban and up to 5 km in rural areas, without crossing national or regional boundaries (36). All georeferenced DHS surveys conducted between 1986 and 2023 were obtained for analysis as of 31 October 2023.

Sample selection

The units of analysis were pregnancy events for ANC and birth-related outcomes, and mothers aged 15–49 years for HIV-related outcomes, reflecting DHS data structure. Mothers outside the 15–49 age range were excluded. To minimize the impact of external factors specific to urban areas, DHS clusters located within cities with populations exceeding 100,000 residents were excluded using the methodology further described in (37). Mines were included if information on production and extraction between 1980 and 2023 was available and if they were geographically isolated, defined as located at least 20 km from any other mine opening to avoid spillover effects from neighbouring operations. DHS clusters were included if located within a 50 km radius of geographically isolated industrial mines with data from both before and after mine opening. Clusters could be resampled if they were within the radius of multiple mines, maintaining independence between pseudo-panels. Additionally, mines were required to have at least 10 mothers or pregnancy events in the mining areas during both periods to ensure sufficient statistical power.

Variables

Exposure variables

The exposure variable consists of an interaction term between spatial proximity to the mine (0–10 km vs. 10–50 km) and its operational status (pre-mining vs. operational) to estimate effects on maternal and HIV service utilization. The 10 km exposure radius was selected based on literature and the research group's field experience, indicating that direct mine-related effects on the community beyond this radius are anticipated to be limited (29, 38, 39).

Outcome variables

The outcome variables included a set of indicators to assess MHS utilization during pregnancy, childbirth and the postpartum period. For ANC, the number of ANC contacts was used to assess MHS utilization during pregnancy. The variable was dichotomized at three different levels: (i) any vs. no ANC contact; (ii) four or more vs. fewer than four ANC contacts (based on 2002 WHO recommendations); and (iii) eight or more vs. fewer than eight contacts (in line with the 2016 WHO recommendation) (4). While the type of health facility where ANC contacts occurred is not explicitly specified in the DHS data, detailed information on the qualifications of the personnel involved is available. A distinction was made

between skilled providers, including trained and licensed doctors, nurses, and midwives, and traditional care providers without formal medical training (36).

For birth-related care outcomes, variables included whether births (i) occurred in a healthcare facility (public or private) or outside the healthcare setting (e.g., at home or elsewhere) and (ii) whether the birth was attended by a skilled professional or traditional birth attendant without medical training.

HIV testing as part of MHS utilization was categorized based on whether the woman (i) had ever been tested for HIV, (ii) knew where to get tested in general, (iii) was offered HIV testing explicitly during an ANC contact, and (iv) got tested for HIV during an ANC contact.

Covariates

This study included socio-economic and demographic covariates that may differ by mine proximity and phase, such as maternal age, highest level of education attained, place of residence (urban/rural), and household wealth quintiles. Covariates were selected a priori based on previous literature and study design (40, 41).

Statistical analysis

A difference-in-differences approach was employed to estimate the effects of mine openings on MHS utilization. The exposure of interest was the interaction between living within 10 km of a mine and the operational phase of the mine. In the absence of an effect of mine openings on MHS utilization, parallel trends would be expected, assuming that the location and timing of mine openings are not systematically correlated with other factors (42). A positive beta-coefficient for the interaction term indicates that a mine opening leads to an increase in the outcomes relative to the general trends in the comparison areas (> 10 km).

Logistic regression models were estimated for each outcome variable, and the reported odds ratios correspond to the interaction term. All models incorporated a mine-level fixed effects to account for the pseudo-panel structure of repeated cross-sectional surveys around each mine. Adjusted models included fixed effects for the covariates listed above. Stratified analyses compared the lower and upper two household wealth quintiles. Estimates were reported with their associated 95% confidence intervals (CI). Statistical analyses were performed in Stata version SE14.2 (Stata Corporation; College Station, USA). Sample selection based on geographical criteria was done using ArcGIS Desktop version 10.6.1. (Environmental Systems Research Institute; Redlands, California, USA).

Results

Study population, demographic characteristics of mothers and pregnancy profiles

Figure 1 shows the results of the sample selection process. Out of 1,062 industrial mines at operational stages, georeferenced DHS data from 1,345,270 mothers and 3,818,980 pregnancy events were available. The final datasets included 48,324 mothers around 17 mines in 14 countries and 390,486 pregnancy events around 72 mines in 23 countries, respectively.

Table 1 presents maternal characteristics and MHS utilization measured at the pregnancy-event level. In total, there were 8,552 and 17,722 pregnancy events in the mining areas and 153,653 and 210,559 in the comparison areas, during the premining and operational phase, respectively. Mining areas were already wealthier in the pre-mining phase, while a greater tendency toward urbanization was observed after mine opening in the mining areas compared to the comparison areas. The utilization of MHS increased over time in both areas, with larger gains in mining areas than in comparison areas.

Table 1

Demographic and descriptive antenatal care- and birth care-related characteristics of pregnancy events in 23 Sub-Saharan African countries, stratified by distance to mine and mining phase

Mining phase	Pre-mining phase		Operational phase	
	(>3 years before mine opening)		(after mine opening)	
Distance to mine	Comparison area (10–50 km)	Mining area (0–10 km)	Comparison area (10–50 km)	Mining area (0–10 km)
N (pregnancy events)	153,653	8,552	210,559	17,722
Demographic characteristics				
Age, mean (SD)	39.6 (7.0)	40.3 (6.7)	33.8 (7.5)	33.8 (7.5)
Wealth				
Lower two quintiles	58,165 (37.9%)	2,863 (33.5%)	94,456 (44.9%)	6,471 (36.5%)
Middle quintile	62,118 (40.4%)	3,078 (36.0%)	51,540 (24.5%)	4,160 (23.5%)
Upper two quintiles	33,370 (21.7%)	2,611 (30.5%)	64,563 (30.7%)	7,091 (40.0%)
Urban residency	21,783 (14.2%)	2,013 (23.5%)	37,648 (17.9%)	6,356 (35.9%)
Highest educational level attended				
No education/preschool	96,556 (62.8%)	5,004 (58.5%)	87,645 (41.6%)	7,273 (41.0%)
Primary	45,657 (29.7%)	2,457 (28.7%)	93,781 (44.5%)	6,487 (36.6%)
Secondary	10,355 (6.7%)	1,005 (11.8%)	25,472 (12.1%)	3,633 (20.5%)
Higher	1,071 (0.7%)	86 (1.0%)	3,658 (1.7%)	325 (1.8%)
Descriptive antenatal care- and birth care-related outcomes				
Antenatal care				
At least 1 ANC contact	6,620 (78.8%)	193 (68.7%)	57,988 (95.9%)	4,248 (96.2%)
<i>Note: Percentages are calculated based on non-missing values.</i>				

Mining phase	Pre-mining phase (>3 years before mine opening)		Operational phase (after mine opening)	
Distance to mine	Comparison area (10–50 km)	Mining area (0–10 km)	Comparison area (10–50 km)	Mining area (0–10 km)
4 + ANC contact	2,769 (32.9%)	61 (21.7%)	29,072 (48.1%)	2,578 (58.4%)
8 + ANC contact	396 (4.7%)	6 (2.1%)	3,705 (6.1%)	493 (11.2%)
Professional ANC provider	6,625 (76.3%)	191 (67.5%)	58,264 (94.7%)	4,374 (95.3%)
Birth care				
Birth at healthcare facility	4,375 (39.1%)	129 (34.8%)	55,724 (66.4%)	4,380 (70.4%)
Skilled birth attendance	5,296 (46.8%)	145 (39.1%)	58,009 (67.8%)	4,695 (74.0%)
HIV testing				
Ever tested for HIV	1,310 (24.5%)	87 (24.6%)	26,004 (78.4%)	19,41 (76.6%)
Know where to get tested for HIV	3,067 (60.9%)	209 (66.6%)	29,269 (93.3%)	2,264 (92.0%)
Offered HIV test during ANC contact	78 (26.0%)	13 (37.1%)	13,504 (89.2%)	1,067 (86.0%)
Tested for HIV during ANC contact	69 (23.0%)	12 (32.4%)	13,454 (88.9%)	1,045 (84.1%)
<i>Note: Percentages are calculated based on non-missing values.</i>				

Table 2 presents the characteristics of 8,400 and 36,653 mothers in the comparison area, and 533 and 2,738 mothers in the mining area during the pre-mining and operational phases, respectively. The data suggests that broader economic changes occurred in both areas over time, but mining areas showed greater wealth inequality, with polarization towards extremes, while comparison areas showed better educational gains. HIV-related service indicators also increased, but by smaller amounts in mining areas than in comparison areas.

Table 2

Demographic and HIV related characteristics of mothers (aged 15–49) in 23 Sub-Saharan African countries, stratified by distance to mine and mining phase

Mining phase	Pre-mining phase		Operational phase	
	(>3 years before mine opening)		(after mine opening)	
Distance to mine	Comparison area (10–50 km)	Mining area (0–10 km)	Comparison area (10–50 km)	Mining area (0–10 km)
N (mothers)	8,400	533	36,653	2,738
Demographic characteristics				
Age, mean (SD)	36.0 (9.0)	36.9 (8.8)	32.1 (7.8)	32.1 (8.0)
Wealth				
Lower two quintiles	2,722 (32.4%)	138 (25.9%)	16,048 (43.8%)	831 (30.4%)
Middle quintile	3,865 (46.0%)	232 (43.5%)	7,798 (21.3%)	542 (19.8%)
Upper two quintiles	1,813 (21.6%)	163 (30.6%)	12,807 (34.9%)	1,365 (49.9%)
Urban residency	1,389 (16.5%)	155 (29.1%)	6,618 (18.1%)	930 (34.0%)
Highest educational level attended				
No education/preschool	5,835 (69.5%)	328 (61.5%)	10,053 (27.4%)	788 (28.8%)
Primary	1,766 (21.0%)	102 (19.1%)	20,500 (55.9%)	1,344 (49.1%)
Secondary	704 (8.4%)	86 (16.1%)	51,30 (14.0%)	554 (20.2%)
Higher	93 (1.1%)	17 (3.2%)	970 (2.6%)	52 (1.9%)
Descriptive HIV-related outcomes				
Ever tested for HIV	1,310 (24.5%)	87 (24.6%)	26,004 (78.4%)	19,41 (76.6%)
<i>Note: Percentages are calculated based on non-missing values.</i>				

Mining phase	Pre-mining phase (>3 years before mine opening)		Operational phase (after mine opening)	
Distance to mine	Comparison area (10–50 km)	Mining area (0–10 km)	Comparison area (10–50 km)	Mining area (0–10 km)
Know where to get tested for HIV	3,067 (60.9%)	209 (66.6%)	29,269 (93.3%)	2,264 (92.0%)
Offered HIV test during ANC contact	78 (26.0%)	13 (37.1%)	13,504 (89.2%)	1,067 (86.0%)
Tested for HIV during ANC contact	69 (23.0%)	12 (32.4%)	13,454 (88.9%)	1,045 (84.1%)
<i>Note: Percentages are calculated based on non-missing values.</i>				

Effects on antenatal and birth-related care

A trend towards more ANC contacts in mining areas was found in the logistic regression models (Table 3). In the difference-in-differences approach, adjusting for baseline levels, temporal trends and covariates, mothers in operational mining sites had 76% more often had 4 or more ANC contacts (aOR: 1.76, 95% CI: 1.27–2.44). Similarly, the new WHO recommendation of 8 or more ANC visits was achieved more often in mining areas than in comparison areas (aOR: 2.68, 95% CI: 1.11–6.49). Additionally, a trend towards more professionalized ANC provision after mine opening was discernible, with more ANC contacts performed by a professional provider (aOR 1.51, 95% CI: 1.09–2.08). Stratification by wealth revealed that these improvements were most pronounced among women in wealthier households, while among mothers from poorer households, no statistically significant improvements were seen.

Similar to ANC care, workforce professionalization in birth care was observed in mining areas. The odds of receiving professional attendance during birth increased significantly (aOR: 1.62, 95% CI: 1.27–2.05). However, no significant differences were observed in the place of birth, with no notable differences between mining and comparison areas in the frequency of births at home or in a healthcare facility. Interestingly, there was large heterogeneity in effect sizes for both outcomes by wealth. While improvements were seen among wealthier population groups, mothers from poorer households were less likely to deliver at healthcare facilities (OR: 0.60, 95% CI: 0.37–0.97) and to be attended by a skilled health professional (OR: 0.48, 95% CI: 0.30–0.76).

Effects on HIV testing among mothers during pregnancy

In the adjusted models, there were no statistically significant differences in HIV testing between mining and comparison areas among the total population (Table 3). Among the poorer households, HIV testing was less likely to be offered (OR: 0.23, 95% CI: 0.07–0.72) and conducted (aOR: 0.17, 95% CI: 0.05–0.53) in operational mining areas than in comparison areas, accounting for baseline differences and temporal trends.

Table 3
Effect of mine openings on antenatal, birth care and HIV testing.

Antenatal care	Crude OR (95% CI)	Adjusted OR (95% CI)	Poorest 40% OR (95% CI)	Wealthiest 40% OR (95% CI)
At least 1 ANC contact	1.61 (1.15–2.24)	1.30 (0.93–1.82)	1.51 (0.61–3.77)	8.10 (2.00–32.92)
4 + ANC contact	1.79 (1.30–2.47)	1.76 (1.27–2.44)	1.99 (0.95–4.14)	3.87 (1.38–10.84)
8 + ANC contact	2.70 (1.13–6.42)	2.68 (1.11–6.49)	n.a.	7.58 (0.91–62.91)
Professional ANC provider	1.82 (1.33–2.51)	1.51 (1.09–2.08)	1.07 (0.45–2.57)	11.84 (3.03–46.17)
Birth care				
Birth at healthcare facility	1.27 (1.00–1.62)	1.08 (0.85–1.38)	0.60 (0.37–0.97)	3.07 (1.31–7.18)
Skilled birth attendance	1.84 (1.46–2.32)	1.62 (1.27–2.05)	0.48 (0.30–0.76)	5.24 (2.33–11.78)
HIV testing				
Ever tested for HIV	1.47 (1.11–1.97)	1.22 (0.91–1.63)	0.93 (0.56–1.53)	1.37 (0.87–2.16)
Know where to get tested for HIV	1.85 (1.33–2.57)	1.19 (0.85–1.67)	1.76 (0.99–3.14)	0.65 (0.36–1.20)
Offered HIV test during ANC contact	1.08 (0.50–2.34)	0.73 (0.33–1.59)	0.23 (0.07–0.72)	n.a.

Antenatal care	Crude OR (95% CI)	Adjusted OR (95% CI)	Poorest 40% OR (95% CI)	Wealthiest 40% OR (95% CI)
Tested for HIV during ANC contact	0.92 (0.42–1.99)	0.58 (0.26–1.29)	0.17 (0.05–0.53)	n.a.

ANC: antenatal care, CI: confidence interval, OR: odds ratio, n.a.: no model convergence

Discussion

This analysis of Demographic and Health Survey (DHS) data from 72 mining areas across 23 SSA countries suggests that mine openings were associated with improved MHS utilization and the professionalization of MHS provision, as reflected in higher proportions of ANC contacts and births attended by trained healthcare professionals. However, these benefits were not equitably distributed, as significant improvements were observed only among women from higher socio-economic backgrounds. These findings suggest that while mining-related development may strengthen maternal healthcare provision, it does not necessarily reduce existing socio-economic inequalities in access to and utilization of MHS. Overall, HIV testing among pregnant women remained unchanged following mine openings.

The results of this study suggest that ANC utilization increased more rapidly over time in mining areas than in comparison areas. However, these gains were not equitably distributed, as improvements were largely confined to women from higher socioeconomic backgrounds. Socio-economic status is a well-established determinant of ANC utilization (43–45), while structural factors, such as improved transportation infrastructure and the professionalisation of healthcare services, have also been shown to facilitate access to ANC in SSA (45). The concentration of benefits among wealthier households suggests that increased ANC utilization may have been driven primarily by broader socio-economic improvements among individuals directly benefiting from mining activities rather than by structural changes in healthcare provision that reached the wider community. Consequently, although mine openings can contribute to improved maternal healthcare utilization, they appear insufficient to reduce existing socioeconomic inequalities in access to ANC. Furthermore, both mining and comparison areas remained well below the current WHO recommendation of eight ANC contacts during pregnancy.

A previous study has shown that even when ANC contact frequency increases, the content and quality of those contacts often remain suboptimal (46). The increased professionalization of healthcare providers for ANC and birth attendance in the mining areas identified in this study might suggest that the quality of MHS in these areas was also improving. The contributing factors to this dynamics, whether better

livelihood opportunities, direct investments in education or infrastructure by the mines, or other factors that attract trained professionals to mining areas, remain to be investigated.

Mining activities often increase the risk of HIV transmission, as well as risky sexual behaviours, and mining communities show lower knowledge on HIV-related issues (30), with women of reproductive age being particularly vulnerable (23). In our analysis, no significant changes in HIV testing patterns among pregnant women were observed following mine openings. The fact that 16% of women did not get tested for HIV during an ANC visit represents a missed opportunity for integrated maternal and HIV services and a health risk for this vulnerable population, particularly concerning the importance of early detection, preventing mother-to-child transmission (3). This finding contrasts with evidence that HIV programmes are often prominent in health management plans of mines (47, 48). However, those studies assessed HIV testing in the general population rather than specifically during ANC.

The overall positive impacts of mine openings were not equally distributed across socio-economic strata. Indeed, in a qualitative study in various mining settings in SSA, mining communities reported such inequities across multiple dimensions (23). Mine development often triggers demographic changes, with many young people seeking livelihood opportunities moving close to mining sites. Further research is needed to discern the impacts on the local population from changes driven by demographic composition.

Recently, significant gaps in global health financing have threatened maternal health and HIV programs (49, 50). If international funding for health programs is cut, ANC in mining regions and beyond could lose recent gains among the poorest populations, reverse modest progress toward eight ANC contact recommendations, undermine healthcare provider professionalization, and further weaken already inadequate HIV testing services (51). These setbacks would severely jeopardize progress toward achieving Sustainable Development Goal targets 3.1 and 3.2, which aim to reduce global maternal mortality and end preventable deaths of newborns and children under 5 years by 2030. Innovative funding mechanisms involving private sector stakeholders, particularly mining companies operating in these regions, should be explored to sustain and expand essential MHS.

In this study, the largest dataset to date on MSH utilization in mining areas across SSA was used. Applying a quasi-experimental methodology to nationally and regionally representative data from multiple countries enabled quantification of the impacts of mine openings on selected antenatal care indicators, providing critical insights into maternal health trends, including HIV testing, across mining regions in SSA (42, 52). Yet, there are several potential limitations:

The social and environmental impacts of mines can extend along access routes. In this study, mining areas were defined based on geodesic distance from the mine; consequently, some clusters located along access routes may have been misclassified as comparison areas. In addition, despite the large amount of data across sub-Saharan Africa, country-specific analyses were not feasible because of insufficient statistical power. Consequently, this study could not investigate how national policy and governance, health system characteristics, or broader structural, socio-economic and cultural factors

influence the equitable distribution of maternal health service improvements following mine openings. Further research is therefore needed to identify the contextual factors that enable industrial development to improve maternal healthcare equitably and to inform interventions tailored to specific national settings.

Conclusions

Mining contexts present both opportunities and challenges for promoting maternal healthcare services. Overall, mine openings, which are largely driven by ongoing globalization processes, including expanding global commodity markets, the low-carbon transition, and geopolitical dynamics, were associated with improvements in ANC utilization and the professionalization of maternal health service providers. However, improvements were largely seen among mothers from wealthier households. No effects on HIV testing rates were observed. Particularly in mining settings where HIV risks are high, efforts to promote HIV testing among pregnant women seem warranted. To harness the potential of industrial development and globalization, the pathways by which mining companies can promote access to maternal health services in SSA need to be better understood.

Abbreviations

ANC	Antenatal care
CI	Confidence interval
DHS	Demographic and Health Survey
GPS	Global Positioning System
HCF	Healthcare facility
HA4SD	Health Impact Assessment for Sustainable Development
HIV	Human Immunodeficiency Virus
HP	Health professional
MTCT	Mother-to-Child Transmission
OR	Odds ratio
r4d	Research for Development
SD	Standard deviation
SDC	Swiss Agency for Development and Cooperation

SNSF	Swiss National Science Foundation
SSA	Sub-Saharan Africa
USAID	United States Agency for International Development
WHO	World Health Organization

Declarations

Ethics clearance

No ethical approval was required for conducting a secondary data analysis using data from the DHS program. The DHS procedures and questionnaires are rigorously reviewed and approved by the International Coaching Federation Review Board (ICF IRB). The ICF IRB, along with IRBs in host countries, ensures that surveys adhere to the ethical standards set by the United States Department of Health and Human Services for the protection of human subjects, as well as the host countries' laws and norms.

Availability of data and materials

Raw data including the Demographic and Health Survey program (<https://www.dhsprogram.com>) and Standard & Poor's mining datasets (<https://www.spglobal.com/market-intelligence/en/industries/metals-mining>) can be downloaded online upon a permission request to access the data. Analytic scripts are available upon reasonable request from Dominik Dietler.

Competing interests

All authors declare no competing interests.

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Author's contribution

J. C. L.: Conceptualization, formal analysis, visualization, writing – original draft, writing – review & editing. **A. M. K.:** Conceptualization, writing – review & editing. **D. D.:** Conceptualization, statistical analysis. writing – review & editing. **M. S. W.:** Conceptualization, supervision, writing – review & editing. All authors have read and agreed to the published version of the manuscript.

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Figures

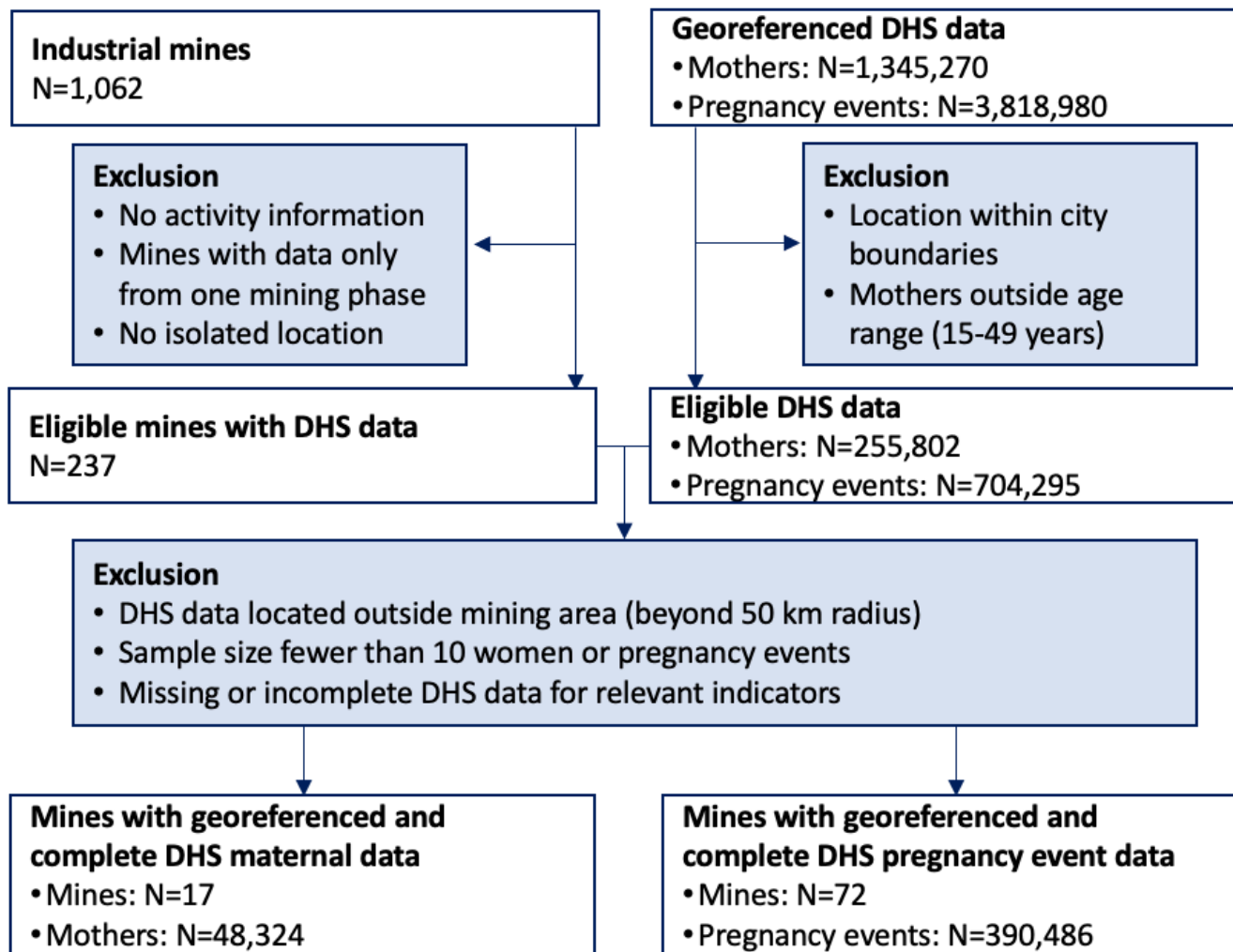


Figure 1

Flow chart showing the selection of Demographic and Health Survey data around mining sites