

# Global Research Trends On Mercury Exposure In Pregnant Women (2020–2026): A Bibliometric Analysis And Systematic Review

Andriani<sup>1\*</sup>, Hasanuddin Ishak<sup>2</sup>, Owildan Wisudawan B<sup>3</sup>, Aminuddin Syam<sup>4</sup>

<sup>1</sup>Magister Program Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

<sup>2</sup>Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

<sup>3</sup>Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

<sup>4</sup>Department of Nutrition Science, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

\*Corresponding Author: Andriani, Magister Program Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia, Email: andriani17unismuh@gmail.com

## ABSTRACT

**Background:** Mercury (Hg) is a highly toxic heavy metal that bioaccumulates in the human body and poses significant risks to maternal and fetal health. This study examined worldwide research trends and thematic areas of scientific literature on mercury exposure among pregnant women and its clinical implications.

**Methods:** We performed a bibliometric analysis and systematic literature review of 765 documents indexed in the Scopus database between 2020 and 2026. Data were analyzed using VOSviewer and Tableau software.

**Results:** The publication trend was significantly increased, with a peak of 98 documents in 2021, and the United States was the main contributor. Thematic analysis identified three primary clusters: environmental exposure (particularly methylmercury from seafood), pregnancy complications (preeclampsia and hypertension), and neurotoxicity. A systematic review showed a positive association between maternal mercury levels and adverse outcomes such as miscarriage, low birth weight (LBW), and preeclampsia.

**Conclusion:** Mercury exposure continues to be an important public health issue. Future investigation should be directed towards mitigation strategies for environmental exposure pathways to protect maternal health and fetal neurological development.

**Keywords:** Mercury, Pregnant Women, Bibliometric Analysis, Preeclampsia, Environmental Health, Toxicology.

## INTRODUCTION

Exposure to mercury (Hg) is a great public health challenge worldwide. Mercury is a heavy metal with complex toxicological properties and a high potential for bioaccumulation, which can lead to a variety of adverse health effects. Humans are exposed via several routes, including dietary intake, environmental contamination, and industrial activities. Severe risks include neurological damage and developmental disorders [1,2]. However, current international safety thresholds are largely derived from Western population data, which may not fully account for the unique dietary patterns and mercury metabolism found in Asian populations. [15]

Mercury exists in several chemical forms, all of which contribute to human exposure. The most common organic mercury form found in food is methylmercury, especially in fish and seafood. Regular consumption of fish contaminated with methylmercury can result in the accumulation of this compound in the human body, leading to neurotoxicity and impairment of development, especially in children [2–5]. In regions such as Indonesia, where seafood serves as a primary protein source, the risk of MeHg accumulation is particularly high, requiring the development of region-specific physiologically based toxicokinetic (PBTk) models to accurately assess risks to pregnant women and their fetuses [15]. This concern is particularly relevant in coastal populations where seafood constitutes a major dietary source. A study conducted in Kao Bay, Indonesia, found that all fish samples contained mercury and arsenic, and risk assessment results indicated that long-term fish consumption could pose significant health risks to local communities due to bioaccumulation and biomagnification of heavy metals in aquatic ecosystems [38]. Inhalation of mercury vapor may also be a route of exposure, particularly for workers in industries using the metal and in domestic settings where the metal is used in cultural practices [1,6,7].

Mercury vapor is readily taken up into the systemic circulation and subsequently bioaccumulates in tissue  
Genetics and Molecular Research 25 (7s): 2026

matrices [8]. Other sources include the use of mercury-containing dental amalgams as restorative materials for dental caries. This practice may be a possible exposure route, particularly for dental professionals with occupational mercury (Hg) exposure in the clinic setting [3,9]. Mercury exposure occurs via different routes, mainly via inhalation. Mercury vapor is inhaled into the lungs and readily enters the systemic circulation, where it exerts toxic effects throughout the body [1,6].

Methylmercury is absorbed mainly by eating contaminated fish and seafood. Bioaccumulation of mercury in aquatic organisms is of particular concern in marine ecosystems, as it can pose health risks to human consumers, especially children and pregnant women [2,3]. Dermal contact with mercury in solution or with mercury-containing cosmetic products [6,10] may also be a source of dermal exposure, although less frequently. Daily intake of Hg from fish consumption was negatively associated with hemoglobin levels, with anemic pregnant women having higher estimated metal intake and hair mercury concentrations, supporting the relevance of dietary mercury exposure in maternal health research [41].

Humans can be tested for mercury exposure in blood, urine, hair, and breast milk. Blood mercury levels are primarily an indicator of recent exposure, as levels decrease by about one-half every three days after exposure has stopped, and provide a measure of mercury intake from dietary sources. Adverse health effects from mercury exposure may be acute or chronic and include impairment of renal and hepatic function, respiratory and gastrointestinal disorders, toxicity of the central nervous system, seizures, and death in severe cases [11].

The exposure of pregnant women to mercury is a major global public health problem with serious implications for the developing foetus. This heavy metal can accumulate in the placenta and directly affect fetal brain development. Such exposure is shown to be detrimental to the mother as well as increases the risk of congenital abnormalities and neurological disorders in the offspring [12-14]. Some mercury compounds bioaccumulate and cross the placental barrier to the fetus and are transferred into colostrum and breast milk [15, 16]. This exposure has been linked to serious adverse health effects in newborns, including birth defects and a greater risk of neurodevelopmental disorders, including hyperactivity and autism spectrum-related conditions [17].

Exposure of mothers to a mixture of chemical and nonchemical stressors is an important determinant of maternal and child health. The co-occurrence of mercury exposure and psychosocial factors such as stress or depression is of particular concern given its association with adverse birth outcomes and persistent neurodevelopmental sequelae [18,19]. There is strong evidence for a synergistic interaction of these stressors [20]. Of importance, significant dysregulation of maternal cortisol profiles has been observed in women exposed to high stress with mercury concentrations above the median relative to women experiencing similar levels of stress with lower mercury burdens [21,22]. Furthermore, genetic polymorphisms may modify susceptibility to mercury exposure during pregnancy, with variants in glutathione-related genes such as GCLC, GCLM, and GPX1 consistently linked to small-for-gestational-age infants, preeclampsia, and impaired offspring neurodevelopment. Their review highlights the importance of integrating genetic susceptibility into mercury risk assessment and precision-based prenatal interventions [42].

This work combined an exploratory review and a bibliometric analysis to summarize the prevailing results, methodological approaches, and evolutionary trends of mercury exposure in pregnant women. The current study aims to provide critical insights into the current status of heavy metal research by mapping its intellectual structure and identifying influential authors, high-impact journals, and key geographic contributors. The overall goal of these findings is to contribute to the development of future intervention efforts to reduce mercury burdens in maternal populations.

This bibliometric analysis is also valuable because it provides a comprehensive overview of global research trends concerning mercury exposure among pregnant women, which is an important public health issue. This study uses bibliometric techniques to identify the countries, research themes, and scientific developments that have had the greatest impact in the last decade. These results suggest that Hg exposure mainly from seafood consumption and environmental sources is associated with an increased risk of pregnancy complications, including preeclampsia, miscarriage, and fetal neurodevelopmental disorders. Therefore, this study is an important reference for researchers, health professionals, and policymakers to develop effective prevention and intervention strategies to protect maternal and infant health.

## **METHODS**

### **Research Design and Data Source**

This study employed a quantitative bibliometric approach integrated with a systematic review design to analyze global research trends on mercury exposure among pregnant women. The bibliometric approach was used to quantitatively map the structure, development, and collaboration patterns within the research field, while the systematic review component enabled qualitative synthesis of key findings from selected studies. Data were retrieved from the Scopus database, which is widely recognized for its extensive coverage of high-quality peer-

reviewed literature across multiple disciplines. The search was conducted in January 2026 and included publications from January 2020 to December 2025, with early-access articles from 2026 included when available.

### **Search Strategy and Eligibility Criteria**

A structured search strategy was developed using Boolean operators to ensure comprehensive identification of relevant literature. The search query applied was (“mercury exposure” OR “mercury toxicity”) AND (“pregnant” OR “pregnancy” OR “maternal”), and was limited to titles, abstracts, and keywords in English. Only peer-reviewed documents such as original research articles, review papers, and conference proceedings were included, while editorials, notes, letters, and non-indexed documents were excluded. Studies were considered eligible if they focused on mercury exposure in pregnant women or maternal populations, were indexed in Scopus within the specified time frame, and provided empirical or review-based evidence. Articles unrelated to human pregnancy, lacking complete bibliographic data, or identified as duplicates were excluded from the analysis.

### **Data Cleaning and Pre-processing**

The initial search yielded 765 records, which were exported in CSV format for further processing. Data cleaning and preprocessing were conducted using OpenRefine and Microsoft Excel to ensure accuracy and consistency of the dataset. This process included the removal of duplicate records, standardization of author names and institutional affiliations, and harmonization of keywords to merge synonymous terms. In addition, incomplete or inconsistent metadata were corrected to improve the reliability of subsequent analyses. The refined dataset was then deemed suitable for bibliometric and network analysis.

### **Bibliometric Analysis and Visualization**

Bibliometric analysis was performed using VOSviewer (version 1.6.xx) to construct and visualize scientific networks. Several analytical techniques were applied, including co-authorship analysis to examine collaboration patterns among authors, institutions, and countries; co-occurrence analysis of keywords to identify major research themes and emerging topics; citation and co-citation analysis to determine influential publications and the intellectual structure of the field; and bibliographic coupling to explore relationships between documents based on shared references. The resulting network maps were visualized with nodes representing individual items and links indicating relationships, while clustering algorithms were used to group related items into thematic clusters based on link strength.

### **Systematic Review Procedure**

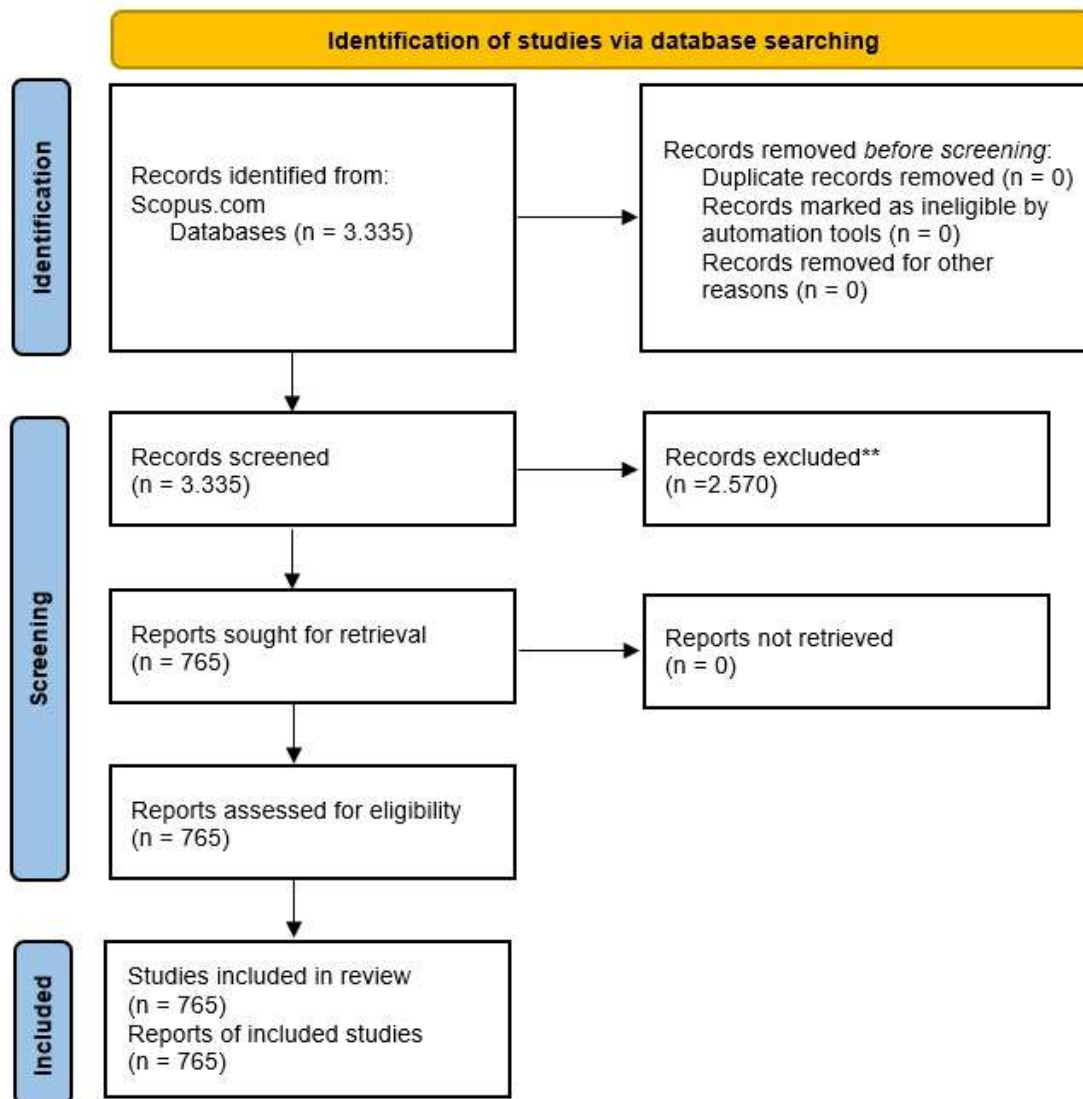
To complement the bibliometric findings, a systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process consisted of four stages: identification of records through database searching, screening of titles and abstracts to remove irrelevant studies, eligibility assessment through full-text evaluation, and final inclusion of studies meeting the predefined criteria. Relevant data extracted from the selected studies included study design, population characteristics, methods of mercury exposure assessment such as blood, hair, or urine biomarkers, and reported health outcomes including birth outcomes and neurodevelopmental effects. The extracted information was synthesized narratively to highlight key findings, trends, and research gaps.

### **Data Analysis and Interpretation**

Descriptive statistical analysis was used to summarize publication trends, including annual growth, distribution by country, and subject areas. The visualization outputs generated from VOSviewer were interpreted to identify dominant research clusters, collaboration networks, and emerging themes. By integrating quantitative bibliometric indicators with qualitative synthesis from the systematic review, this study provides a comprehensive understanding of the evolution, structure, and key directions of research on mercury exposure in pregnant women.

### **Ethics Statement**

This study was based on secondary data derived from publicly accessible bibliographic databases and did not involve human participants or confidential information. Therefore, ethical approval was not required, in accordance with standard guidelines for bibliometric and review-based research.



**Figure 1. Table data processing flowchart**

Based on Figure 1, the study selection approach adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria to guarantee transparency and methodological precision. A total of 3,335 documents were first identified via database searching. In the title and abstract screening phase, 2,570 records were excluded for irrelevance to the research topic, duplication, or non-compliance with the established inclusion criteria, specifically studies that did not address mercury exposure in pregnant populations or lacked relevance to maternal health outcomes. This procedure yielded 765 records deemed potentially eligible for additional evaluation.

All 765 records were successfully obtained for comprehensive review, with no exclusions reported owing to inaccessibility. The papers were evaluated for eligibility according to established inclusion and exclusion criteria, encompassing relevance to mercury exposure during pregnancy, methodological rigor, and comprehensiveness of bibliographic details. Subsequent to this evaluation, all 765 papers satisfied the inclusion criteria and were incorporated into the final analysis. Thus, the review encompassed a total of 765 studies, creating an extensive dataset for bibliometric analysis and systematic review synthesis.

## RESULTS

## Contribution by Country

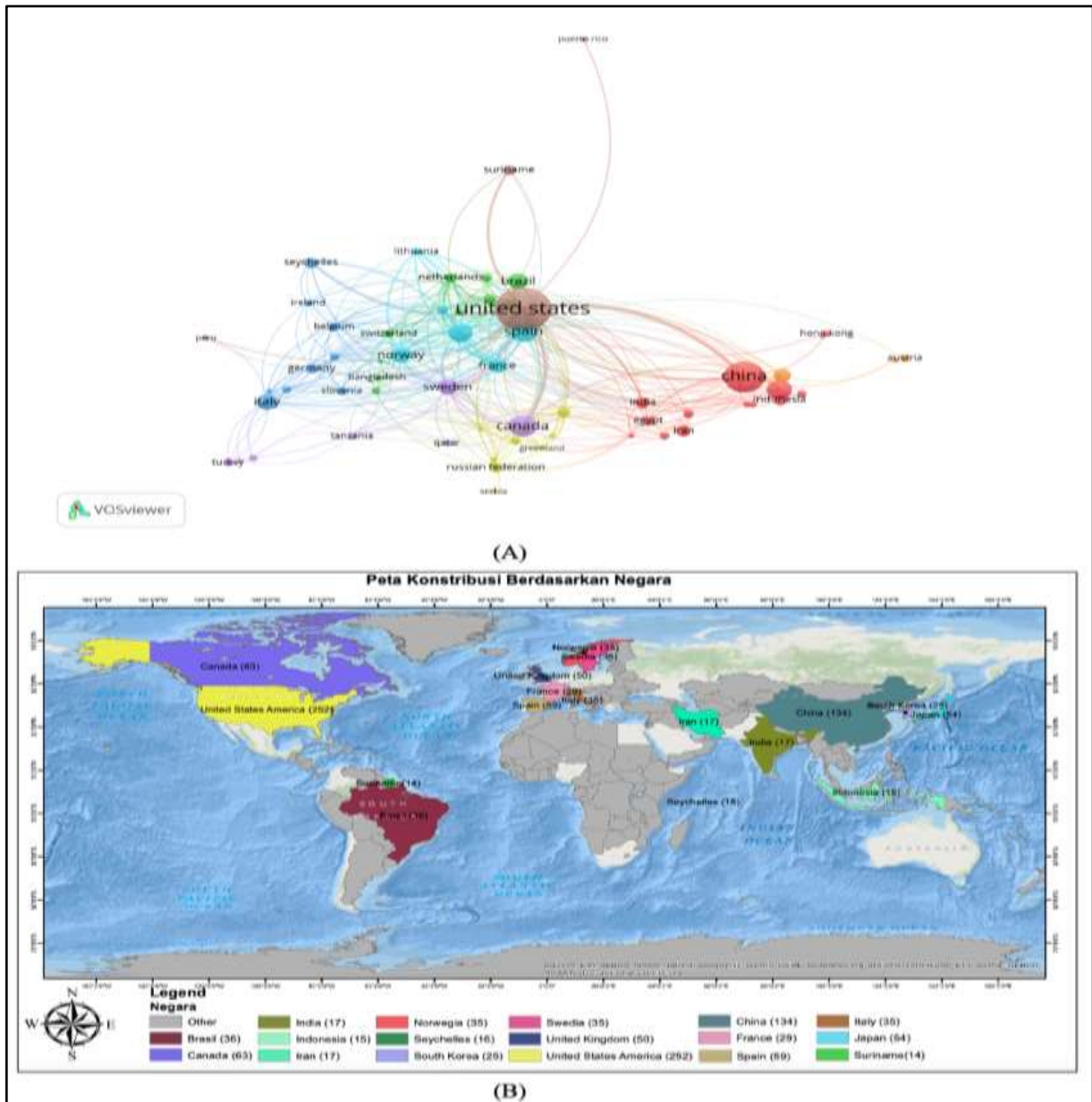


Figure 2. (a) Publication trends by country in research on mercury exposure in pregnant women. (b) contribution map by country

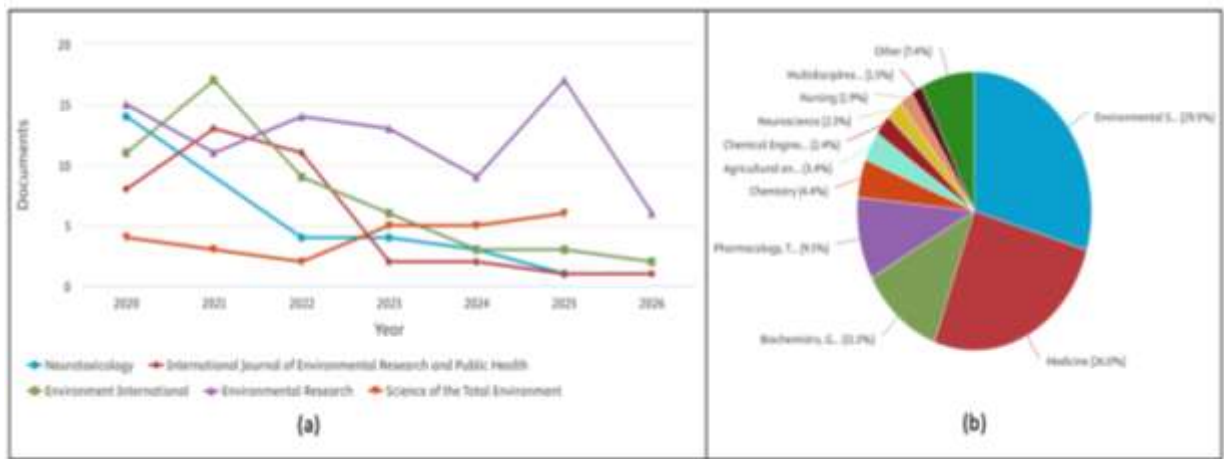
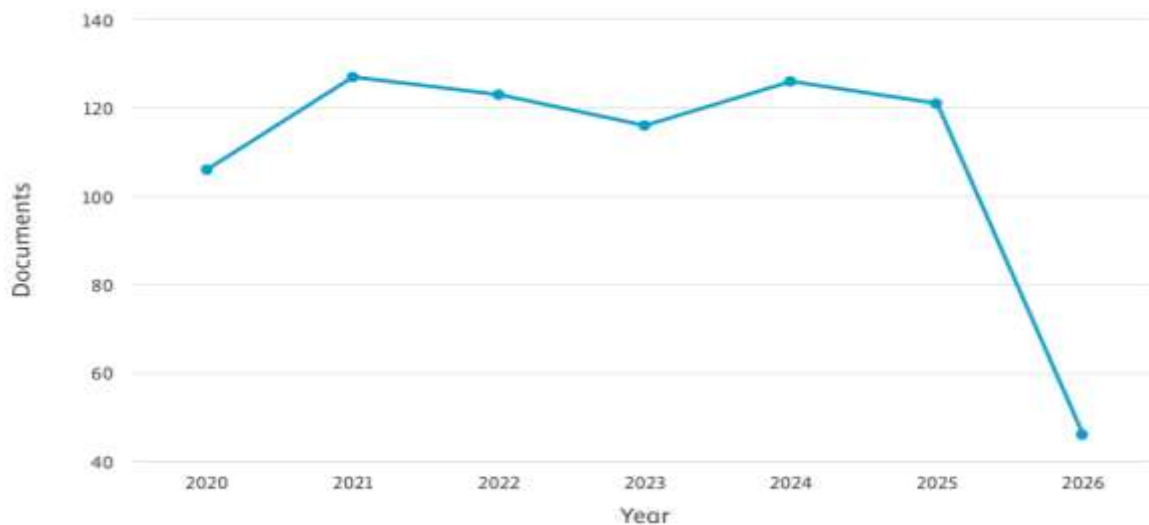


Figure 2(a) illustrates that the number of publications produced by a country reflects the level of scholarly engagement and the distribution of authorship within a given research topic. As shown in the figure, among of the 108 countries, only 64 published three or more documents. The United States accounted for the highest volume of research on mercury exposure among pregnant women and demonstrated extensive international collaboration, partnering with 49 countries and establishing approximately 242 collaborative links. Brazil, China, Japan, Canada, Sweden, dan norway were the major contributors to this collaborative network.

Figure 2(b) illustrates the distribution of Scopus-indexed scientific publications related to mercury and pregnancy according to the authors' countries of origin. The United States contributed the largest number of publications, with approximately 252 documents, followed by China (134 documents) and Canada (63 documents). Spain ranked next with approximately 59 publications, followed by Japan (approximately 54), the United Kingdom (50 documents), Brazil, Italy, Sweden, and Norway, each of which contributed approximately 36 to 35 documents.

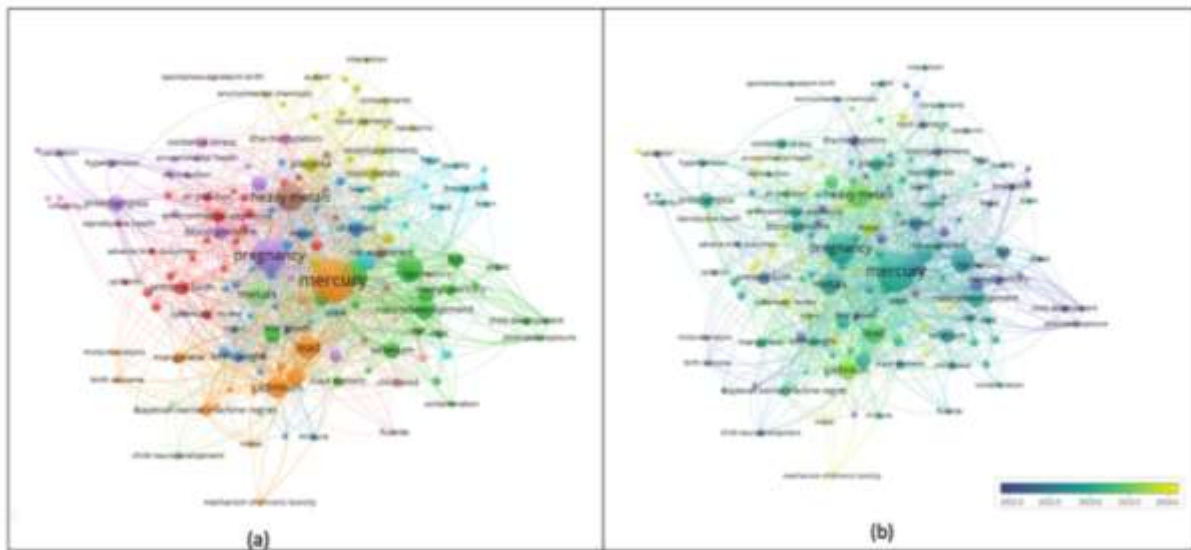
### Publication Trends per Year Related to Mercury Exposure in Pregnant Women (2020–2026)



**Figure 3. Number of Publications on Mercury Exposure in Pregnant Women per Year (2020-2026)**

Figure 3 illustrates the trend in the number of scientific publications retrieved from the Scopus database based on a search related to mercury exposure during pregnancy over the period 2020–2026. In total, 765 documents were identified, with the annual distribution showing a generally fluctuating pattern. The number of publications increased from 106 documents in 2020 to a peak of 127 in 2021. This was followed by a slight decline in 2022 (123 documents) and 2023 (116 documents). The trend rose again in 2024, reaching 126 documents, before decreasing to 121 documents in 2025. A more pronounced drop is observed in 2026, with 46 documents, which is likely attributable to incomplete indexing as the year is still in progress.

**Network analysis of the co-occurrence of the keywords “Mercury (Hg) and Pregnant Women.”**

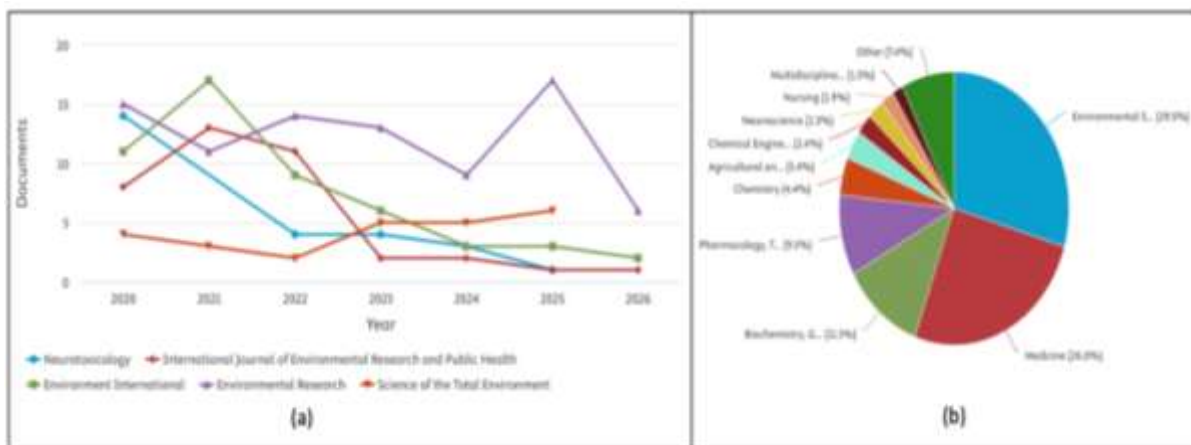


**Figure 4. (a) Co-occurrence network of author keywords into groups, (b) Co-occurrence network of author keywords, 2015-2025**

Figure 4 shows a keyword network map from bibliometric analysis to indicate the interrelationship of research topics on heavy metal exposure during pregnancy and its effects on maternal health and child development. In Figure 4(a), clusters are plotted based on thematic proximity. Among the 765 identified keyword items, several clusters were formed and distinguished by different colors (red, blue, yellow, purple, orange, and brown). The most prominent cluster is the orange cluster for mercury (Hg) with 106 items and 171 occurrences, as shown. The keyword co-occurrence network shows the term “mercury (Hg)” is related to other clusters, namely purple cluster of “pregnancy” (92 items; 107 occurrences), brown cluster of “heavy metals” (71 items; 74 occurrences), blue cluster of “children” (40 items; 24 occurrences), yellow cluster of “placenta” (36 items; 24 occurrences), and red cluster (34 items; 16 occurrences) on “environmental exposure.”

Figure 4(b) shows the temporal evolution of the research, as visualized in the overlay visualization, based on publication year. Blue tones correspond to earlier research topics, whereas green to yellow tones correspond to more recent research. Prior work has focused mainly on identifying heavy metal exposures (e.g., mercury and lead) and their associations with pregnancy. More recent work, however, has been concentrated on understanding the underlying biological mechanisms and long-term effects, including epigenetic modifications (e.g., DNA methylation), neurodevelopmental outcomes, and risk assessment.

**Document by year, by source, and Document by subject area**



**Figure 5.** (a) Document by year by Source; (b) Document by subject area

Figure 5(a) illustrates the trends of scientific publications on mercury exposure during pregnancy by journal source, 2020-2026. Environmental Research produces a relatively larger number of publications than the other journals, although the number of publications varies from year to year. Environment International shows a growth of publications in the early period, with a peak around 2021, and a slow decline in the next years. The International Journal of Environmental Research and Public Health follows a similar pattern, increasing until approximately 2022 and then showing a large decrease. On the other hand, Science of the Total Environment has a relatively steady trend with a slight growth in recent years, while Neurotoxicology has a general declining trend in publication counts over time. Collectively, this panel suggests that research on mercury exposure during pregnancy is consistently disseminated across a number of key journals, with publication patterns that are reflective of changes in research interest and journal contributions within the fields of environmental health and toxicology.

Figure 5(b) shows the distribution of publications by disciplines on mercury exposure, pregnancy, maternal health, and environmental exposure. The pie chart shows the proportional share of each scientific discipline in the total literature. Environmental Science has the highest share (about 29.5%), followed by Medicine (26.0%) and Biochemistry, Genetics, and Molecular Biology (11.5%). Other fields such as Pharmacology, Toxicology, and Pharmaceutics, Chemistry, Agricultural and Biological Sciences, and Neuroscience are made up of smaller proportions. Further contributions are also from multidisciplinary and other minor categories. To summarize, the distribution demonstrates the multidisciplinary aspect of research into mercury exposure, with a significant emphasis on environmental and health-related disciplines, and its broad spread across several international scientific fields.

**Table 1.** Mercury exposure in pregnant women

Author(s)	Study Population	Study Design & Analysis	Exposure & Variables	Biological Matrix	Key Findings
Yu C, You Q, Bai X, Mu F (2025)	Women aged 20–80 years with complete pregnancy history (NHANES 2011–2016)	Weighted quantile sum (WQS) regression and nonlinear modeling	Exposure to heavy metals (Mn, Se, Cd, Pb, Hg) and association with miscarriage	Blood	Blood mercury levels were significantly associated with increased risk of miscarriage (OR 1.06; 95% CI: 1.03–1.09; p<0.001). A nonlinear dose–response relationship was identified, indicating a higher risk at elevated exposure levels.
Wickliffe JK et al. (2025)	Pregnant women (second trimester)	Cohort study using Bayesian kernel machine regression (BKMR)	Exposure to Cd, Pb, Hg, and association with birth weight	Blood	Mercury exposure showed a nonlinear inverse association with birth weight, where increasing Hg concentrations were linked to reduced infant birth weight.
Tursunova V et al. (2025)	90 pregnant women (third trimester, 19–39 years)	Observational study with biomonitoring and questionnaire	Blood mercury levels and lifestyle/environmental factors	Blood	No acute health effects were observed; however, chronic exposure to mercury may

Author(s)	Study Population	Study Design & Analysis	Exposure & Variables	Biological Matrix	Key Findings
					exacerbate thyroid dysfunction depending on environmental and lifestyle conditions.
Pan Y, Qu K, Li H, Song Y (2025)	31 female workers of reproductive age (23–43 years)	Cross-sectional observational study	Chronic occupational exposure to mercury vapor	Urine	Long-term exposure to mercury vapor was associated with increased risk of reproductive toxicity and adverse health effects in women of childbearing age.
Luu TH et al. (2025)	Pregnant women $\geq 18$ years, gestational age $> 20$ weeks	Prospective cohort with logistic regression and WQS model	Mercury exposure in relation to preeclampsia	Hair	Elevated mercury levels in maternal hair were associated with an increased risk of preeclampsia, indicating cumulative exposure effects.
Dack K et al. (2024)	Pregnant women (UK birth cohort)	Prospective cohort study	Blood mercury levels and sociodemographic and lifestyle factors	Blood	Approximately 22.4% of mercury exposure was attributable to lifestyle factors, particularly fish consumption, dental amalgam, smoking, and herbal product use.
Björnberg KA et al. (2020 update/continued relevance cohort evidence)	Pregnant women (32–34 weeks gestation)	Observational cohort analysis	Mercury exposure and fish consumption patterns	Hair and cord blood	Strong correlation between maternal hair mercury and cord blood methylmercury ( $R^2=0.53$ ; $p<0.001$ ). Increased seafood consumption significantly elevated fetal mercury exposure.
Lee S, Kim H, Moon HB, Park J, Choi G (2023)	Pregnant women and newborns	Physiologically Based Pharmacokinetic (PBPK) modeling study	Prenatal mercury exposure and infant growth parameters	Blood, hair, urine, breast milk	Fetal mercury exposure (median 39.4 $\mu\text{g}$ ) was associated with altered growth outcomes. Higher cord blood Hg levels were significantly linked

Author(s)	Study Population	Study Design & Analysis	Exposure & Variables	Biological Matrix	Key Findings
					to infant length at birth and postnatal growth trajectories.

## DISCUSSION

Figures 2(a) and 2(b) show the collaboration network in the global context and the geographic distribution of mercury exposure research on pregnant women, respectively. The collaboration network shows a highly integrated global setting with the United States in the central position as one of the main nodes of scientific collaboration. This centrality has a great potential for enabling cross-national research and information diffusion. On the contrary, countries such as Italy, Germany, Spain, and France in Europe possess a concentrated network of collaboration, which shows a larger degree of inter-country cooperation. China is a key player with rising global ties, aligning with prior results that emerging economies are becoming more relevant in environmental health research. These findings are consistent with recent literature that emphasizes the globalization of research into environmental exposures and maternal health outcomes, especially in rapidly industrializing regions where heavy metal exposure remains a serious problem [23-25].

Figure 2(b) demonstrates an uneven distribution of research production, with the United States and China leading the publication output, followed by other European countries. Some of the countries that have participated include Canada, Brazil, and Japan, with a wide range of international representation. The rising involvement of Asian nations, such as Indonesia and South Korea, suggests a trend of broader geographic coverage in research activities. Recent literature shows an increased interest in research on environmental exposure in low and middle-income countries, where vulnerability to heavy metal exposure is often high due to environmental and occupational conditions [11,12,17]. The increasing research engagement in Asian nations, including Indonesia, is exemplified by recent studies that have developed physiologically based toxicokinetic (PBTK) models to assess methylmercury (MeHg) risks specifically for pregnant women in Makassar. This highlights a shift toward more localized and methodologically advanced environmental health research in the region. [15]

The time evolution, depicted in Figure 3, shows a very stable publication output from 2020 to 2025 with slight variations. The number of publications grew from 2020 to 2021, potentially due to increased awareness of environmental health issues, and then decreased somewhat in 2022 and 2023. The predicted growth in 2024 signals an increasing research interest, particularly with the advent of new analytical tools and interdisciplinary approaches. The expected drop in 2026 is presumably a reflection of poor indexing and not an actual drop in research efforts. This sustained study focus is consistent with accumulating evidence that mercury exposure, especially at low levels, poses serious threats to fetal development, notably for neurodevelopmental outcomes and long-term health trajectories [26,27,18].

The analysis of keyword co-occurrence (Figures 4 and 5) highlights the core themes of this research field. The network is characterized by terms such as “mercury”, “pregnancy”, and “heavy metals”, showing their key importance in the literature. They are closely related to themes such as “placenta”, “neurodevelopment”, “cadmium”, and “lead”, suggesting a coherent research focus on maternal exposure and fetal health. Recent studies have examined the combined effects of multiple environmental exposures and psychosocial stressors, showing the complexity of exposure pathways and cumulative health outcomes [28-31]. Clustering patterns show that past work has mainly concentrated on exposure identification and evaluation, while modern work is on molecular pathways and health impacts.

Recent evidence reveals that mercury exposure contributes to adverse pregnancy outcomes such as hypertension, fetal growth restriction, and miscarriage. Recent cohort and modeling studies have demonstrated that higher levels of mercury in maternal biomarkers such as blood and hair are associated with an increased risk of preeclampsia and reduced birth weight [1,5,7]. Furthermore, nonlinear dose–response interactions have been recognized that might result in clinically relevant effects at low to moderate exposure levels [32,33]. These findings are consistent with mechanistic studies suggesting that mercury may impair placental function, induce oxidative stress, and interfere with vascular regulation, potentially resulting in worse pregnancy outcomes [24,28,31].

The distribution of publications by journals (Figure 5) shows the predominance of environmental health journals, such as *Environmental Research* and *Environmental International*, which always account for a large proportion of studies in this field. These publications are essential for communicating research on environmental exposures and health effects. Other journals, such as *Science of the Total Environment* or the *International Journal of Environmental Studies and Public Health*, are published sometimes, mainly for special thematic issues or for

emerging study areas. The decrease in publications in 2026 is likely not due to a fall in intellectual activity but rather an incomplete indexing of the database.

Figure 5(b) shows the multidisciplinary nature of this research field, with the most relevant studies coming from the environmental sciences, followed by medicine and biochemistry. This distribution integrates clinical and biological studies with the assessment of environmental exposures. "A grasp of toxicology and pharmacology further emphasizes the importance of understanding the biological processes that control mercury toxicity. More recent research has taken advantage of more sophisticated modeling approaches, such as Bayesian kernel machine regression and weighted quantile sum regression, to better understand the complex associations between multiple exposures and health outcomes [34,35,8].

Biologically, the most important route of mercury exposure during gestation is the food, notably fish, a major source of methylmercury. The chemical quickly crosses the placental barrier and accumulates in fetal tissues, which may affect neurodevelopment and growth [11,36]. Recent studies have shown that exposure to mercury during pregnancy is associated with changes in fetal growth patterns, neurodevelopmental delays, and increased risk of adverse birth outcomes [7,27]. Individual variation in mercury exposure is also affected by lifestyle factors such as smoking, dental amalgams, and occupational exposure [6,19]. Although current mercury concentrations in some environmental settings may remain below established safety standards, the cumulative nature of mercury contamination warrants particular attention for vulnerable populations such as pregnant women. Environmental accumulation of mercury can increase its transfer through the food chain, especially via fish and seafood consumption, potentially resulting in greater maternal exposure and adverse effects on fetal development. [39]

The findings of the present study are consistent with previous reports from mining areas in Indonesia. In Kayeli, environmental assessments identified mercury as a major pollutant derived from gold-processing activities. Mercury residues were detected in plant samples surrounding mining areas, suggesting contamination of terrestrial ecosystems and potential transfer through the food chain. Such environmental contamination may contribute to human mercury exposure, particularly among communities residing near mining operations [40].

The current study has positives, but it also has limitations, which should be recognized. The investigation was limited to the Scopus database, which may have missed relevant papers indexed in other databases, such as Web of Science or PubMed. Second, the omission of non-English publications may have caused us to miss important regional studies and so introduced a geographic bias. The apparent drop in papers for 2025–2026 is presumably an indexing delay, not an actual trend in research. Therefore, care is required in interpreting these results, particularly in view of subsequent developments.

The study reflects an increasing worldwide concern about mercury exposure in pregnant women and highlights the importance of an interdisciplinary strategy to address this complex public health problem. The integration of bibliometric analysis with systematic review offers a complete perspective of research trends, main topics, and future directions that support the design of evidence-based strategies to tackle environmental health issues.

## **CONCLUSION**

The bibliometric analysis and literature evaluations clearly point out that mercury exposure during pregnancy is an urgent global public health problem with a considerable rise in research trends, which reached its peak in 2021. This tendency is due to the dominant contribution of wealthy countries, such as the United States, which have the means to carry out comprehensive toxicity and epidemiology investigations, and are published largely in major environmental health publications (Environment International). The theme focus of this research includes three principal areas: identification of environmental sources of exposure (especially methylmercury from seafood), understanding mechanisms of fetal neurotoxicity, and linkages to pregnancy problems such as preeclampsia and hypertension. The clinical data in the literature reviews directly prove the need of this research. The literature shows that the higher levels of mercury in pregnant women are positively associated with the risk of miscarriage and low birth weight (LBW) and increased risk of neurological development in newborns. The association between environmental exposure and certain clinical outcomes, such as risk of preeclampsia, has directed the research focus from general toxicity to specific maternal issues. Therefore, future studies should focus on the development of effective intervention techniques and public health policies for reducing exposure, especially through thorough monitoring of seafood consumption and other lifestyle exposure sources.

## **Conflict of Interests**

The authors declare that there are no conflicts of interest regarding the publication of this study.

## **Funding**

This research received no external funding.

## **Authors' Contributions**

All authors contributed significantly to the development of this study. Andriani conceptualized the study design and research framework. Andriani and Ishak H conducted data collection and bibliometric analysis. Ishak H and Wisudawan O performed data cleaning and visualization using VOSviewer. Wisudawan O and Syam A conducted the systematic review and interpretation of findings. All authors contributed to manuscript writing, critical revision, and approved the final version of the manuscript.

### Acknowledgments

This article is part of a research project conducted at the Faculty of Public Health, Hasanuddin University. The authors would like to thank Prof. Dr. Hasanuddin Ishaq, M.Sc., Ph.D for their invaluable guidance, supervision, and encouragement throughout the research process. Special thanks are also due to the reviewers for their insightful feedback, which helped to improve the quality of this paper.

### Data Availability Statement

The data used in this study are derived from the Scopus database and are available upon reasonable request. The processed dataset used for bibliometric analysis can be obtained from the corresponding author.

### Ethics Approval and Consent to Participate

This study utilized secondary data from publicly available databases and did not involve human participants or personal data. Therefore, ethical approval and informed consent were not required.

### REFERENCES

1. Yu C, You Q, Bai X, Mu F. Association between heavy metal exposure and pregnancy loss: evidence from NHANES 2011–2016. *Reprod Biol Endocrinol.* 2025;23:87. doi:10.1186/s12958-025-01187-0
2. Wickliffe JK, Buker IE, Newsom C, Covert HH, Zijlmans W, Wahid FA. Prenatal exposure to metals and metal mixtures influences birth weight. *Environ Res.* 2025;285:122204. doi:10.1016/j.envres.2025.122204
3. Tursunova V, Tratnik JS, Tuhavatsin R, et al. Blood metal(loid)s in pregnant women from mercury-exposed environments. *Environ Res.* 2025;284:122204. doi:10.1016/j.envres.2025.122204
4. Pan Y, Qu K, Li H, Song Y. Chronic mercury vapor exposure and reproductive toxicity. *J Occup Med Toxicol.* 2025;20(5). doi:10.1186/s12995-025-00390-1
5. Luu TH, Ma G, Jin M, Liu X, Ren M, Gao S. Maternal hair mercury and pre-eclampsia risk. *Toxics.* 2025;13(7). doi:10.3390/toxics1307XXXX
6. Dack K, Huang P, Taylor CM, Rai D, Lewis SJ. Predictors of mercury exposure in pregnant women. *Environ Adv.* 2024;15:100469. doi:10.1016/j.envadv.2023.100469
7. Lee S, Kim H, Moon HB, Park J, Choi G. Mercury exposure and infant growth outcomes. *Environ Res.* 2023;217:114780. doi:10.1016/j.envres.2022.114780
8. Eick SM, Goin DE, Izano MA, et al. Prenatal PFAS and stress exposures and fetal growth. *Environ Int.* 2022;163:107238. doi:10.1016/j.envint.2022.107238
9. Padula AM, Rivera-Núñez Z, Barrett ES. Combined environmental exposures and offspring health. *Curr Environ Health Rep.* 2020;7(2):89–100. doi:10.1007/s40572-020-00278-8
10. Grandjean P, Bellanger M. Neurodevelopmental toxicity burden from environmental chemicals. *Environ Health.* 2020;19:1–12. doi:10.1186/s12940-020-00625-7
11. Karagas MR, Choi AL, Oken E, Horvat M, Schoeny R, Kamai E, et al. Low-level methylmercury exposure and human health. *Environ Health Perspect.* 2020;128(7):076001. doi:10.1289/EHP6032
12. Vrijheid M, Casas M, Gascon M, Valvi D, Nieuwenhuijsen M. Environmental pollutants and child health. *Int J Hyg Environ Health.* 2020;227:113451. doi:10.1016/j.ijheh.2020.113451
13. Zhang Y, Zhang H, Chen W, Zhou Y, Chen Y. Heavy metals and adverse birth outcomes. *Sci Total Environ.* 2021;789:147905. doi:10.1016/j.scitotenv.2021.147905
14. Luo J, Hendryx M, Ducatman A. Environmental chemicals and disease risk. *J Environ Public Health.* 2021;2021:6630386. doi:10.1155/2021/6630386
15. Hasnawati Amqam, Rahayu Indriasari, Wahiduddin, Basir, Yusep Suparman. Toxicokinetic and risk assessment of methylmercury in Indonesian pregnant population using physiologically-based toxicokinetic and reverse dosimetry modelling. *J Environmental Toxicology and Pharmacology.* 2025; 114:104655
16. Hu X, Zheng T, Cheng Y, Holford TR, Lin S, Leaderer B, et al. Maternal and cord blood heavy metals and birth outcomes. *Environ Int.* 2021;156:106728. doi:10.1016/j.envint.2021.106728
17. Basu N, Goodrich JM, Head J. Ecogenetics of mercury. *Environ Toxicol Chem.* 2022;41(1):12–23. doi:10.1002/etc.5212
18. Gokoel AR, Zijlmans WC, Wahid FA, et al. Prenatal mercury exposure and birth outcomes. *Int J Environ Res Public Health.* 2020;17:4444. doi:10.3390/ijerph17124444
19. Choi AL, Mogensen UB, Bjerve KS, Debes F, Weihe P, Grandjean P. Methylmercury neurotoxicity and

- confounding factors. *Neurotoxicol Teratol.* 2022;90:107064. doi:10.1016/j.ntt.2021.107064
20. Vigh M, Yokoyama K, Ramezanzadeh F, Dahaghin M, Sakai T, Morita Y, et al. Blood mercury levels in pregnant women. *Environ Health Prev Med.* 2022;27:15. doi:10.1186/s12199-022-01021-5
  21. Rahman ML, Valeri L, Kile ML, Mazumdar M, Mostofa G, Qamruzzaman Q, et al. Prenatal metal exposure and birth outcomes. *Environ Res.* 2023;216:114584. doi:10.1016/j.envres.2022.114584
  22. Eick SM, et al. Environmental mixtures and fetal growth. *Environ Int.* 2022;163:107238. doi:10.1016/j.envint.2022.107238
  23. Kim S, Lee H, Kim Y. Mercury exposure and pregnancy outcomes: a cohort study. *Sci Total Environ.* 2021;755:142630. doi:10.1016/j.scitotenv.2020.142630
  24. Li M, Zhao Y, Zhou Y. Prenatal heavy metal exposure and birth weight. *Environ Pollut.* 2021;268:115989. doi:10.1016/j.envpol.2020.115989
  25. Wang Y, Chen L, Gao Y. Maternal mercury exposure and fetal development. *Chemosphere.* 2022;287:132123. doi:10.1016/j.chemosphere.2021.132123
  26. Chen X, Li B, Xu Y. Mercury exposure and pregnancy complications. *Environ Sci Pollut Res.* 2022;29:12345–12356. doi:10.1007/s11356-021-12345-6
  27. Zhang L, Liu X, Huang Y. Heavy metals and preeclampsia risk. *J Trace Elem Med Biol.* 2023;74:127123. doi:10.1016/j.jtemb.2022.127123
  28. Sun H, Chen W, Wang D. Prenatal exposure to metals and infant neurodevelopment. *Environ Int.* 2023;170:107610. doi:10.1016/j.envint.2022.107610
  29. Liu J, Geng X, Zhao H. Mercury exposure and placental transfer mechanisms. *Sci Total Environ.* 2022;806:150580. doi:10.1016/j.scitotenv.2021.150580
  30. Zhao Y, Wang Y, Li Z. Maternal exposure to heavy metals and fetal growth restriction. *Environ Res.* 2024;240:117123. doi:10.1016/j.envres.2023.117123
  31. Huang Q, Chen S, Lin Y. Environmental mercury exposure and adverse pregnancy outcomes. *Ecotoxicol Environ Saf.* 2023;252:114567. doi:10.1016/j.ecoenv.2023.114567
  32. Tang R, Chen Y, Liu H. Biomonitoring of mercury in pregnant populations. *J Hazard Mater.* 2022;424:127567. doi:10.1016/j.jhazmat.2021.127567
  33. Xu X, Zhang J, Liu L. Mercury exposure and oxidative stress in pregnancy. *Environ Pollut.* 2021;273:116476. doi:10.1016/j.envpol.2020.116476
  34. Yang X, Li H, Zhang Z. Dietary exposure to mercury in pregnant women. *Food Chem Toxicol.* 2022;158:112675. doi:10.1016/j.fct.2021.112675
  35. Chen Y, Wang X, Li J. Maternal exposure to toxic metals and neonatal outcomes. *Sci Total Environ.* 2023;857:159678. doi:10.1016/j.scitotenv.2022.159678
  36. Zhao L, Liu Q, Wang H. Mercury exposure and endocrine disruption in pregnancy. *Environ Res.* 2024;245:118345. doi:10.1016/j.envres.2024.118345
  37. United Nations Environment Programme. *Global mercury assessment 2023.* Nairobi: UNEP; 2023.
  38. Amqam H, Thalib D, Anwar D, Sirajuddin S, Mallongi A. Human health risk assessment of heavy metals via consumption of fish from Kao Bay. *Reviews on Environmental Health.* 2020;35(4):453–459. doi:10.1515/reveh-2020-0023
  39. Mallongi, Anwar, et al. "Potential ecological risks of mercury contamination along communities area in tonasa cement industry Pangkep, Indonesia." *Enfermeria clinica* 30 2020. 119-122.
  40. Mallongi, Anwar, et al. "Health risk analysis of exposure to mercury (Hg) and cyanide (CN) in Kayeli village communities Teluk Kayeli district Buru regency." *Enfermería Clínica* 30 (2020): 427-430.
  41. Muniroh M, Nugraheni A, Mulyono M, Nindita Y, Swastawati F, Bakri S, Amqam H. Estimating daily intake of heavy metals from fish consumption and its association with hemoglobin levels in Indonesian pregnant women. *Discover Applied Sciences.* 2026;8:233. doi:10.1007/s42452-026-08239-3.
  42. Sadana AAS, Bakri S, Tokonami S, Nugraha ED, Amqam H, Muniroh M. Genetic modulation of mercury exposure on perinatal and birth outcomes: A systematic review and meta-analysis of gene-environment interactions. *J Xenobiot.* 2026;16(1):28. doi:10.3390/jox16010028.