HTechJ Health and Technology Journal (HTechJ)

Volume 04 Number 04
August 2026
p-ISSN: 2986-5662
e-ISSN: 2985-959X

Prenatal Pesticide Exposure and Maternal-Fetal Health Outcomes: A Systematic Review Informing Agro-Nursing Practice

Enggal Hadi Kurniyawan[1], Alfid Tri Afandi[1], Kholid Rosyidi Muhammad Nur[1], Dicky Endrian Kurniawan[1], Iraha Emerson[2], Sa Sa Aung[3]

[1] Faculty of Nursing, Universitas Jember, Indonesia
[2] Delaware Skills Center, United States of America
[3] Department of Adult Health Nursing, University of Nursing, Mandalay, Myanmar

Correspondence should be addressed to:
Enggal Hadi Kurniyawan
enggalhadi.psik@unej.ac.id

Abstract:
Prenatal pesticide exposure poses significant risks to maternal and child health in agricultural communities worldwide. This systematic review evaluated recent empirical evidence on the impact of agricultural chemical exposure during pregnancy to inform agro-nursing practice directly. A systematic literature search was conducted in Scopus, PubMed, and ProQuest following PRISMA guidelines. Studies published within the last year, written in English, and featuring active DOIs were strictly included. Methodological quality was rigorously assessed using the Joanna Briggs Institute critical appraisal tools. Ten studies ultimately met the inclusion criteria, comprising seven cohort studies, one case-control study, one cross-sectional study, and one ecological analysis. Eight studies demonstrated high methodological quality. The synthesized evidence revealed strong associations between prenatal pesticide exposure and a range of adverse health outcomes. Specifically, exposure to organochlorines and organophosphates correlated with impaired early childhood neurodevelopment and increased childhood neuroblastoma risk. Maternal exposure to pyrethroids and organophosphates significantly elevated the risk of gestational diabetes mellitus and disrupted maternal thyroid homeostasis. Spatial analyses further confirmed increased risks of low birth weight in high-application agricultural zones. Agricultural chemical exposure during pregnancy constitutes a critical determinant of adverse perinatal outcomes. Agro-nurses must integrate comprehensive histories of environmental exposures into standard prenatal assessments. Proactive patient education and targeted clinical surveillance are essential for mitigating toxicological risks and optimizing maternal-fetal health trajectories globally.

Article info:
Submitted:
18-06-2026
Revised:
02-07-2026
Accepted:
08-07-2026
Published:
03-08-2026

Keywords:
agro-nursing, environmental health, maternal-fetal outcomes, organophosphates, prenatal pesticide exposure

DOI: https://doi.org/10.53713/htechj.v4i4.754

INTRODUCTION

The escalating global reliance on agricultural pesticides poses a profound, ubiquitous environmental health challenge, particularly for vulnerable populations in farming communities (Zhou et al., 2025). Modern agricultural practices depend heavily on chemical interventions to ensure crop yields and maintain global food security amidst a growing population (Iqbal et al., 2025). This widespread application results in pervasive environmental contamination across soil, water, and air systems worldwide (Pathak et al., 2022). Human populations residing in or near agricultural zones experience continuous, low-level exposure to complex chemical mixtures (González, 2026). The sheer magnitude of this exposure necessitates a comprehensive, multidisciplinary understanding of its global public health implications and demands immediate attention from the scientific community.

Pregnant women and their developing fetuses represent a highly susceptible demographic to the toxicological impacts of agrochemical exposure (Felisbino et al., 2024). Physiological adaptations during pregnancy alter maternal metabolism and increase respiratory rates, potentially amplifying the absorption of environmental toxicants (Ventura-Miranda et al., 2022). The placental barrier, while inherently protective, remains permeable to numerous lipophilic pesticide compounds, allowing direct fetal exposure during critical windows of organogenesis (Colopi et al., 2023). Emerging clinical observations consistently link these exposures to a spectrum of adverse outcomes, including neurodevelopmental delays, metabolic disruptions, and endocrine alterations (Botnaru et al., 2025). Protecting this specific demographic requires targeted, rigorous scrutiny of the risks posed by agricultural chemicals to ensure that maternal and fetal well-being remains a paramount public health priority.

Recent advancements in environmental epidemiology and biomonitoring have significantly refined our understanding of prenatal pesticide toxicity (Dhananjayan et al., 2022). Contemporary research has successfully transitioned from relying on subjective, self-reported occupational histories to utilizing highly objective biomarkers. Advanced analytical techniques, such as liquid chromatography-tandem mass spectrometry, now enable the precise quantification of pesticide metabolites in maternal biological samples (Birolli et al., 2024). The integration of geographic information systems allows researchers to accurately map ambient exposure risks based on residential proximity to agricultural applications (Thompson et al., 2022). These methodological improvements provide a much more accurate and granular assessment of chemical exposure pathways, ultimately strengthening the validity of epidemiological associations.

Despite these methodological advancements, critical inconsistencies remain regarding the precise health outcomes associated with varying exposure windows and chemical formulations. Existing literature frequently presents conflicting data concerning the impact of specific organophosphate concentrations on birth weight and gestational age (De Joode et al., 2024). Many studies fail to adequately control for individual-level confounding variables, such as maternal nutrition and socioeconomic status, particularly in ecological study designs. There is a distinct lack of synthesis on how these diverse toxicological findings can be translated directly into actionable clinical nursing practices (Rueda-Ruzafa et al., 2023). This fragmentation actively hinders the development of unified public health guidelines for rural populations, leaving healthcare providers without clear directives for patient care.

This systematic review introduces a novel synthesis by specifically evaluating recent, high-quality empirical evidence through the lens of agro-nursing and maternal-fetal health. Previous broad environmental reviews failed to apply rigorous Joanna Briggs Institute critical appraisal tools, whereas this investigation ensures only methodologically sound studies inform the conclusions. The review focuses exclusively on the most recent literature published in the past year, capturing the latest breakthroughs in toxicogenomic and spatial analyses. This targeted approach isolates the most relevant and reliable data available for contemporary healthcare decision-making. The integration of clinical nursing perspectives elevates the practical utility of the synthesized epidemiological data, bridging the gap between environmental science and bedside nursing care (Nurhadijah et al., 2025).

The primary objective of this study is to systematically evaluate the association between prenatal pesticide exposure and adverse maternal and child health outcomes. This investigation utilizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses framework to ensure transparent and reproducible literature selection. The research aims to identify specific chemical classes and exposure periods that pose the highest risk to pregnant women and their offspring. By categorizing findings across neurodevelopmental, metabolic, and oncological domains, the study provides a structured overview of the current toxicological landscape (Reed et al., 2023). This systematic evaluation serves as a foundational resource for evidence-based clinical interventions, ultimately guiding the development of specialized agro-nursing protocols.

Translating these synthesized findings into clinical practice is urgently needed to equip agro-nurses with evidence-based protocols for mitigating prenatal risks. Healthcare providers in rural settings currently lack standardized frameworks for assessing and counseling patients regarding environmental chemical exposures. Immediate implementation of comprehensive environmental health screenings during prenatal intake can significantly reduce the fetal burden of agricultural toxicants. Empowering the nursing workforce with advanced environmental health competencies will directly safeguard vulnerable agricultural populations (Steel & Hyland, 2025). This research provides the critical evidence base necessary to drive immediate policy advocacy and optimize perinatal care trajectories globally, preventing long-term developmental and metabolic consequences in future generations.

METHOD

Study Design

This research employed a systematic review methodology to evaluate the existing literature on the specified topic.

Data Sources and Search Strategy

The literature search was conducted across three primary electronic databases: Scopus, PubMed, and ProQuest. The search strategy utilized the specific keywords "pregnancy," "pesticide," and "agriculture" to identify relevant publications.

Inclusion and Exclusion Criteria

Studies were selected based on predefined eligibility parameters. Inclusion criteria required articles to be original research published within the last year, available via open access, written in the English language, and featuring an active DOI. Exclusion criteria eliminated duplicates, abstracts, case reports, conference presentations, reviews lacking original data, editorials, and expert opinions.

Study Selection and Reporting

The screening and selection process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A PRISMA flow chart was generated to transparently document the literature search, screening, and selection phases.

Quality Assessment

The methodological rigor of the included studies was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal tools to ensure the reliability and validity of the synthesized evidence.

RESULT

The systematic review search identified 14,161 records across three databases, with Scopus contributing the largest number at 7,972, followed by ProQuest with 5,444 and PubMed with 745. A substantial number of records (12,658) were removed because they were published before 2025, leaving 1,503 records for screening. The screening process excluded 723 records that were not research articles, resulting in 780 reports sought for retrieval. Access restrictions led to the exclusion of 208 records, leaving 572 reports for eligibility assessment. The application of inclusion and exclusion criteria resulted in the exclusion of 562 reports. The final review included 10 studies, with Scopus contributing 5, PubMed 4, and ProQuest 1. The rigorous screening process demonstrates a significant reduction from initial identification to final inclusion, reflecting strict adherence to the predefined selection criteria and the temporal restriction to recent publications.

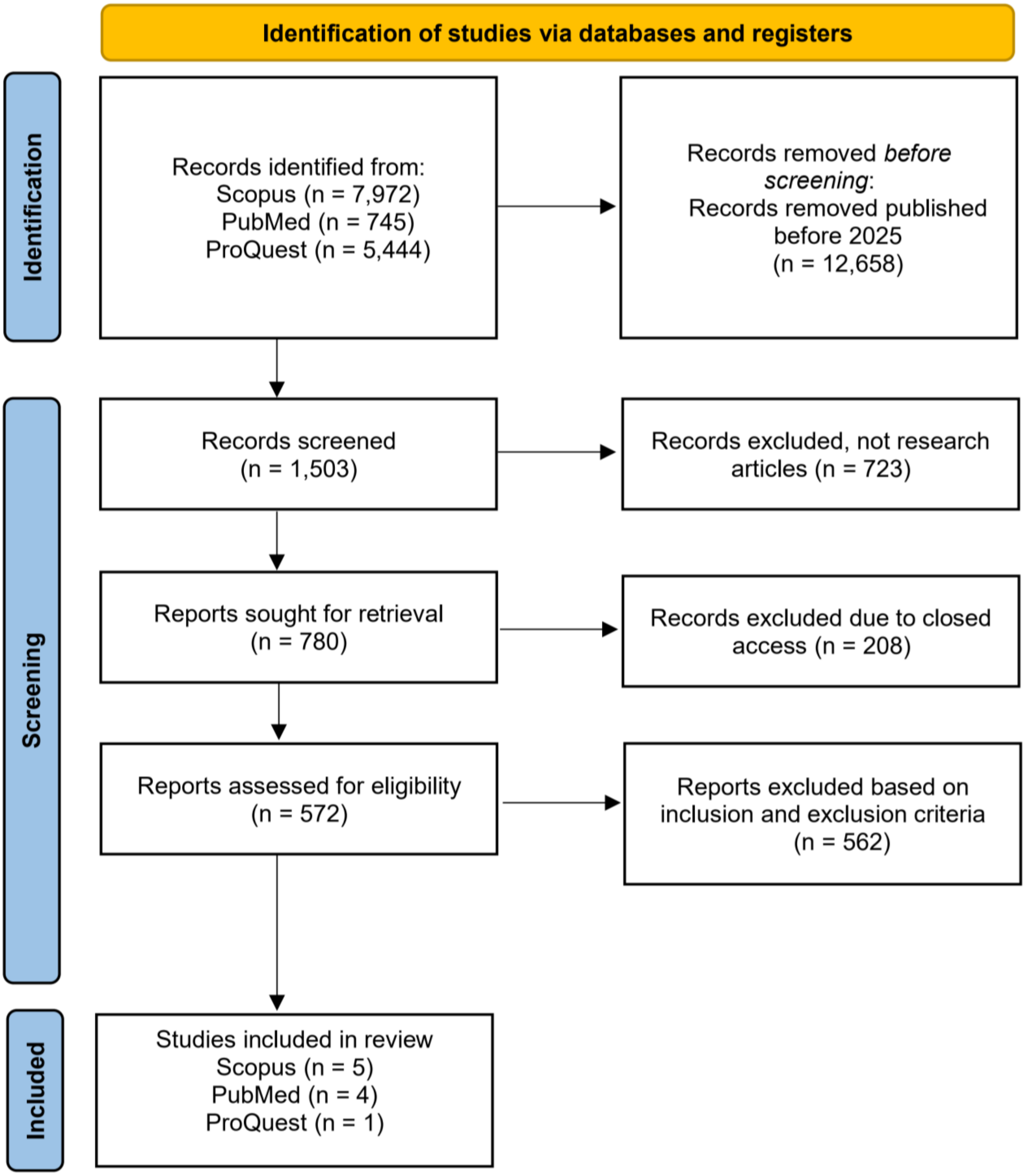

Figure 1. PRISMA Flow Chart for Literature Search

Table 1. Results of Included Studies

Author	Objectives	Study Design	Sample Size	Instrument	Main Findings
Mwakalasyaet al., 2025. Tanzania.	Examined associations between self-reported maternal pesticide exposure during pregnancy and neurodevelopmental outcomes in children aged 4-6 years.	A cross-sectional design.	432 mother-child pairs.	International Development and Early Learning Assessment (IDELA).	An association between maternal pesticide exposure during pregnancy and adverse neurodevelopmental outcomes in offspring.
Van Deventer et al., 2025. USA.	To evaluate associations between childhood neuroblastoma and prenatal exposure to specific pesticides through residential proximity to agricultural applications.	A statewide case-control study.	199 cases, 202,796 controls.	Neuroblastoma cases from the California Cancer Registry and cancer-free controls from birth certificates	Ambient exposure to certain pesticides during pregnancy may increase the risk of neuroblastoma.
Guesdon et al., 2025. France	To assess the association between non-occupational exposures to pesticides and the risk of Gestational diabetes mellitus.	nationwide Elfe cohort.	11.512 women.	Self-reported, geographic information system, a food-frequency questionnaire, and monitoring data of pesticide residues in foods.	This toxico-genomic-based study identifies five pesticides associated with gdm through agricultural or dietary exposure.
Parra et al., 2026. USA	Examined associations between OP/PYR/CAR and gestational diabetes mellitus (GDM) risk, particularly during preconception (T0) and across pregnancy (Trimesters 1-3: T1-T3).	population-based study, Az-PEARS cohort	475,017 births	Birth records were linked to Arizona's Pesticide Use Reports (PUR)	Exposure to pyrethroids in T0 and organophosphates in T3 are associated with higher GDM risk.
Xu et al., 2026. China.	Investigated the association between prenatal OCP exposure and early childhood neurodevelopment, and explored the potential sex-specific effects.	A prospective birth cohort study.	1046 pregnant women.	Bayley Scales of Infant Development.	Prenatal exposure to certain ocps, particularly γ-HCH and p,p'-DDT, is associated with poorer neurodevelopment in early childhood, especially in girls.
Yin et al., 2026. China.	Associations of co-exposure to organophosphate flame retardants and pesticides with maternal thyroid function in early pregnancy.	prospective research framework.	403 pregnant women.	Ultra-performance liquid chromatography-tandem mass spectrometry.	Early pregnancy exposure to opfr/opp mixtures is associated with potential disrupted maternal thyroid homeostasis and increased autoimmune risk.
Baba et al., 2025. Japan.	To examine the association between antenatal exposure to organophosphate (OP) pesticides, measured using urinary dialkyl phosphate (DAP) metabolite concentrations, and pregnancy outcomes.	birth cohort study	4444 pregnant women	A liquid chromatography-tandem mass spectrometer (LC-MS/MS)	Exposure to higher concentrations of ops, measured by urinary DAP metabolites, had no robust association with gestational age at birth or birth weight.
López-Flores et al., 2025. Spain	Examined urinary metabolomic profiles of pregnant women to identify metabolic disruptions associated with ops exposure	GENEIDA (Genetics, Early life enviroNmental Exposures and Infant	387 pregnant women.	Liquid chromatography-mass spectrometry (LC-MS/MS) on the Agilent 1290	Organophosphate exposure may disrupt maternal metabolic processes during pregnancy, potentially affecting fetal development.

HTechJ Health and Technology Journal (HTechJ)

Volume 04 Number 04
August 2026
p-ISSN: 2986-5662
e-ISSN: 2985-959X

Author	Objectives	Study Design	Sample Size	Instrument	Main Findings
	measured via dialkyl phosphate (daps).	Development in Andalusia) birth cohort.		UHPLC coupled to an Agilent 6460 triple quadrupole mass spectrometer.	
Iversen et al., 2025. Denmark	Examined the association between maternal pesticide exposure and pituitary, gonadal, and adrenal hormones in offspring during infancy.	Odense Child Cohort (OCC).	489 mother.	High-performance liquid chromatography combined with tandem mass spectrometry (LC-MS/MS).	Prenatal exposure to chlorpyrifos and 2,4-D may affect the reproductive hormones in girls, but not boys, during minipuberty, which may have long-term implications.
Andrade-Rivas et al., 2026. Colombia.	Assessing the national-level effect of environmental exposures to pesticides	a two-stage spatial analysis approach	500,192 live birth records	PEST-chemgridsv1 global gridded spatial database	Mothers living in areas with high application rates of specific pesticides (G+C+C) had a significantly increased risk of delivering a low birth weight baby.

Table 2. Joanna Briggs Institute (JBI) Critical Appraisal of Included Studies

Study (Author, Year)	Study Design (JBI Tool)	Inclusion Criteria & Setting	Exposure Measurement	Confounding Factors	Outcome Measurement	Statistical Analysis	Overall Quality
Mwakalasya et al., 2025	Analytical Cross-Sectional	Yes	Unclear	Yes	Yes	Yes	Moderate
Van Deventer et al., 2025	Case-Control	Yes	Yes	Yes	Yes	Yes	High
Guesdon et al., 2025	Cohort	Yes	Yes	Yes	Yes	Yes	High
Parra et al., 2026	Cohort	Yes	Yes	Yes	Yes	Yes	High
Xu et al., 2026	Cohort	Yes	Yes	Yes	Yes	Yes	High
Yin et al., 2026	Cohort	Yes	Yes	Yes	Yes	Yes	High
Baba et al., 2025	Cohort	Yes	Yes	Yes	Yes	Yes	High
López-Flores et al., 2025	Cohort	Yes	Yes	Yes	Yes	Yes	High
Iversen et al., 2025	Cohort	Yes	Yes	Yes	Yes	Yes	High
Andrade-Rivas et al., 2026	Ecological / Spatial	Yes	Yes	Unclear	Yes	Yes	Moderate

The Joanna Briggs Institute (JBI) critical appraisal revealed a predominantly high methodological quality across the ten included studies. Eight investigations achieved a high overall quality rating by satisfying all evaluated criteria. The study designs comprised seven cohort studies and one statewide case-control study. Specifically, Van Deventer et al., 2025; Guesdon et al., 2025; Parra et al., 2026; Xu et al., 2026; Yin et al., 2026; Baba et al., 2025; López-Flores et al., 2025; and Iversen et al., 2025 demonstrated rigorous research frameworks. These high-quality studies provided clear inclusion criteria, utilized valid and reliable exposure measurements, adequately identified and controlled for confounding factors, and applied appropriate statistical analyses. The robust methodologies in these cohorts and the case-control design significantly strengthen the reliability of their findings regarding prenatal pesticide exposure.

Two studies received a moderate overall quality rating due to specific methodological limitations identified during the appraisal process. Mwakalasya et al. (2025) employed an analytical cross-sectional design in which the exposure measurement was marked as unclear. This ambiguity in exposure assessment introduces potential recall bias and limits the precision of the observed associations between maternal pesticide exposure and child neurodevelopment. Andrade-Rivas et al. (2026 utilized an ecological and spatial analysis approach that lacked clarity regarding the control of confounding factors. Spatial and ecological study designs inherently face challenges in accounting for individual-level confounders, which may lead to ecological fallacy or unmeasured-variable bias. Despite these moderate ratings, both studies still met the criteria for inclusion, setting, outcome measurement, and statistical analysis, providing valuable complementary evidence to the systematic review.

The systematic review identified ten recent studies investigating the impact of prenatal pesticide exposure on various maternal and child health outcomes. Neurodevelopmental and oncological effects were prominent areas of research. Mwakalasya et al. (2025) established a link between self-reported maternal pesticide exposure during pregnancy and adverse neurodevelopmental outcomes in children aged four to six years. Xu et al. (2026) corroborated these findings by demonstrating that prenatal exposure to specific organochlorine pesticides leads to poorer early childhood neurodevelopment, with girls exhibiting heightened vulnerability. Endocrine disruption was also evident in pediatric outcomes. Iversen et al. (2025) observed that prenatal exposure to chlorpyrifos and 2,4-D affects reproductive hormones in infant girls during minipuberty. Regarding oncological risks, Van Deventer et al. (2025) reported that ambient prenatal pesticide exposure increases the risk of childhood neuroblastoma.

Metabolic and endocrine disruptions in mothers constituted another major focus of the included literature. Guesdon et al. (2025) identified five specific pesticides associated with gestational diabetes mellitus through agricultural or dietary exposure pathways. Parra et al. (2026) expanded on this metabolic risk by finding that preconception exposure to pyrethroids and third-trimester exposure to organophosphates elevate the risk of gestational diabetes mellitus. Maternal thyroid function and overall metabolic profiles were also affected by chemical exposures. Yin et al. (2026) demonstrated that early-pregnancy co-exposure to organophosphate flame retardants and pesticides disrupts maternal thyroid homeostasis and elevates the risk of autoimmunity. López-Flores et al. (2025) revealed that organophosphate exposure induces significant metabolic disruptions in pregnant women, potentially compromising fetal development.

Pregnancy and birth outcomes presented mixed findings across the analyzed cohorts. Baba et al. (2025) reported no robust association between higher concentrations of organophosphate pesticides and adverse pregnancy outcomes such as gestational age at birth or birth weight. In contrast to this null finding, Andrade-Rivas et al. (2026) used spatial analysis to show that mothers residing in areas with high pesticide application rates face a significantly increased risk of delivering low-birth-weight babies. These diverse results underscore the complex nature of pesticide toxicity, varying by chemical class, exposure timing, and geographic context.

DISCUSSION

The synthesized evidence underscores the critical role of agro-nursing in mitigating the adverse maternal and child health outcomes associated with prenatal pesticide exposure. This systematic review identified ten recent studies demonstrating profound impacts across multiple physiological domains. Neurodevelopmental risks were prominently featured, with research linking maternal exposure to adverse cognitive outcomes in early childhood. Metabolic disruptions, particularly the increased incidence of gestational diabetes mellitus, emerged as a significant concern for pregnant women in agricultural settings. Endocrine alterations and potential oncological risks further compounded the vulnerability of this specific demographic. Birth outcomes presented a complex picture, varying significantly by chemical class and exposure assessment methodology.

Agro-nurses must recognize this multifaceted threat to provide comprehensive, evidence-based prenatal care in rural and farming communities (Kurniyawan et al., 2026).

Neurodevelopmental and oncological vulnerabilities represent the most severe consequences of agricultural chemical exposure during pregnancy, demanding proactive nursing surveillance. Mwakalasya et al. (2025) established a clear association between self-reported maternal pesticide exposure during pregnancy and adverse neurodevelopmental outcomes in children aged four to six years. Xu et al. (2026) corroborated these developmental concerns by demonstrating that prenatal exposure to specific organochlorine pesticides leads to poorer early childhood neurodevelopment, with girls exhibiting heightened vulnerability. The oncological risks are equally alarming. Van Deventer et al. (2025) highlighted that ambient prenatal pesticide exposure increases the likelihood of childhood neuroblastoma through residential proximity to agricultural applications. These findings necessitate that agro-nursing assessments rigorously evaluate both occupational and residential environmental histories to identify at-risk pregnancies early.

Metabolic and endocrine disruptions constitute a pervasive yet frequently overlooked consequence of prenatal pesticide exposure in agricultural communities. Guesdon et al. (2025) identified five specific pesticides associated with gestational diabetes mellitus through agricultural or dietary exposure pathways in a nationwide cohort. Parra et al. (2026) expanded on this metabolic risk by finding that preconception exposure to pyrethroids and third-trimester exposure to organophosphates elevate the risk of gestational diabetes mellitus. Maternal thyroid function and overall metabolic profiles were also affected by chemical exposures. Yin et al. (2026) demonstrated that early-pregnancy co-exposure to organophosphate flame retardants and pesticides disrupts maternal thyroid homeostasis and elevates the risk of autoimmunity. Iversen et al. (2025) observed that prenatal exposure to chlorpyrifos and 2,4-D affects reproductive hormones in infant girls during minipuberty. Agro-nursing clinical protocols must expand beyond traditional occupational hazard screenings to actively monitor these subtle biochemical shifts.

The impact of organophosphate exposure on maternal metabolic profiles and subsequent birth outcomes presents a complex clinical picture requiring nuanced nursing interpretation. Baba et al. (2025) reported no robust association between higher concentrations of organophosphate pesticides, measured by urinary dialkyl phosphate metabolites, and adverse pregnancy outcomes such as gestational age at birth or birth weight. In contrast to this null finding, López-Flores et al. (2025) reported that organophosphate exposure induces significant metabolic disruptions in pregnant women, potentially compromising fetal development. Andrade-Rivas et al. (2026) used spatial analysis to show that mothers residing in areas with high pesticide application rates face a significantly increased risk of delivering low-birth-weight babies. This discrepancy highlights the need for agro-nurses to consider both individual biomarkers and community-level environmental data when counseling expectant mothers.

The findings of this systematic review align with and significantly expand upon the existing body of occupational and environmental health literature regarding agricultural chemical toxicity. Previous research established broad associations between farming occupations and adverse pregnancy outcomes, often relying on crude exposure metrics (Chen et al., 2023). The current synthesis refines this understanding by identifying specific chemical classes, including organophosphates, pyrethroids, and organochlorines, as primary drivers of pathology. The identification of precise exposure windows, such as preconception periods and specific trimesters, marks a critical evolution in environmental health science. Advanced analytical techniques like liquid chromatography-tandem mass spectrometry have replaced subjective self-reporting in high-quality studies, providing objective biomonitoring data. This progression from general occupational correlations to precise toxicogenomic and spatial analyses provides agro-nurses with highly specific targets for clinical intervention.

These synthesized findings mandate a paradigm shift in agro-nursing practice toward comprehensive environmental health screening and targeted patient education. Nurses in agricultural settings must routinely incorporate detailed occupational and environmental exposure histories into standard prenatal intake assessments. Patient education on proper use of personal protective equipment, thorough dietary washing practices, and the benefits of alternative farming methods is a primary nursing intervention. Community health nurses must also facilitate connections between pregnant agricultural workers and occupational health specialists. Developing culturally competent educational materials tailored to rural farming populations will enhance the efficacy of these preventive measures (Pumsopa et al., 2025). Proactive nursing interventions can reduce the fetal burden of environmental toxicants when implemented early in the prenatal care trajectory.

Translating these research findings into actionable health policies requires robust interdisciplinary collaboration led by advanced practice agro-nurses. Agro-nurses are uniquely positioned to advocate for stricter regulatory frameworks governing pesticide application near residential zones and schools. The spatial findings by Andrade-Rivas et al. (2026) provide empirical support for establishing larger, scientifically validated buffer zones around agricultural fields. Nursing leadership must drive the integration of environmental health competencies into standard nursing curricula to prepare the next generation of rural healthcare providers. Collaboration with agricultural extension services, toxicologists, and public health departments is essential for developing community-wide mitigation strategies. Policy advocacy remains a fundamental responsibility of the nursing profession in safeguarding vulnerable agricultural populations.

The interpretation of these findings must be tempered by several methodological limitations inherent in the included studies. Mwakalasya et al. (2025) relied on self-reported exposure, introducing significant recall bias and limiting the precision of the observed associations. Andrade-Rivas et al. (2026) used an ecological design, which is susceptible to ecological fallacy and cannot adequately control for individual-level confounders such as maternal nutrition or socioeconomic status. Variability in exposure measurement techniques, ranging from broad spatial databases to advanced mass spectrometry, creates heterogeneity that complicates direct meta-analytical comparisons. The cross-sectional design of some included studies also precludes establishing definitive causal relationships between pesticide exposure and adverse health outcomes. These methodological constraints highlight the ongoing need for rigorous, longitudinal research designs in environmental epidemiology.

The scope of this systematic review is further constrained by its strict inclusion criteria, which may have omitted relevant historical or non-English literature. Restricting the search to publications from the last year with active DOIs and open access ensures high contemporary relevance. This temporal restriction excludes foundational studies or valuable regional research published in local languages. The exclusion of conference abstracts missed emerging preliminary data on novel pesticide formulations currently entering the agricultural market. The focus on open-access articles may also introduce a publication bias, favoring studies with positive or statistically significant findings. Future research must prioritize large-scale, prospective longitudinal designs with objective biomonitoring to overcome these current evidentiary gaps and further solidify the evidence base for agro-nursing practice.

CONCLUSION

This systematic review establishes prenatal pesticide exposure as a critical determinant of adverse maternal and child health outcomes, necessitating immediate integration of environmental health competencies into agro-nursing practice. The synthesized evidence reveals profound neurodevelopmental, metabolic, and endocrine vulnerabilities linked to agricultural chemical exposure during pregnancy. Healthcare providers in rural settings must prioritize comprehensive environmental exposure histories and proactive patient education to mitigate these toxicological risks. Future epidemiological investigations should employ rigorous longitudinal designs with objective biomonitoring to clarify causal pathways and inform evidence-based public health policies. Empowering agro-nurses with advanced training in environmental health will ultimately safeguard vulnerable agricultural populations and optimize perinatal care trajectories globally.

REFERENCES

Andrade-Rivas, F., Spiegel, J., Delgado-Ron, J. A., Van den Bosch, M., Parrott, L., & Henderson, S. B. (2026). Agricultural pesticide exposures in Ecuador and their spatial association with low birth weight: A combined cluster detection and Bayesian modelling approach. *Environmental Pollution, 398*, 128090. https://doi.org/10.1016/j.envpol.2026.128090

Baba, S., Tanigawa, K., Nakayama, S. F., Nishihama, Y., Hirata, K., Ikehara, S., Miyazaki, J., Kawasaki, R., & Iso, H. (2025). Associations between antenatal organophosphate pesticide exposure and pregnancy outcomes: The Japan Environment and Children's Study (JECS). *Science of the Total Environment, 997*, 180117. https://doi.org/10.1016/j.scitotenv.2025.180117

Birolli, W. G., Lanças, F. M., José, Á., & Silveira, H. C. (2024). Determination of pesticide residues in urine by chromatography-mass spectrometry: Methods and applications. *Frontiers in Public Health, 12*, 1336014. https://doi.org/10.3389/fpubh.2024.1336014

Botnaru, A. A., Lupu, A., Morariu, P. C., Jităreanu, A., Nedelcu, A. H., Morariu, B. A., Anton, E., Di Gioia, M. L., Lupu, V. V., Dragostin, O. M., Vieriu, M., & Morariu, I. D. (2025). Neurotoxic effects of pesticides: Implications for neurodegenerative and neurobehavioral disorders. *Journal of Xenobiotics, 15*(3), 83. https://doi.org/10.3390/jox15030083

Chen, K. C., Lee, S. F., Lin, S. W., Xie, J. S., Chang, Y. H., Yiin, L. M., & Hsieh, C. J. (2023). Associations between residential proximity to agricultural land use as pesticide exposure and birth outcomes. *Environmental Science and Pollution Research, 30*(12), 33253–33263. https://doi.org/10.1007/s11356-022-24571-8

Colopi, A., Guida, E., Cacciotti, S., Fuda, S., Lampitto, M., Onorato, A., Zucchi, A., Balistreri, C. R., Grimaldi, P., & Barchi, M. (2023). Dietary exposure to pesticide and veterinary drug residues and their effects on human fertility and embryo development: A global overview. *International Journal of Molecular Sciences, 25*(16), 9116. https://doi.org/10.3390/ijms25169116

De Joode, B. V. W., Peñaloza-Castañeda, J., Mora, A. M., Corrales-Vargas, A., Eskenazi, B., Hoppin, J. A., & Lindh, C. H. (2024). Pesticide exposure, birth size, and gestational age in the ISA birth cohort, Costa Rica. *Environmental Epidemiology, 8*(2), e290. https://doi.org/10.1097/EE9.0000000000000290

Felisbino, K., Milhorini, S. D. S., Kirsten, N., Bernert, K., Schiessl, R., & Guiloski, I. C. (2024). Exposure to pesticides during pregnancy and the risk of neural tube defects: A systematic review. *Science of the Total Environment, 913*, 169317. https://doi.org/10.1016/j.scitotenv.2023.169317

González, H. (2026). Beyond the take-home pathway: Community-level pesticide exposure among children living in an intensively cultivated agricultural landscape. *International Journal of Environmental Research and Public Health, 23*(5), 664. https://doi.org/10.3390/ijerph23050664

Guesdon, L., Warembourg, C., Chevrier, C., De Lauzon-Guillain, B., Caudeville, J., Charles, M., Le Lous, M., Blanc-Petitjean, P., & Béranger, R. (2025). Maternal exposure to pesticides and gestational diabetes mellitus in the Elfe cohort. *Environmental Research, 284*, 122275. https://doi.org/10.1016/j.envres.2025.122275

Iqbal, J., Ali, S., Zahid, A., Fatima, A., Zahra, A., Siddiqi, K., & Ahmad, M. (2025). Agriculture, pesticide pollution, and climate change—Interconnected challenges. In *Food systems and biodiversity in the context of environmental and climate risks: Dynamics and evolving solutions* (pp. 491–517). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-89167-0_18

Iversen, A., Bruun, J., Lund, L. C., Andreasen, S. B. M., Halldórsson, Þ. I., Juul, A., Frederiksen, H., Andersson, A., Hagen, C. P., Nielsen, F., Andersen, M. S., Jensen, T. K., & Andersen, H. R. (2025). Prenatal exposure to the pesticides chlorpyrifos and 2,4-dichlorophenoxyacetic acid is associated with circulating levels of reproductive hormones in healthy infant girls. *Reproductive Toxicology, 139*, 109112. https://doi.org/10.1016/j.reprotox.2025.109112

Kurniyawan, E. H., Kurniawan, D. E., Nur, K. R. M., Afandi, A. T., Fitria, Y., Wuryaningsih, E. W., & Erlando, R. P. A. (2026). Health impacts of pesticide exposure among farmers: A systematic review and implications for agronursing practice. *Health and Technology Journal (HTechJ), 4*(1), 109–119. https://doi.org/10.53713/htechj.v4i1.593

López-Flores, I., González-Alzaga, B., Romero-Molina, D., Hernández, A. F., Pérez-Luzardo, O., Acosta-Dacal, A., Macías-Montes, A., Henríquez-Hernández, L. A., Boada, L. D., Pelegrí, D., González, J. R., & Lacasaña, M. (2025). Gestational exposure to organophosphate pesticides and maternal urine metabolomic profile in the GENEIDA birth cohort. *Environmental Toxicology and Pharmacology, 118*, 104793. https://doi.org/10.1016/j.etap.2025.104793

Mwakalasya, W. N., Mamuya, S. H., Manji, K., Moen, B. E., & Ngowi, A. V. (2025). Neurodevelopment in children born to women exposed to pesticides during pregnancy. *PLOS ONE, 20*(12), e0326007. https://doi.org/10.1371/journal.pone.0326007

Nurhadijah, S., Zamaa, M. S., Harun, B., Sahida, M., & Wahyuni, A. (2025). Environmental nursing practices as a solution for reducing exposure to environmental hazards. *EcoVision: Journal of Environmental Solutions, 2*(1), 31–51. https://doi.org/10.61511/evojes.v2i1.2025.1725

Parra, K. L., Harris, R. B., Farland, L. V., Beamer, P., Fournier, A. J., Ellsworth, P. C., & Furlong, M. (2026). Prenatal exposure to agricultural pesticide applications and gestational diabetes mellitus in the AZ-PEARS population-based study (2014–2020). *Environment International, 207*, 109989. https://doi.org/10.1016/j.envint.2025.109989

Pathak, V. M., Verma, V. K., Rawat, B. S., Kaur, B., Babu, N., Sharma, A., Dewali, S., Yadav, M., Kumari, R., Singh, S., Mohapatra, A., Pandey, V., Rana, N., & Cunill, J. M. (2022). Current status of pesticide effects on environment, human health, and its eco-friendly management as bioremediation: A comprehensive review. *Frontiers in Microbiology, 13*, 962619. https://doi.org/10.3389/fmicb.2022.962619

Pumsopa, N., Jirapongsuwan, A., Kalampakorn, S., & Siri, S. (2025). The effect of strengthening nurse practitioners' competency in occupational health services for agricultural workers exposed to pesticides in primary care units, Thailand: A before-and-after study. *Journal of Educational Evaluation for Health Professions, 22*, 14. https://doi.org/10.3352/jeehp.2025.22.14

Reed, J. E., Burns, C. J., & Pisa, F. (2023). Literature landscape of neurodevelopment and pesticides: A scoping review of methodologies. *Global Epidemiology, 6*, 100121. https://doi.org/10.1016/j.gloepi.2023.100121

Rueda-Ruzafa, L., Ropero-Padilla, C., Ruiz-González, C., Rodriguez-Arrastia, M., Roman, P., & Sánchez-Labraca, N. (2023). A nursing socio-environmental approach for acute pesticide poisoning: A qualitative focus group study. *Journal of Advanced Nursing, 79*(5), 1754–1764. https://doi.org/10.1111/jan.15319

Steel, S. K., & Hyland, C. (2025). Examining healthcare providers' knowledge, attitudes, and practices in supporting pregnant farmworkers to mitigate occupational pesticide exposure in California: A qualitative study. *Journal of Primary Care & Community Health*. https://doi.org/10.1177/21501319251407545

Thompson, S., Ritz, B., Cockburn, M., & Heck, J. E. (2022). Prenatal ambient pesticide exposure and childhood retinoblastoma. *International Journal of Hygiene and Environmental Health, 245*, 114025. https://doi.org/10.1016/j.ijheh.2022.114025

Van Deventer, D., Ritz, B., Cockburn, M., & Heck, J. E. (2025). Prenatal pesticide exposure and neuroblastoma: A statewide case-control study in California. *Environmental Research, 287*, 123027. https://doi.org/10.1016/j.envres.2025.123027

Ventura-Miranda, M. I., Fernández-Medina, I. M., Guillén-Romera, E., Ortíz-Amo, R., & Ruíz-Fernández, M. D. (2022). Effect of gestational pesticide exposure on the child's respiratory system: A narrative review. *International Journal of Environmental Research and Public Health, 19*(22), 15418. https://doi.org/10.3390/ijerph192215418

Xu, Z., Fang, J., Yang, C., Wang, A., Xu, S., Cai, Z., Li, Y., Liu, H., Li, Q., Liu, B., Cao, Z., & Xia, W. (2026). Prenatal exposure to organochlorine pesticides and early childhood neurodevelopment: A prospective birth cohort study. *Ecotoxicology and Environmental Safety, 312*, 119927. https://doi.org/10.1016/j.ecoenv.2026.119927

Yin, S., Fu, D., Kang, N., Fan, C., Liu, X., Jin, H., Wang, X., Tian, Y., Zhang, J., & Wei, J. (2026). Associations of co-exposure to organophosphate flame retardants and pesticides with maternal thyroid function in early pregnancy: Findings from the Shanghai Birth Cohort. *Ecotoxicology and Environmental Safety, 319*, 120328. https://doi.org/10.1016/j.ecoenv.2026.120328

Zhou, W., Li, M., & Achal, V. (2025). A comprehensive review on environmental and human health impacts of chemical pesticide usage. *Emerging Contaminants, 11*(1), 100410. https://doi.org/10.1016/j.emcon.2024.100410