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Investigating Prevention Practices and Developing Intervention Materials for Common Pesticide Exposures in the United States and Thailand: A Scoping Review

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Abstract

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Objective: The main goal of this scoping review is to examine the research findings and identify the barriers that contribute to people's reproductive health and fetal health in Thailand relating to insecticide exposures and developing intervention materials.

Goal: The main goal is to review the current literature using a scoping review to examine the findings within research studies and identify the barriers that contribute to people's reproductive health and fetal health in Thailand relating to insecticide exposures. The data collected in this scoping review will be used to develop intervention strategies.

Methods: A scoping review was conducted after searching the PubMed database to retrieve original publications. 24 studies were determined to fit all the inclusion criteria after they were thoroughly reviewed. Relevant information including exposure type, population, methods, and results were identified. This information was reviewed to develop intervention strategies.

Results: There are interventions to consider regarding reducing pesticide exposures amongst an individual's diet, within their home, and occupational space. These practices included the use of protective equipment while working in hazardous environments and the practice of safe hygienic practices such as washing your hands and produce before consumption to decrease exposure toxicants.

Conclusion: It is important to inform individuals about the detrimental effects of being exposed to pesticides with the hopes that it would increase awareness along with behavioral change. For government officials, effort should be made on their part to develop or revise policies to protect vulnerable populations that are exposed to pesticides and to provide funding for

employers who work closely with those populations to better protect them from these toxicants.

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Table of Contents

Chapter 1: Introduction

Pesticides are a unique class of chemicals as they are the only chemicals that are created or isolated to kill, mitigate, or regulate growth of living things (Marrone, P.G., 2019). Pesticides represent a large fraction of industrial chemicals purchased annually across the globe and we willingly place them in the environment (Clunies-Ross & Hildyard, 2013). According to the Food and Agriculture Organization of the United Nations (FAO), 1.4 million metric tons were reached globally for herbicide consumption while 606 and 471 thousand metric tons of consumption of fungicides and bactericides (FAO, 2022). Pesticides comprise a broad group of similar and dissimilar chemicals and organisms intended to control pests, so they are often classified by their target organism (Yadav & Devi, 2017). Herbicides, insecticide, miticide, rodenticides, fungicides, arachnicides, nematicides, among others, all fit into this broad class of chemicals.

According to the United States Environmental Protection Agency (EPA), pesticide products contain both “active” and “inert” ingredients which act to prevent, destroy, repel, or mitigate any pest and include growth regulators, desiccants, and defoliants (United States Environmental Protection Agency, 2022). Active ingredients and their percentage must be labeled on the pesticide product. Active pesticidal ingredients include synthetic and natural pesticides (Chaudhary, S., et. al., 2017). Synthetic pesticides are comprised as the most conventionally used pesticides, but natural pesticides such as biopesticides (e.g., bacteria or viruses) or pyrethrum derived from chrysanthemums are also used (Oguh, C.E., et. al., 2019). Most synthetic pesticides came into use after World War II and often are more stable and more efficacious analogues of natural pesticides (Gerhardson, B., 2002). Natural pesticides cover a broad range of chemicals and chemical mixtures including plant-derived and living bio-organisms (Ibrahim, M. A., et. al., 2001).

So called “inert” ingredients are contained within most pesticide formulations (Tominack & Tominack, 2000). Inert ingredients have no pesticidal activity, but they may be synergists or help the pesticides to volatilize or be otherwise delivered (Liu, B., et. al., 2022). Furthermore, inert ingredients are a combination of compounds, substances, chemicals, and natural materials that must be approved by the EPA before they can be combined in a pesticide (United States Environmental Protection Agency, 2022). Inert ingredients play a significant role in the effectiveness of pesticides and their performance for they can help to extend the product’s self-life, to act as a solvent to assist the active ingredient to penetrate a plant’s leaf surface or more importantly, to improve the safety for the applicator (United States Environmental Protection Agency, 2022).

Before manufacturers can distribute and sell pesticide products to the public, they are required to evaluate the products to make sure that the products meet the federal safety standards that are supposed to protect human health as well as the environment (United States Environmental Protection Agency, 2022). This testing requires both acute and chronic toxicity testing of both active ingredients and formulations in laboratory animals; no human data are required (Damalas & Eleftherohorinos, 2011). Once the product has been approved for meeting the scientific and regulatory requirements, the United States EPA grants a license to the manufacturer which permits them to distribute and sell the pesticide for a specific use (United States Environmental Protection Agency, 2022).

Pesticides have become important public health tools for increasing and improving the safety of our food supply and for mitigating vector-borne diseases (Sutherst, R.W., 2004). Globally approximately 1.8 billion individuals engage in agriculture and utilize pesticides to protect their food and commercial products they produce (Alavanja, M.C., 2009). Many of these products are used in low-and-middle income countries (LMICs) whose economy relies heavily on exporting produce (Abdalla, S., et. al., 2017). However, developing and enforcing regulations to limit or control exposures to pesticides in LMICs is often difficult because of limited resources, fractured regulatory systems, competing priorities in public health, and industry pressure (Abdalla, S., et. al., 2017). The consequences of limited regulations or their effective enforcement have led to an estimated 25 million agriculture workers worldwide experiencing unintentional pesticide poisoning each year (Dinham & Malik, 2003). Organophosphates (OPs) and pyrethroids are commonly used insecticides for crop protection around the globe (Kang, J., et. al., 1995). OP pesticides are used because they are readily available and tend not to develop insect-resistance over time and considered highly toxic and among the most widely used ones available (Elliott, M., et. al., 1978). They were the original choice to replace legacy pesticides in the 1970s after the ban of dichlorodiphenyltrichloroethane (DDT) and other environmentally persistent and bio accumulative pesticides (Kang, et. al., 1995). Structurally, they are like chemical warfare agents such as sarin and tabun and have the same mechanism of biological action, so they are often referred to as “junior strength” nerve agents (Weerasekera, G., et. al., 2008). They act by binding acetylcholinesterase (AChE) in the blood and brain and preventing breakdown of the neurotransmitter acetylcholine at the neuronal terminus (Weerasekera, G., et. al., 2008). Over the years, several OPs have been discontinued for use along with chlorpyrifos which is no longer registered to use in homes since 2001 and was recently banned for use in agriculture in the United States.

Similarly, pyrethroid insecticide works to modulate nerve impulses but they act on the axonal membrane of the neuron, altering sodium-potassium “gating” voltages (Anger, T., et. al., 2001). This is the same mechanism of action as DDT. Both OP and pyrethroid insecticides are neurotoxic, by design, and unfortunately, can affect other living organisms similarly (Anger, T., et. al., 2001).

After exposure to both OPs and pyrethroids, the chemicals can be rapidly metabolized via enzymatic or hydrolytic pathways (Godin, S.J., et. al., 2006). In the case of OPs, they wear down to produce a super-reactive oxon that binds AChE firmly. They can also be metabolized to their dialkylphosphate (DAPs) metabolites and metabolites representing the other half of the molecule. (Zhang, X., et. al., 2008). Pyrethroids are typically metabolized to a common chemical, 3-phenoxybenzoic acid (Laffin, B., et. al., 2010). These metabolites all undergo Phase II metabolism to bind to biomolecules such as glucose to make them more water soluble, then they are excreted in urine over a 72-hour period after exposure (Barr, D.B., 2008). These metabolites in urine or the intact pesticides in blood have been used to assess exposure to these chemicals (Barr, D. B., 2008).

Because of their widespread use, humans cannot avoid exposure to pesticides (Langley, R.L. & Mort, S.A., 2012). People are exposed daily to environmental toxicants such as pesticides at various levels. They can be exposed to these toxicants from an assortment of pathways such as their home, school, or work environment through air contamination, the water they drink, or within the soil where they grow their produce (Langley, R.L. & Mort, S.A., 2012). The improper use of pesticide products can potentially result in high cases of exposure. In the occupational setting, employers who are not taking necessary precautions or do not have set guidelines or protocols in place to protect their employees can result in pesticide-related illnesses long-term (Mehrpour, O., et. al., 2014). The health risks pertaining to pesticide exposures vary depending on how hazardous the pesticide is as well as the amount an individual has been exposed to, the duration of the exposure, and the many ways that the individual was exposed to the pesticide (Gilden, R.C., et. al., 2010).

Exposure to pesticides such as OPs have been proven to affect the nervous system causing neuropsychological and cognitive functioning deficits such as attention deficit hyperactivity disorder (ADHD), decrease in Intelligence Quotient (IQ), and/or autism spectrum disorder (ASD) in both children and adults (Rauh, V.A., et. al., 2012). Direct methods used in the past to measure pesticide exposure levels in individuals are through multi-pathway measurements or human biomonitoring with blood or urine (Barr, D.B., 2008). However, indirect methods have been used to measure exposure levels through pesticide use data, telephone interviews, or questionnaires.

Agriculture in northern Thailand, which employs over 40 percent of the workforce and adds significantly to the country's gross domestic product, is a major segment of its economy (Laohaudomchok, W., et al., 2021). Import and utilization of pesticides has risen over the past decade due to Thailand's significant role as a prominent exporter of food and agricultural products (Laohaudomchok, W., et al., 2021). The Study of Asian Women and their Offspring’s Development and Environmental Exposures (SAWASDEE) examined the effects of prenatal exposure to pesticides with the aim to enable earlier interventions to increase better outcome prognoses in pregnant Thai agriculture farmworkers and their children (Baumert, B.O., et. al., 2022). Indicators of cognitive and motor skills, inhibitory control, emotion regulation, and memory have been recorded during this study regarding the development of neurobehavioral and neurodevelopmental diseases (Engel, S.M., et. al., 2011).

I. ***Need Statement***

To reduce pesticide exposure for pregnant individuals, we need to strengthen employer's adherence to regulations and/or manufacturer's guidelines by providing recommendations to monitor pesticide exposures not only for pregnant individuals but those who have yet to be pregnant to reduce pesticide exposure and prevent pesticide-related disease. In addition, we need to educate farmworkers so they understand individual precautions they can take to limit their own exposure and their fetus' exposure as well. To do this effectively, a proper investigation of typical pathways of exposures that can be mitigated needs to be undertaken via a scoping review approach.

A scoping review design is a methodological approach for taking the first step in research development which allows the evaluation of prominent evidence (Peterson, et al., 2017).

II. ***Scope Review Goal***

A scoping review aims to review evidence-based research that is relative to a specific research question. "Scoping reviews are therefore particularly useful when a body of literature has not yet been comprehensively reviewed or exhibited a complex or heterogeneous nature not amenable to a more precise systematic review of the evidence" (Munn, et al., 2018). A scoping review was chosen for this thesis because multiple exposure assessment techniques, exposure scenarios, and populations were used in studies that may prevent a proper meta-analysis of a systematic review. Furthermore, a scoping review has a design that enables us to better independently characterize exposure pathways to enable the development of intervention strategies. The scoping review would serve as a precursor to a larger broad-based systematic review. The main goal of this scoping review is to not only examine the findings within research studies but also to identify the barriers that contribute to people's reproductive health along with fetal health in Thailand relating to insecticide exposures.

III. ***Significance***

The utilization of a scoping review design and implementing it well has the potential to inform and guide practitioners, policy makers, educators, and researchers on how to identify the strengths and weaknesses in future research to better tackle public health issues around the globe. Specifically, this scope view informs issues regarding pesticide exposure and population health, specifically women's health. Furthermore, when it comes to creating change at the community level, it is vital to take into consideration the significance of behavioral change and how communication conveyed to the general population can have an impact on program effectiveness both positively and negatively. Finally, future research may be able to focus on exploring other factors that contribute to preventative measures for reducing pesticide exposures.

Chapter 2: Methods

I. ***Literature Search and Selection Strategy***

To identify relevant literature, a specific search strategy for peer-reviewed literature using the database PubMed was developed. The review strategy followed Preferred Reporting

Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for scoping reviews (Page, M.J., 2017). The following key search terms were utilized in various combinations in order to identify the relevant literature: pregnant people, children, organophosphate (i.e., OP pesticides, OP insecticides, or OP), blood, chlorpyrifos, urine DAP (diallyls phosphate), urinary TCPY, insecticide, neurocognition, neurodevelopment, prenatal, human, exposure, outcome, children, occupational, paraoccupational, environmental, indigestion, health outcomes, air, indoor, pesticides, females, women, Thailand, Asia, Southeast Asia, dietary, farmers, fetal development, agriculture farmers, and reproductive health. In Table 1, it highlights the search strategies that were taken and the days that PubMed database was searched.

Primary Database: PubMed	
Search Terms	**Date of Search**
((reproductive health AND Southeast Asia)) OR ((reproductive health AND Thailand)) OR ((females AND Asia)) OR ((females AND pesticides)) OR ((women AND pesticides)) OR ((women AND insecticides)) OR ((females AND insecticides)) OR ((agriculture farmers AND pesticide exposure)) OR ((farmers AND insecticides))	Searched on January 12th, 2023
((Organophosphate OR OP pesticides)) OR ((OP pesticides AND OP insecticides)) OR ((OP pesticides AND Urine DAP)) OR ((OP pesticides AND Urinary TCPY)) OR ((Organophosphate OR Chlorpyrifos)) OR ((Blood AND OP insecticides)) OR ((Thailand AND OP pesticides)) OR ((Thailand AND OPs))	Searched on January 17th, 2023
((Pregnant people AND insecticides)) AND ((Human outcomes AND prenatal AND Op pesticides)) OR ((Neurodevelopment AND children AND OP insecticides)) OR ((Occupational AND exposure AND farmers)) OR ((Pregnant people AND exposure AND	Searched on January 18th, 2023

health outcomes)) OR ((Pregnant people AND prenatal AND chlorpyrifos))	
((Paraoccupational AND exposure AND women)) OR ((Environmental AND exposure AND air)) OR ((Occupational AND ingestion AND dietary)) OR ((Indoor AND OP pesticides AND pregnant people)) OR ((Indoor AND pesticides AND children))	Searched on January 25th, 2023
((Fetal development AND paraoccupation AND exposure)) OR ((Prenatal development AND Chlorpyrifos AND exposure)) OR ((Neurocognition AND children AND OP pesticides)) OR ((Prenatal exposure AND insecticides AND outcomes))	Searched on February 7th, 2023

Table 1: *PubMed Database Search Strategy*

All citations and pdf formats of the articles were downloaded and exported to EndNote, which is a commercial reference management software utilized to manage bibliographies and references when authoring essays, reports, and articles (EndNote, 2023). Titles and abstracts were reviewed according to the following inclusion and exclusion criteria.

Inclusion Criteria included:

- Articles published between 2000 and 2020
- Articles conducting observational studies on pregnant people and children
- Articles exclusively in the English language
- Articles implementing studies domestically and internationally (e.g., Philippines, New York)
- Articles focusing on insecticide exposures (e.g., Chlorpyrifos, Pyrethroid, Organophosphates)
- Articles accessible through Emory University library systems
- Human studies

Exclusion Criteria included:

- Articles in a language other than English
- Articles published before 2000 and after 2020
- Articles not accessible through Emory University library systems
- Non-human studies

II. ***Geographic Considerations***

While this study focuses on Southeast Asian countries such as Thailand; the review was not limited to any specific geographical location because issues regarding maternal and child health and pesticide-related environmental health can co-exist anywhere in the world. To get a full scope of the impact of pesticide-related environmental issues and how they affect not only the mother but the fetus, all studies meeting the inclusion criteria were included.

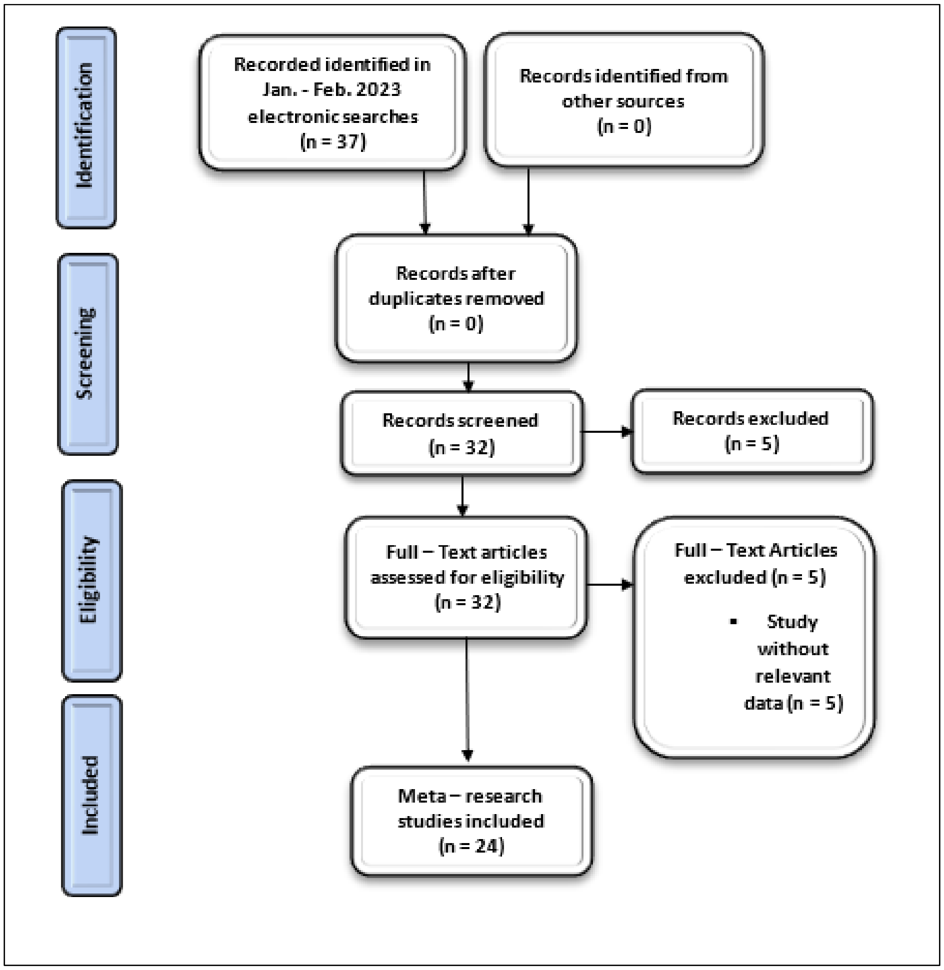
III. ***Ethical Considerations***

An Institutional Review Board (IRB) protocol was not required because no human subjects were involved in this study. Only extant information that is publicly available was used.

IV. ***Selection of Studies***

Studies that met the inclusion and exclusion criteria for further analysis were selected for inclusion in this scoping review if they met the following inclusion criteria: 1) study assessed prenatal pesticide exposures; 2) the expected pathway of exposure was identified; 3) the location of the study was provided; and 4) the study design was clearly stated. Exclusion criteria included 1) acute poisoning events, 2) case studies, 3) studies that did not involve prenatal exposure to pesticides; 4) studies where biomarker data were not provided. Papers describing the same study but with a different pesticide or outcome were not excluded. Typically, the inclusion and exclusion criteria of a study could be identified by reading the study abstract. All abstracts were reviewed, and the relevant studies were selected for inclusion. In Figure 1, it displays a flow-chart detailing the source selection during each stage of the process.

Figure 1: *A Flow Diagram of Identification, Screening, and Inclusion of Studies*



V. ***Data Extraction***

A strawman table was developed to facilitate data extraction from the papers. The data extracted included primary author, study type, location 1, location 2, population, number of individuals in the study, purpose of the study, methods, exposure 1, exposure 2, matrix, outcome, pathway of maternal exposure, and the results. Each paper was reviewed in its entirety and the extracted data was recorded on the strawman table. After the table was populated, it was reviewed for consistency, accuracy, and to determine if any additional study features or data were needed to facilitate the development of infographic intervention materials.

VI. **Development of Infographic Intervention Materials**

Two infographics were developed using Canva, which is an online graphic designing tool. One infographic dealt primarily with environmental exposures and the other focused on occupational exposures such as those experienced in the SAWASDEE birth cohort in Thailand. By evaluating the various pathways of exposure, several potential exposure mitigation strategies were identified. Most of these mitigation strategies were simple hygienic practices or required the use of personal protective equipment. The recommendations for producing the development of these two infographics are referenced from an accumulation of articles retrieved from PubMed database through sources such as Elsevier, HHS (Health and Human Services) Public Access, and NIH (National Institutes of Health) Public Access.

Chapter 3: Results & Discussion

The results from the scoping review using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines are shown in Figure 1. Originally, there were over 35 articles that were found evaluating pesticide exposures and outcomes. However, in total, there were 24 studies selected for review (Table 2). Thirteen studies were conducted in the United States, specifically 8 studies in New York City, 4 studies in California, and 1 study in Mexico. There were 11 studies conducted internationally, specifically 3 studies in China, 1 study in the Philippines, 1 study in South Asia, 2 studies in Denmark, 1 study in Taiwan, and 3 studies in Northern Thailand/Thailand. The targeted population for the studies varied either focusing on pregnant persons, newborns, and/or children. Over half of the studies used human biomonitoring methods by analyzing urine and blood and other approach methods such as administering questionnaires and the implementation of telephone interviews.

Many of the studies focused on exposures such as organophosphates (OP) and pyrethroid insecticides. In most studies, prenatal exposures were associated with neurodevelopmental effects such as decreased intelligence quotient (IQ), failure to meet neurodevelopmental target goals, decreased cognition in mental development, and attention deficit hyperactivity disorder (ADHD). About 80% of the studies that evaluated pesticide exposures for pregnant people and neurological developmental effects on the fetus indicated that significant evidence exists to implicate pesticide exposures in children correlated with neurological deficits. In addition, 20% of the studies evaluated early childhood pesticide exposures and noticed a correlation between OP pesticides and subsequent adverse effects on motor development as well as reducing the risk of autism spectrum disorder (ASD).

Below in Table 2, it lists the article citations with the author's first name and year of publication, the location that the study took place, the study’s targeted population, the methods that were used, the exposure types, and the results of being exposed to the pesticide.

Table 2: *Summary of Existing Studies on Prenatal & Early Childhood Exposures & Adverse Outcomes*

Article ID	Location 1	(N) Population	Methods	Exposure 1	Results
Andersen, et al., 2021	Denmark	755 Pregnant women	Human Biomonitori	Organophos phates (OP) and	Pesticide exposure

			ng (HBM) in urine	Pyrethroid Insecticides	resulted in decreased IQ
Balalian, et al., 2021	New York City	121 Pregnant women	Human Biomonitoring (HBM) in urine	OP and Pyrethroid Insecticides	Pesticide exposure resulted in children's neurodevelopment
Baumert, et al., 2022	Northern Thailand: Chang Mai Province	330 Pregnant women	Human Biomonitoring (HBM) in urine	OP Insecticides	Pesticide exposure resulted in neurological deficits
Baumert, et al., 2022	Northern Thailand: Chang Mai Province	322 Pregnant women	Human Biomonitoring (HBM) in urine	OP Insecticides	Pesticide exposure resulted in neurodevelopment outcomes
Berkowitz, et al., 2004	New York City	404 Pregnant women	Human Biomonitoring (HBM) in urine	Pyrethroids and Chlorpyrifos Insecticides	Pesticide exposure resulted in fetal neurodevelopment/cognitive activity
Chiu, et al., 2021	Taiwan	486 Pregnant women, newborns	Human Biomonitoring (HBM) in urine	Chlorpyrifos Insecticides	Pesticide exposure resulted in neurodevelopment in children
Dalsager, et al., 2019	Denmark	948 Pregnant women	Human Biomonitoring (HBM) in urine	Chlorpyrifos and Pyrethroids Insecticides	Pesticide exposure resulted in neurobehavioral development

Engel, et al., 2011	New York City	149 Pregnant women	Human Biomonitoring (HBM) in urine	OP Insecticides	Pesticide exposure resulted in cognitive development
Eskenazi, et al., 2007	California	372 Pregnant women	Human Biomonitoring (HBM) in urine	OP pesticides	Pesticide exposure resulted in mental development
Fortenberry, et al., 2014	Mexico	187 Pregnant women	Human Biomonitoring (HBM) in urine	OP pesticides	Pesticide exposure resulted in ADHD (attention deficit hyperactivity disorder) deficits
Guo, et al., 2019	China	377 Pregnant women and 3 yr. old children	Human Biomonitoring (HBM) in urine	Chlorpyrifos (CPF) Insecticide	Pesticide exposure resulted in neurodevelopment deficits
Huen, et al., 2010	California	434 Pregnant women	Human Biomonitoring (HBM) in blood	OP pesticides	Pesticide exposure resulted in oxidative stress
Jaacks, et al., 2019	South Asia	289 Mother - Child pairs	Human Biomonitoring (HBM) in urine	OP pesticides	Pesticide exposure resulted in substantial risk of adverse birth outcomes
Liang, et al., 2022	Thailand	50 Pregnant women	Human Biomonitoring (HBM) in urine	OP pesticides	Pesticide exposure resulted in biological pathways linked to inflammation,

					oxidative stress, and endocrine implications
Lovasi, et al., 2011	New York	266 Children	Psychomotor Development Index (PDI), Mental Development Index (MDI)	OP pesticides	Neighborhood demographics resulted in birth outcomes
Ostrea, et al., 2012	Philippines	696 Children	Human Biomonitoring (HBM) in blood	Meconium, Propoxur, Bio allethrin	Pesticide exposure to propoxur showed subsequent adverse effects on motor development
Perera, et al., 2005	New York	214 Pregnant women, newborns	Human Biomonitoring (HBM) in blood	OP pesticides (Prenatal Insecticides)	Prenatal environmental toxicant exposure resulted in adverse effects in fetal growth and child development
Rauh, et al., 2011	New York	265 Pregnant women	Human Biomonitoring (HBM) in blood	Chlorpyrifos (CPF) Insecticide	Prenatal exposure resulted in decreased IQ
Rauh, et al., 2012	New York	329 Pregnant women	Human Biomonitoring (HBM) in blood	Op pesticides	Prenatal exposure resulted in decreased IQ

Schmidt, et al., 2017	California	466 Children	Telephone interviews/ Mothers' direct measures of pesticide usage	OP pesticides	Folic Acid intake resulted in potentially reducing risk of ASD (autism spectrum disorder)
Shelton, et al., 2014	California	970 Pregnant women	Questionnaire	Op pesticides	Children of mothers living near agricultural areas are at higher risk of neurodevelopmental disorders
Silver, et al., 2018	China	359 Pregnant women	Human Biomonitoring (HBM) in blood	OP pesticides	Prenatal exposure to Chlorpyrifos resulted in infant sensory function deficits
Silver, et al., 2017	China	359 Pregnant women	Human Biomonitoring (HBM) in blood	OP pesticides/ Chlorpyrifos / Naled	Prenatal exposure to Naled and CPS resulted in decreased motor function in infants
Whyatt, et al., 2002	New York City	316 Pregnant women	Questionnaire	OP pesticides	Prenatal exposures are uncertain to be associated with neurocognitive development

I. ***Potential Interventions to Alleviate Prenatal & Childhood Exposures***

In the studies evaluated, dietary, inhalational residential, and paraoccupational were considered the primary exposure pathways for pyrethroid and OP insecticide exposure among pregnant people and children. However, there are potential interventions that can be considered when reducing pesticide exposures amongst these two groups regarding an individual’s diet, their place of residence, work environment, their use of personal protective equipment, and the adoption of safe hygienic practices.

II. ***Reduction in Dietary Exposures***

One way to reduce pesticide exposures through dietary intake is to consume organic produce. However, organic produce on average costs 47% than conventional food which is a barrier for why many families find it to be difficult to switch over to eating organic foods exclusively according to Consumer Reports (Wilcox, 2019).

While the cost of organic foods is high, there are other options that an individual or family can take to be able to have access to clean, organic food. Many supermarkets sell organic foods, but the costs are high, so people can check prices of the food that they purchase on a regular basis and compare the prices online with hopes to get the best deals on food (Joshi, Y. & Rahman, Z., 2015). People have the option of growing their own garden which requires not much effort depending on what a person is trying to grow. It would be important to encourage individuals to take small steps and learn how to grow their own herbs, fruits, and vegetables whether that be in their windowsills, on their porch, and/or the backyard of their home. According to the United States Department of Agriculture (USDA), co-ops consist of producers and user-owned businesses that are controlled by and operate for the benefit of their members rather than outside investors (United States Department of Agriculture, n.d.). Connecting with a local farmer’s co-op business is a fantastic way to connect with others who are not only interested in buying organic foods but growing their own organic foods according to USDA. Furthermore, buying from co-ops helps to save money on organic foods. If an individual purchases organic food from a fresh market or a co-op business, it is important that the person remembers to thoroughly clean their produce before eating them (United States Department of Agriculture, n.d.).

The United States Food & Drug Administration (FDA) mentioned that an estimate of 48 million people is sickened by food contaminated by harmful bacteria each year (Office of the Commissioner, n.d., 2021). Before washing produce, it is essential to remember to wash your hands first with soap and water for at least 20 seconds (Bradman, A., et. al., 2009, Centers for Disease Control and Prevention, 2022). Once the individual washed their hands thoroughly, cut off bruised or damaged areas of the produce, then washed it with hot water (Gil. M. I., et. al., 2015). The person can consider using a brush to clean the surface of the produce as well. Furthermore, dry the produce with a dry paper towel to reduce any bacteria or substance left over on the surface of the produce. Once you have cleaned the produce, follow – up by washing your hands with soap and water for at least 20 seconds (Bradman, A., et. al., 2009, Centers for Disease Control and Prevention, 2022).

Lastly, it is important to consider that using vinegar or baking soda can result in the breakdown of pesticides to remove more pesticide residue than water (Balkan & Yilmaz, 2022). However, hot water would be just as effective in removing residue from produce and one's hands more than cold water (Balkan & Yilmaz, 2022). While hot water is the most common solution for cleaning produce, other methods to consider are the use of vinegar and baking soda with water (Balkan & Yilmaz, 2022).

III. ***Reduction in Inhalational Residential Exposures***

In developed countries, people spend more than 90% of their time indoors in which indoor environments are substantial contributors to human environmental exposures and the population health (Zota, A.R., et. al., 2017). Products such as furniture, personal care, and household cleaning products contain chemicals that mitigate and are released into the home's air (Williams, M.K., et. al., 2006). To decrease inhalational residential exposures, it would require behavioral changes as far as using baking soda, vinegar, and warm water as a household cleaner (Williams, M.K., et. al., 2006). Furthermore, instead of using a broom and dustpan, use a mop to clean the floors as well as reduce the use of commercial products which withhold many detrimental toxins (Whyatt, R.M., et. al. 2002). In addition, individuals should consider wearing disposable masks and gloves while cleaning and following the manufacturing instructions of commercial products if one chooses not to discontinue using the product (Sapbamrer and Thammachi, 2020). Furthermore, property owners need to be held responsible for safety protocols that are detrimental to the tenants who live in their residence. In some studies, leasing companies were not following safety protocols like changing out ventilation systems, which led to their residence experiencing issues resulting in respiratory illnesses such as asthma (Morgan, W.J., et.). al., 2004).

IV. ***Reduction in Paraoccupational Exposures***

According to the Boston University School of Public Health, not having access to a worker locker or place to launder their work clothes can impact the levels of toxic metals that travel from the workplace to home (McKoy, J., 2022). Due to the lack of policies and training in the workplace to cease this contamination in high-exposure workplaces such as construction sites, it is inevitable that these toxicants will mitigate to the homes, families, and communities of exposed workers (Ceballos, D.M., et al., 2021). Primarily, it is important that the employers inform their employees of the effects of environmental exposures that they may be subjected to and provide guidance and safety protocols that will not only benefit the health of the employee on a short-term but a long-term basis for themselves and their families. This information can be provided through on-board training before the employees are sent out to work. A safety protocol for employers is to make sure that employees are protected from toxic exposures such as wearing protective gear (e.g., masks, eyeglasses, fully covered clothes, and shoes) to reduce their exposure to the toxins within the environment they work (Sapbamrer & Thammachi, 2020). Another safety protocol that should be considered would be to emphasize the importance of separating the workplace from the home by leaving work clothes at work versus wearing them at home. Accessibility to showers and lockers for employees to bathe, change clothes, and leave behind work clothes before going home are vital in reducing toxicant exposure to themselves and their families (Bradman, A., et. al., 2009). In addition, providing washer and drying machines for employees to be able to wash their work clothes at work versus taking them home to do so or potentially hiring employees to clean their clothes for them could be another solution (Bradman, A. et. al., 2009). However, there would need to be safety protocols and guidelines in place for those who are handling the clothes of the employees who are exposed to the toxins. For equipment or hazardous materials employees use for work, there would need to be a designated area at work where employees could place these items until they return to work the next day, so they do not have to take them home. When an employee arrives at home, the first thing they should do is wash their hands for 10-20 seconds to reduce the transfer of hazardous substances to their loved ones. Lastly, policy makers should develop policies that protect and advocate for employees and their families who have been exposed to toxicants with the possibility of an incentive if the employee were to die due to the high exposure to the toxicants they can in contact with.

V. ***Goals for the Infographic***

While creating the infographics, located below in Image 1 and 2, the goals were to make it instructive and easy to follow for people regardless of a person's educational background. To provide steps on how to decrease pesticide exposures for people that would not only be affordable, but useful. There was an emphasis on good visual appeal to the audience and to highlight inclusive language and images no matter who encounters the infographic. For pregnant people, it was important to convey in the infographic that various evidence indicated that there is a greater impact of prenatal exposure than early childhood or later exposure. While it is great for everyone to work diligently to minimize their exposure, it is most important that pregnant people are well informed and that not only do person try their best to reduce exposures to pesticides due to prenatal exposure to their fetus, but that their employers try to protect them as well as their fetus from being exposed.

Image 1: *Pesticide Exposure Prevention Infographic – English Language Version*

Image 2: *Pesticide Exposure Prevention Infographic – Thai Language Version*

There were some limitations while conducting the scoping review. The review focused only on prevention interventions within the last two decades. Many of the studies that were reviewed only took place in specific states and countries such as New York, California, China, the Philippines, and Thailand versus across all 50 states and various countries on across 6 –7 continents. The studies only focused on specific pesticides exposures and not all of them. This lack of variety in the information being used within the studies was a limitation for the scoping review. The search of the literature review did not produce remarkable results for pesticide exposure interventions approaches used in Africa and Europe. Lastly, another limitation relates to only searching and reviewing studies published in English. Publications in other languages should be able to evaluate similar studies around the globe that could have been utilizing preventative measures to reduce pesticide exposures in various populations, specifically vulnerable populations.

Chapter 4: Conclusion

Overall, taking simple preventative measures to reduce pesticide exposures is an effective approach in engaging communities on the health issues related to being exposed to pesticides at a high rate. While pesticide exposures are still a growing topic, there have been necessary steps put in place to protect the environment as well as humanity. However, there is much effort that needs to be made for the world that we live in to be a safe place for us to live. Those efforts require new policies to be developed, increase awareness of environmental toxicants, and encouraging behavioral change that will be efficient and beneficial for everyone, but that takes time and ample amounts of patience, but it can be done by further research on the topic at hand.

*I. **Public Health Implications***

While conducting this scoping review, it has been adequately demonstrated that exposure to pesticides during critical periods of development has led to short- and long-term neurological deficits for fetuses, children, and adults. However, a lack of research on preventative measures to reduce pesticide exposure and to reduce the health problems associated with it highlights the need for intervention materials. More research needs to be conducted in this area including implementation and evaluation through proactive monitoring. Furthermore, the preventative measures may not consider the culture, regular practices, and feasibility of these measures in developing countries. To better identify new, more effective, and implementable interventions to mitigate potential exposure to pesticides, research should be expanded to include additional countries to evaluate the most productive practices to add into their existing occupational and environmental protocols and strategies.

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