Systematic Review Protocol on

Multi-Pathway, Multi-Pesticide Exposure and Cumulative Risk Assessment in Ethiopia

# Objectives and Research Questions

Against the above-mentioned background, this study aims to map important sources of pesticide exposure focusing on Ethiopia and maintain curated data for further analysis.

The specific objectives are:

* To systematically search and include published pesticide residue measurements across multiple matrices (e.g., air, water, soil) and food in Ethiopia.
* To compile and synthesize nationally representative multi-pathway exposure dataset applying state-of-the-art, advanced statistical methods (e.g., multiple imputation, multilevel meta-analysis).
* To estimate population-wide health risks and health burden (in terms of DALYs) attributed pesticide exposure in Ethiopia.

***The study will be guided by the following research questions:***

* For the studied communities, what media in their immediate environment are contaminated with measurable levels of pesticides and considered primary exposure pathway?
* For the general population, what are immediate and long-term health risks and contribution to the total health burden?

# Methods

This study will employ established systematic review methodologies specifically tailored to systematic evidence mapping (SEM) in the field of environmental health. The Office of Health Assessment and Translation (OHAT) framework (OHAT, 2019) will be used as a primary guide, supplemented by the Navigation Guide framework where appropriate (Woodruff and Sutton, 2014). The OHAT framework consists of a seven-step process, of which the first three are relevant to the development of this protocol: (1) Problem Formulation, (2) Search and Selection of Studies for Inclusion, and (3) Data Extraction. PRISMA framework will be used for reporting.

## Scoping and problem formulation

Given the diverse sources of pesticides and their varying properties, accurately characterizing human exposure remains challenging. However, understanding pesticide levels in multiple media and identifying potential exposure pathways is essential for establishing clear links between exposure and adverse health outcomes (El Afandi and Irfan, 2024; Ahmad *et al.*, 2024; U.S.EPA, 2022b). Comprehensive exposure assessments should consider all possible sources and pathways of exposure, along with major predictors, but such comprehensive approaches are rarely employed in existing literature.

Unlike occupational pesticide exposure, where the magnitude, frequency, and duration of exposures are more easily quantified and controlled, assessing exposure in the general population is more challenging (Gangemi *et al.*, 2016; U.S.EPA, 2023). General population exposures are influenced by a variety of factors, contributing to greater uncertainty. For example, pesticides in environmental media (i.e., air, soil, water) can enter the human body through several pathways, with exposure routes being governed by personal habits, environmental conditions, and other factors (Kalyabina *et al.*, 2021; Tudi *et al.*, 2022). Although non-occupational exposure pathways are often considered negligible, they may be more significant than previously thought, as the general population is constantly exposed to pesticides through various indirect pathways (Holder *et al.*, 2023). However, studies addressing these pathways are limited in scope, typically focusing on specific pesticides (e.g., neonicotinoids), populations (e.g., farming families), sample types (e.g., house dust), and developed nations.

Given these gaps, it is essential to explore and synthesize how pesticide exposure among the general population has been studied thus far. Information regarding the primary sources, routes of exposure, temporal variability, and relevant predictors will help improve study designs, sampling strategies, and the interpretation of health implications. Such information will also guide the development of recommendations to limit exposure where necessary. Unfortunately, there is significant geographical bias in pesticide study landscape, where majority of the evidence is extrapolated from Global North. Pesticide research in Global South, including Ethiopia, remains fragmented and sparse, despite the fact that these part of the globe hosts most exposed and vulnerable populations (~85% of world’s population live here).

## Literature Search Strategy

A systematic search will be conducted to identify research on pesticide occurrence in various environmental media to create a comprehensive database of pesticide occurrence in Ethiopia.

Briefly, in order to identify studies reporting pesticide levels in environmental various matrices (e.g., air, water, soil) and foods in Ethiopia, 13 international and local databases, including gray literature sources, were searched on xx/xx (see Table S1; last updated on xx/xx). Our search strategy used combinations of terms related to pesticides (e.g., agrochemical, insecticide, fungicide, herbicide) and occurrence (e.g., pollution, exposure, monitoring, residue, contamination, air, soil, water) with geographic limitation to Ethiopia. Before undertaking the initial search, we evaluated and validated our strategy against a pre-defined benchmark set of 35 studies collected from multiple sources using Scopus database (Lagisz *et al.*, 2025). A list of benchmark studies used for search strategy validation was provided in Table S2. Our preliminary search retrieved all of the benchmark studies (100%), indicating the sensitivity and comprehensiveness of our terms. Then the validated search terms were tailored to each database based on its indexing system, controlled vocabulary, and search functionalities.

Database-specific modifications were applied where necessary to optimize search results. To ensure completeness, we manually searched the reference lists of relevant studies and review articles.

We identified a total of 1,539 studies across databases and repositories, including additional 50 studies identified through reference scanning of relevant studies and Google search. These records were then imported into EndNote, merged and exported as RefMan (RIS) file. Initially, 250 duplicates were removed using the *synthesisr* R package (Westgate and Grames, 2020) and then the remaining 1248 records were imported to Rayyan (<https://rayyan.ai/>), where additional 20 duplicates were removed.

Table S1: Lists of database and repositories, search strategies used, and retrieved studies.

|  |  |  |
| --- | --- | --- |
| **Database** | **Search strategy** | **Hits** |
| Web of Science | ((TS=(pesticide OR agrochemical OR insecticide OR fungicide OR herbicide)) AND TS=(pollution OR exposure OR monitoring OR residue OR contamination OR air OR soil OR water OR food)) AND TS=(Ethiopia) | 426 |
| Scopus | ( TITLE-ABS-KEY ( pesticide OR agrochemical OR insecticide OR fungicide OR herbicide OR organochlorine OR ocp OR ddt ) AND TITLE-ABS-KEY ( pollution OR exposure OR monitoring OR concentration OR level OR residue OR contamination OR air OR soil OR water OR food ) AND TITLE-ABS-KEY ( ethiopia ) AND NOT TITLE-ABS-KEY ( mosquito\*) ) | 478 |
| PubMed | (((pesticide[MeSH Terms] OR agrochemical[MeSH Terms] OR insecticide[Title/Abstract] OR fungicide[Title/Abstract] OR herbicide[Title/Abstract] OR organochlorine[Title/Abstract] OR ocp[Title/Abstract] OR ddt[Title/Abstract]) AND (pollution[Title/Abstract] OR exposure[Title/Abstract] OR monitoring[Title/Abstract] OR concentration[Title/Abstract] OR level[Title/Abstract] OR residue[Title/Abstract] OR contamination[Title/Abstract] OR air[Title/Abstract] OR soil[Title/Abstract] OR water[Title/Abstract] OR food[Title/Abstract])) AND (Ethiopia[Title/Abstract])) NOT (mosquito[MeSH Terms]) AND (2000:2025[pdat]) | 231 |
| OpenAlex | (pesticide OR agrochemical OR insecticide OR fungicide OR herbicide) (pollution OR exposure OR monitoring OR concentration OR level OR residue OR contamination OR air OR soil OR water OR food) Ethiopia | 990 |
| Google Scholar | allintitle: (pesticide OR agrochemical OR insecticide OR fungicide OR herbicide) (pollution OR exposure OR monitoring OR residue OR contamination OR air OR soil OR water OR food) Ethiopia | 63 |
| Semantic scholar | (pesticide) (air, water, soil, food pollution OR contamination) "Ethiopia" | 90 |
| OAIster | (pesticide OR agrochemical OR insecticide OR fungicide OR herbicide) AND (pollution OR exposure OR monitoring OR concentration OR level OR residue OR contamination OR air OR soil OR water OR food) AND Ethiopia | 116 |
| Local repositories | Addis Ababa University, Haramaya University, Jimma University, Bahir Dar University, Hawassa University, The University of Gondor (Pesticide) |  |

## Eligibility Criteria

***Studies were included if they met the following criteria:***

* **Study population and setting**: Conducted in Ethiopia and reported pesticide levels in environmental media relevant to population exposure.
* **Exposure assessment**: Provided quantitative or semi-quantitative data on pesticide concentrations in air, soil, water, or food.
* **Study design**: Cross-sectional studies, environmental monitoring studies, and surveillance reports with original pesticide occurrence data.
* **Publication type**: Peer-reviewed journal articles, theses, dissertations, conference proceedings, and governmental or institutional reports.
* **Language**: Published in English or Amharic (with translation where applicable).

***Studies were excluded if they:***

* Focused solely on occupational pesticide exposure without relevance to general population exposure.
* Lacked quantitative pesticide concentration data.
* Were opinion pieces, editorials, or review articles without original data.

## Study screening and Inclusion

Two-staged screening was conducted. First, the title/abstract of each record was assessed for relevance using Rayyan. At this stage, a total of 134 records were retained after exclusion of 1114 non-relevant records including commentaries and editorials (), reviews (), different country (), and unrelated focus (). We then retrieved the full-texts of all relevant studies and further assessed if original residue data in any Ethiopian matrix is presented, non-duplicate (the measurement across multiple studies), published in English or any local languages the authors understand (the detailed eligibility criteria is presented in attached protocol). At this stage, 74 studies were removed including . Finally, the remaining 60 studies were tagged according to their respective matrix type (e.g., air, water, food) and archived (at: xx).

The PECO criteria presented in Table 1 will be used to focus the scope of present study; to address the defined research question, search terms, and inclusion/exclusion criteria.

At both stages, studies that cannot be definitively included or excluded based on the available information will be tagged as “Maybe” for further evaluation (see main text). Studies lacking extractable data or sufficient reporting will be excluded during full-text screening.

Language restriction will not be used in the selection process as criteria. Inclusion of studies published in other language than English will decided after reading their respective English abstract translation and all the eligibility criteria will be applied accordingly if the study deemed relevant after translation of full-text using online tools.

Table 1: The population, exposure, comparator, and outcome (PECO) criteria

|  |  |
| --- | --- |
| **PECO Element** | **Description** |
| Population | Adults and/or children in the general population |
| Exposure | Real-world occurrence of pesticides in the following environmental media: outdoor air, indoor air, (indoor) dust, drinking water, food (breast milk is included as a food), food packaging, products (articles and consumer products), and soil |
| Comparator | Not applicable |
| Outcomes | Not applicable |

## Data Extraction

Both databases will be organized, synthesized, and presented interactively by extracting key data. The final version will be publicly released. Evidence will be mapped for the most studied pesticides, exposure sources and pathways, health outcomes, and their spatiotemporal distribution. Identified gaps will also be highlighted.

Two types of data – bibliographic and statistical – will be extracted from the included studies using standardized Excel spreadsheets. The detailed data extraction codebook is provided in SI Table S2. A summary of the study, including its objectives, sample details, main results, and conclusions, will be generated using SciSpace (<https://typeset.io/>). Each dataset will be independently extracted and cross-checked by EMA and BS. Final reviews for completeness, consistency, and robustness will be conducted by senior authors SN and LM.

*Bibliographic Data Extraction:*

* Study information (e.g., title, DOI, journal).
* Population/location information (e.g., study area, country, exposure group).
* Sample information (e.g., sampled matrix, sample collection year, sample extraction method, instrument used).

*Statistical Data Extraction:*

* Pesticide information (e.g., pesticide name, CAS number, class, detection frequency).
* Statistical information (e.g., type of statistic such as geometric or arithmetic mean, sample size).
* Predictors (e.g., risk factors reported, associated statistics).

For the purpose of present study, we included 40 studies specifically focusing on pesticides in food and provided quantitative residue data (e.g., mean, median, standard deviation). From these studies, we extracted study characteristics (first author, title, DOI, publication year), sample characteristics (food source type, analytical instrument, sample size, sample year), and pesticide data (name, summary statistics) (See SI Table S3). All analyzed pesticides, regardless of detection status, were extracted from included studies along with analytical instrument used and respective limits of detection and quantification (LOD/LOQ) (Table S4). Raw pesticide residue concentrations were prioritized (i.e., unique sample/location measurements), and if unavailable, summary statistics (e.g., mean and standard deviation) were extracted. Data from figures were extracted using PlotDigitizer.

Study identification, screening and inclusion as well as data extraction were primarily performed by one author (EMA) and independently verified by the remaining authors, with disagreements resolved through discussion. The overall process was summarized using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram as shown in SI Figure 1.

## Dataset Coding

Pesticides analyzed in each study will be extracted and coded as “Detected” if quantified in biological samples and “Not Detected” if below the detection limit of the instrument used. Each pesticide will then be broadly categorized as “Legacy” for banned highly toxic pesticides and “Current-Use” for new-generation pesticides that are widely used and approved in many countries. The list of identified pesticides will be supplemented with additional information, including the CAS number, chemical class, use type, and physicochemical properties (e.g., half-life, solubility) obtained from the Pesticide Properties Database (PPDB, 2023). Exposed individuals sampled, referred to as the exposure group, will be classified as “Occupational” if the primary exposure is directly related to pesticide application (e.g., agricultural workers or pesticide applicators in any setting) or “Non-Occupational” if the primary exposure is indirect (e.g., dietary intake, proximity to agricultural areas, or exposure within the home). Ambiguous exposure groups will be coded as missing and excluded from meta-analysis.

Potential Moderator Variables

* *Study Characteristics [Categorical and Continuous]:*
  + Coded based on study design (cross-sectional, cohort, experimental) and study year (continuous).
* *Sample Characteristics [Categorical]:*
  + Pesticide type (insecticide, fungicide, herbicide).
  + Biomatrix (whole blood, cord blood, serum, urine, hair).
  + Analytical method (“GC-based” or “LC-based,” depending on the primary instrument used; if both are used, coded as “Multiple”).
  + Sample adjustment (“Adjusted” if pesticide concentrations were corrected for lipid content or creatinine levels; otherwise coded as “Not Adjusted”).
* *Population Characteristics [Categorical]:*
  + Age groups: Children (2–11 years), Adolescents (12–19 years), Adults (≥20 years), Pregnant Women, and Infants (<2 years).
  + Gender: Male/Female/Mixed.
* *Country Characteristics [Categorical and Continuous]:*
  + Agricultural land area, GDP, socioeconomic status, and region.

# Data Synthesis

The extracted datasets will be qualitatively summarized and visualized using scoping reviews (evidence maps) and bibliometrics according to a meta-analysis enrichment framework as suggested by Yang et al. (2023). This approach will summarize and map datasets based on study characteristics, population attributes, sampling characteristics, analyzed pesticides, and the spatiotemporal coverage of data. It will also provide a user-friendly overview of the datasets and enhance the subsequent meta-analysis, identifying the potential moderators and the effective model structure. Importantly, the framework will help interpret results in context, identify key themes, uncover knowledge gaps, and suggest areas for future research (Yang et al., 2023).

The primary objective of our study is to estimate pesticide exposure levels in Africa using published biological sample data. The secondary objective is to identify potential moderators that influence these exposure levels. Our dataset will follow a hierarchical structure, where individual pesticide measurements are nested within pesticide classes in a given study and/or country. This structure introduces dependencies in effect sizes because a single study, using shared measurement methodologies (e.g., population characteristics, biomatrices, analytical methods), can contribute multiple effect sizes. Additionally, dependencies may arise from broader spatiotemporal correlations in effect sizes, such as shared geographical locations or sampling periods. Unlike conventional random-effects meta-analysis, multilevel meta-analysis is designed to accommodate such hierarchical data structures, effectively addressing dependencies within and across studies (Nakagawa et al., 2023).

We will perform a three-level random-effects meta-analysis using the *rma.mv* function in the *metafor* package (R) to calculate mean country-level pesticide exposure levels separately for occupational and non-occupational exposure groups along quantifying heterogeneity for both within-study and between-study levels (and the total variance; obtaining within-study, between-study and total *I*2 values). To enhance model fit, account for systematic differences, and reduce unexplained variance, moderators will be included, such as: study characteristics (study design, publication year, and geographical region), sample characteristics (pesticide type, sampled biomatrix, and analytical instrument used), population characteristics (age and gender), where available; for each or combinations of modrators, we quantify the variance (heterogeneity) accounted for (i.e. *R*2). Publication bias will be evaluated by visually inspecting funnel plot asymmetry. A multi-level version of Egger’s regression test will statistically assess asymmetry, while the trim-and-fill method will estimate and adjust for missing studies. Sensitivity analysis will further assess the robustness of findings by sequentially excluding individual publications through leave-one-out analysis.

# References

# Appendices

## Appendix A: List of benchmarking studies (n=35)

|  |  |  |
| --- | --- | --- |
| **No.** | **Title** | **DOI** |
| 1 | Biomagnification of DDT and its metabolites in four fish species of a tropical lake | 10.1016/j.ecoenv.2013.03.020 |
| 2 | Biological and chemical monitoring of the ecological risks of pesticides in Lake Ziway, Ethiopia | 10.1016/j.chemosphere.2020.129214 |
| 3 | DDT and Its Metabolites in Ethiopian Aquatic Ecosystems: Environmental and Health Implications | 10.1177/11786302241307471 |
| 4 | Pesticide concentration in three selected fish species and human health risk in the Lake Tana sub-basin, Ethiopia | 10.1007/s10661-023-11594-y |
| 5 | Pesticide residue levels in vegetables and surface waters at the Central Rift Valley (CRV) of Ethiopia | 10.1007/s10661-020-08452-6 |
| 6 | Apparent Khat chewers exposure to DDT in Ethiopia and its potential toxic effects: A scoping review | 10.1016/j.yrtph.2023.105555 |
| 7 | Organochlorine pesticides in Ethiopian waters: Implications for environmental and human health | 10.1016/j.toxrep.2024.06.001 |
| 8 | Qualitative assessment of 27 current-use pesticides in air at 20 sampling sites across Africa | 10.1016/j.chemosphere.2020.127333 |
| 9 | Levels of organochlorine pesticides in five species of fish from Lake Ziway, Ethiopia | 10.1016/j.sciaf.2022.e01252 |
| 10 | Pesticide Contamination of Surface and Groundwater in an Ethiopian Highlands’ Watershed | 10.3390/w14213446 |
| 11 | Exposure to DDT and its metabolites from khat (Catha edulis) chewing: Consumers risk assessment from southwestern Ethiopia | 10.1016/j.yrtph.2017.05.008 |
| 12 | Ecological risk assessment of organochlorine pesticides and polychlorinated biphenyls in water and surface sediment samples from Akaki River catchment, central Ethiopia | 10.1016/j.emcon.2020.11.004 |
| 13 | Concentrations and human health risk assessment of organochlorine pesticides in edible fish species from a Rift Valley lake-Lake Ziway, Ethiopia | 10.1016/j.chemosphere.2016.07.096 |
| 14 | Monitoring and risk assessment of pesticides in irrigation systems in Debra Zeit, Ethiopia. | 10.1016/j.chemosphere.2016.07.031 |
| 15 | Residue analysis of selected organophosphorus and organochlorine pesticides in commercial tomato fruits by gas chromatography mass spectrometry | 10.1016/j.heliyon.2023.e14121 |
| 16 | Assessment of pesticide residues in vegetables produced in central and eastern Ethiopia | 10.3389/fsufs.2023.1143753 |
| 17 | Analysis of organochlorine pesticide residues in human and cow's milk in the towns of Asendabo, Serbo and Jimma in South-Western Ethiopia | 10.1016/j.chemosphere.2012.09.008 |
| 18 | Organochlorine pesticides, polybrominated diphenyl ethers and polychlorinated biphenyls in surficial sediments of the Awash River Basin Ethiopia | 10.1371/journal.pone.0205026 |
| 19 | Persistent organochlorine pesticides residues in cow and goat milks collected from different regions of Ethiopia | 10.1016/j.chemosphere.2014.02.012 |
| 20 | Investigating the Spatial Trends in the Level of Organic Contaminants in the Ethiopian Rift Valley Lakes Using Semipermeable Membrane Devices | 10.1007/s00128-018-2358-9 |
| 21 | Levels and Trophic Transfer of Selected Pesticides in the Lake Ziway Ecosystem | 10.1007/s00128-022-03497-4 |
| 22 | Organochlorine pesticide residues in tea and their potential risks to consumers in Ethiopia | 10.1016/j.heliyon.2021.e07667 |
| 23 | Environmental and Human Health Risks of Pesticide Presence in the Lake Tana Basin (Ethiopia) | 10.3390/su142114008 |
| 24 | Concentrations and human health risk assessment of organochlorine pesticides in edible fish species from a Rift Valley lake-Lake Ziway, Ethiopia | 10.1016/j.ecoenv.2014.04.014 |
| 25 | Organochlorine pesticides and polychlorinated biphenyls in carnivorous waterbird and fish species from Lake Hawassa, Ethiopia | 10.1007/s42452-022-05177-8 |
| 26 | Exposure to DDT and HCH congeners and associated potential health risks through khat (Catha edulis) consumption among adults in South Wollo, Ethiopia | 10.1007/s10653-021-00846-w |
| 27 | Temporal Trends of Persistent Organic Pollutants across Africa after a Decade of MONET Passive Air Sampling | 10.1021/acs.est.0c03575 |
| 28 | Risk of DDT residue in maize consumed by infants as complementary diet in southwest Ethiopia | 10.1016/j.scitotenv.2014.12.087 |
| 29 | Pesticide Residues and Associated Public Health Risks in Vegetables from Irrigated Farms Adjacent to Rift Valley Lake Ziway, Ethiopia | 10.1155/2024/5516159 |
| 30 | Bioaccumulation of persistent organic pollutants (POPs) in fish species from Lake Koka, Ethiopia: The influence of lipid content and trophic position | 10.1016/j.scitotenv.2011.09.008 |
| 31 | Assessment of organochlorine pesticide pollution in Upper Awash Ethiopian state farm soils using selective pressurised liquid extraction | 10.1016/j.chemosphere.2008.03.041 |
| 32 | Organochlorine pesticides in bird species and their prey (fish) from the Ethiopian Rift Valley region, Ethiopia | 10.1016/j.envpol.2014.05.007 |
| 33 | Occurrence, distribution, and ecological risk assessment of DDTs and heavy metals in surface sediments from Lake Awassa-Ethiopian Rift Valley Lake | 10.1007/s11356-013-1821-8 |
| 34 | Organochlorine, organophosphorus, and carbamate pesticide residues in an Ethiopian Rift Valley Lake Hawassa: occurrences and possible ecological risks | 10.1007/s11356-024-32848-3 |
| 35 | Levels of organochlorine pesticides in onion and tomato samples from selected towns of Jimma Zone, Ethiopia | 10.1016/j.heliyon.2024.e35033 |

*Search string validated for Scopus (sensitivity = 100%)*

( ( TITLE-ABS-KEY ( pesticide OR agrochemical OR insecticide OR fungicide OR herbicide OR organochlorine OR ocp OR ddt ) AND TITLE-ABS-KEY ( pollution OR exposure OR monitoring OR concentration OR level OR residue OR contamination OR air OR soil OR water OR food ) AND TITLE-ABS-KEY ( ethiopia ) AND NOT TITLE-ABS-KEY ( mosquito\* ) ) ) AND ( ( DOI ( "10.3389/fsufs.2023.1143753" ) OR DOI ( "10.1371/journal.pone.0205026" ) OR DOI ( "10.1016/j.scitotenv.2011.09.008" ) OR DOI ( "10.1016/j.ecoenv.2013.03.020" ) OR DOI ( "10.1007/s00128-018-2358-9" ) OR DOI ( "10.1016/j.chemosphere.2020.127333" ) OR DOI ( "10.1007/s10653-021-00846-w" ) OR DOI ( "10.1016/j.chemosphere.2012.09.008" ) OR DOI ( "10.1016/j.heliyon.2024.e35033" ) OR DOI ( "10.1016/j.emcon.2020.11.004" ) OR DOI ( "10.1007/s10661-020-08452-6" ) OR DOI ( "10.1016/j.scitotenv.2014.12.087" ) OR DOI ( "10.1016/j.chemosphere.2016.07.096" ) OR DOI ( "10.1016/j.yrtph.2017.05.008" ) OR DOI ( "10.1177/11786302241307471" ) OR DOI ( "10.1016/j.chemosphere.2020.129214" ) OR DOI ( "10.1007/s00128-022-03497-4" ) OR DOI ( "10.1016/j.heliyon.2021.e07667" ) OR DOI ( "10.3390/w14213446" ) OR DOI ( "10.1016/j.chemosphere.2016.07.031" ) OR DOI ( "10.1016/j.chemosphere.2008.03.041" ) OR DOI ( "10.1021/acs.est.0c03575" ) OR DOI ( "10.1016/j.heliyon.2023.e14121" ) OR DOI ( "10.1007/s11356-013-1821-8" ) OR DOI ( "10.1016/j.ecoenv.2014.04.014" ) OR DOI ( "10.1016/j.envpol.2014.05.007" ) OR DOI ( "10.1016/j.yrtph.2023.105555" ) OR DOI ( "10.1007/s10661-023-11594-y" ) OR DOI ( "10.3390/su142114008" ) OR DOI ( "10.1016/j.toxrep.2024.06.001" ) OR DOI ( "10.1016/j.sciaf.2022.e01252" ) OR DOI ( "10.1007/s42452-022-05177-8" ) OR DOI ( "10.1007/s11356-024-32848-3" ) OR DOI ( "10.1155/2024/5516159" ) OR DOI ( "10.1016/j.chemosphere.2014.02.012" ) ) )

## Appendix 2: Screening Decision Tree

***Stage 1: Title/Abstract Screening***

1. Is the study population located in Africa?
   * No → EXCLUDE.
   * Yes/Maybe → Continue.
2. Does the study assess pesticide exposure in human populations?
   * No → EXCLUDE.
   * Yes/Maybe → Continue.
3. Does the study report either primary outcomes (e.g., pesticide concentrations in biomatrices) or secondary outcomes (e.g., determinants of pesticide exposure)?
   * No → EXCLUDE.
   * Yes → Continue.
4. Is the study a primary research article (e.g., cross-sectional, cohort, longitudinal biomonitoring study, pilot study, or short communication)?
   * No *(e.g., review articles, methodology studies, editorials, conference abstracts, etc.)* → EXCLUDE.
   * Yes/Maybe → Continue.
5. Is the study type relevant to pesticide biomonitoring (e.g., excludes external exposure modeling studies or effect biomarker studies)?
   * No → EXCLUDE.
   * Yes/Maybe → Continue.

***Stage 2: Full-Text Screening***

1. Is the full text available?
   * No → EXCLUDE.
   * Yes → Continue.
2. Is the study population clearly defined as African populations (occupationally or non-occupationally exposed)?
   * No → EXCLUDE.
   * Yes → Continue.
3. Does the study use biological samples (e.g., serum, urine, hair) to measure pesticide concentrations?
   * No → EXCLUDE.
   * Yes → Continue.
4. Does the study use a reliable exposure measurement methodology (e.g., valid enrollment process, exposure definition, quality assurance/quality control)?
   * No → EXCLUDE.
   * Yes → Continue.
5. Does the study report pesticide-specific data (e.g., individual pesticide/metabolite, chemical class, or use type)?
   * No *(e.g., studies on pesticide mixtures without specific data)* → EXCLUDE.
   * Yes → Continue.
6. Does the study report sufficient and extractable data for pesticide exposure or its determinants?
   * No → EXCLUDE.
   * Yes → Continue.
7. If the study uses repeated cohort data (e.g., longitudinal studies), is it eligible for inclusion (e.g., latest or largest dataset preferred)?
   * No → EXCLUDE.
   * Yes → INCLUDE [Tag for discussion and possible exclusion].

## Appendix 3: Data Abstraction

Table S2: Data extraction codebook.

|  |  |  |  |
| --- | --- | --- | --- |
| **Domain (Extractor)** | **Data Category** | **Data Prompts** | **Notes** |
| Bibliographic data (BS) | Study information | Title |  |
| Doi |
| Journal |
| Publication Year |
| Study\_id |
| Overall summary | Objectives | Powered by Sci-Space (<https://typeset.io/>) |
| Sample details |
| Main results |
| Conclusions |
| Population/ Location Information | City |  |
| State |
| Country |
| Study population | Brief description of the study population |
| Exposure type | General population or exposed? Provide detailed info as much as possible |
| Number of participants |  |
| Sample Information | Sampled Matrix | Human blood (whole blood serum plasma cord blood), Human urine, breast milk |
| Sample collection | Summarize sample collection method and procedures |
| Sample Extraction | Summarize sample extraction and analysis method and procedures |
| Analytical Instrument used |  |
| Data start year | Period of sample collection |
| Data end year |  |
| Overall Notes | Overall Notes |  |
| Statistical data (EMA) | Pesticide Information | Analysed Pesticides | List all analysed pesticides in the study |
| Individual pesticide/metabolite name | p,p-DDT, endosulfan |
| CAS No |  |
| Pesticide class | Organochlorine, Organophosphate, Carbamates, |
| Pesticide type | Insecticide, fungicide, herbicide |
| Detection frequency |  |
| LOD |
| LOQ |
| Units of LOD and LOQ |
| Notes on DF, LOD, LOQ |
| Statistics (stat) Information | stat type | Is stat reported as an overall or according to subgroups? |
| Stat type | Arithmetic Mean, Geometric Mean, Median, Min, Max, Percentile, Variance, Std. Deviation, Standard Error, GSD, Point |
| Stat est | Creatinine-Lipid-adjusted or not adjusted |
| Stat units | Whether it was reported by the authors or calculated by the extractor |
| Sample n | Number (n) of samples included in the occurrence statistic |
| Stat notes | Text field to provide any useful information on the occurrence stat |
| Predictors | Risk factor reported? | Any risk factor associated with pesticide exposure level (Yes/No) |
| Factor class | Dietary/non-dietary determinants |
| Factor sub-class | Age, gender, BMI, residence, education level and employment status, lifestyle habits |
| Statistics | Spearman ρ correlation coefficient (r), beta regression coefficient |
| Overall Notes | Overall Notes |  |