Supplementary File S1. PRISMA-ScR Checklist

Section	Item	PRISMA-ScR checklist item	Description of compliance	Reported on Page#	Notes
TITLE	1	Identify the report as a scoping review	Yes	1	Indicated in the title
ABSTRACT	2	Provide a structured summary including background, objectives, methods,	Yes	1	Structured abstract included
INTRODUCTION	3	Describe the rationale for the review	Yes	2–4	Scientific and environmental justification provided
INTRODUCTION	4	State the objectives and/or questions of the review	Yes	4	Explicit objective of scoping review stated
METHODS	5	Indicate whether a protocol exists and registration information	No	N/A	No registered protocol (not applicable)
METHODS	6	Specify eligibility criteria	Yes	5–6	Inclusion and exclusion criteria described
METHODS	7	Describe all information sources used	Yes	6	PubMed, Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley, Google Scholar
METHODS	8	Present the full search strategy	Yes	6	Search terms and combinations specified
METHODS	9	State the process for selecting sources of evidence	Yes	6	Duplicate removal, title/abstract screening, full-text assessment
METHODS	10	Describe the data charting process	Yes	7	Manual extraction and structured organization described
METHODS	11	List and define all variables for which data were sought	Yes	7	Phase, size, dose, exposure route, biological model, effects

METHODS	12	Describe any critical appraisal conducted	No (Scoping design)	5, 7	Formal risk-of-bias not conducted; explicitly stated
METHODS	13	Describe methods of synthesis of results	Yes	7	Narrative qualitative synthesis described
RESULTS	14	Give numbers of sources screened, assessed, and included	Yes	6	223 retrieved; 153 screened; 86 included; PRISMA Figure S1
RESULTS	15	Describe characteristics of included sources	Yes	8–20	Presented in Tables 1–6 and Results section
RESULTS	16	Present data on critical appraisal within sources	No (Scoping design)	5	Not applicable; clarified
RESULTS	17	Present results of individual sources	Yes	8–20	Organized by oxide phase and biological model
RESULTS	18	Summarize and synthesize results	Yes	18–21	Comparative narrative synthesis provided
DISCUSSION	19	Summarize main findings	Yes	21–23	Key trends and mechanistic pathways discussed
DISCUSSION	20	Discuss limitations of the review process	Yes	21	Methodological heterogeneity addressed
CONCLUSIONS	21	Provide conclusions and implications	Yes	23	Research gaps and environmental implications stated
FUNDING	22	Describe funding sources	Yes	24	Funding statement included

Supplementary File S2. Detailed Database-Specific Search Strategies

Search Strategy Overview

The literature search was conducted in the following databases:

I. PubMed/MEDLINE

II. Scopus

III. Web of Science Core Collection

IV. ScienceDirect

V. SpringerLink

VI. Wiley Online Library

Google Scholar was used as a complementary source to identify additional relevant records not indexed in the primary databases. The final search was conducted on **January 15, 2026**. The search strategy combined free-text keywords related to iron oxide phases and toxicological outcomes. Controlled vocabulary (e.g., MeSH terms) and database-specific syntax were applied where appropriate.

Core Search Logic (Applied Across Databases)

The structured search logic was based on the following conceptual blocks:

Block 1 – Iron Oxide Phases

("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite OR Fe3O4 OR Fe2O3 OR "iron oxide particles")

Block 2 – Toxicological / Biological Effects

(toxicity OR toxicological OR "oxidative stress" OR genotoxicity OR inflammation OR "mitochondrial dysfunction" OR cytotoxicity OR "biological effects")

Block 3 – Biological Models / Exposure Context

("in vivo" OR "in vitro" OR "ex vivo" OR "animal model" OR exposure OR inhalation OR instillation)

The final structured query combined these blocks using Boolean operators:

(Block 1) AND (Block 2) AND (Block 3)

Database-Specific Adaptations

1. PubMed/MEDLINE

Search conducted using Title/Abstract fields and MeSH terms where applicable.

Example structure:

((("iron oxide nanoparticles"[Title/Abstract] OR magnetite[Title/Abstract] OR hematite[Title/Abstract] OR maghemite[Title/Abstract])
AND
(toxicity[Title/Abstract] OR "oxidative stress"[Title/Abstract] OR genotoxicity[Title/Abstract] OR inflammation[Title/Abstract])
AND
("in vivo"[Title/Abstract] OR "in vitro"[Title/Abstract] OR inhalation[Title/Abstract]))

Filters applied:

I. Language: English

II. Article type: Experimental research

2. Scopus

Search conducted using TITLE-ABS-KEY fields.

Example structure:

TITLE-ABS-KEY ("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite OR Fe3O4 OR Fe2O3)
AND
TITLE-ABS-KEY (toxicity OR "oxidative stress" OR genotoxicity OR inflammation OR "mitochondrial dysfunction")
AND
TITLE-ABS-KEY ("in vivo" OR "in vitro" OR exposure OR inhalation)

Filters applied:

I. Language: English

II. Document type: Article

3. Web of Science Core Collection

Search conducted using Topic (TS) field.

Example structure:

TS=("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite OR Fe3O4 OR Fe2O3)
AND
TS=(toxicity OR "oxidative stress" OR genotoxicity OR inflammation OR "mitochondrial dysfunction")
AND
TS=("in vivo" OR "in vitro" OR exposure OR inhalation)

Filters applied:

I. Language: English

II. Document type: Article

4. ScienceDirect

Search performed using keyword combinations in title, abstract, and keywords fields.

Example structure:

("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite)
AND
(toxicity OR "oxidative stress" OR genotoxicity OR inflammation)

AND
("in vivo" OR "in vitro" OR exposure)

Filters applied:

I. Research articles

II. English language

5. SpringerLink

Search conducted using advanced search with keyword combinations.

Example structure:

("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite)
AND
(toxicity OR "oxidative stress" OR genotoxicity OR inflammation)
AND
("in vivo" OR "in vitro")

Filters applied:

I. Article

II. English

6. Wiley Online Library

Search conducted using keyword combinations in title, abstract, and keywords.

Example structure:

("iron oxide nanoparticles" OR magnetite OR hematite OR maghemite)
AND
(toxicity OR "oxidative stress" OR genotoxicity OR inflammation)
AND
("in vivo" OR "in vitro")

Filters applied:

I. Research articles

II. English language

Additional Search Procedures

I. Duplicate records were removed prior to screening.

II. Title and abstract screening was conducted according to predefined eligibility criteria.

III. Reference lists of included studies were manually screened to identify additional relevant publications when appropriate.

Supplementary File S3. Data Extraction Template and Variable Definitions

Variable	Description	Units / Categories	Data Entry Rules
Study ID	First author and year	Text	As reported in publication
Iron Oxide Phase	Crystalline phase studied	Magnetite (Fe_3O_4); Hematite (α-Fe_2O_3); Maghemite (γ-Fe_2O_3); Mixed; Not specified	Recorded as explicitly reported by authors
Particle Size (Numeric)	Reported particle size or size range	nm or µm	Exact value or range as reported
Size Metric Basis	Measurement technique used for size determination	Aerodynamic diameter; TEM/SEM primary size; DLS hydrodynamic size; Not specified	Recorded according to method described in study
PM Classification	Assigned size fraction	PM_{10}; $PM_{2.5}$; $PM_{1.0}$; Nanoscale (<100 nm)	Categorized according to predefined size thresholds described in Methods
Dose / Concentration	Exposure concentration or administered dose	mg/kg; µg/mL; mg/m³; other (as reported)	Recorded as reported; no unit conversion unless explicitly comparable
Exposure Route	Route of administration	Inhalation; Intratracheal; Intranasal; Oral; Intravenous; Intraperitoneal; Dermal; Aquatic; Other	Categorized based on study description

Exposure Duration	Duration of exposure	Hours; Days; Weeks; Chronic	Recorded exactly as reported
Biological Model	Species, strain, or cell type	Text	As specified by authors
Study Type	Experimental design	In vivo; In vitro; Ex vivo	Categorized based on study methodology
Main Biological Outcomes	Reported biological effects	Oxidative stress; Inflammation; Genotoxicity; Mitochondrial dysfunction; Neurotoxicity; Developmental effects; Other	Recorded descriptively as reported
Key Mechanistic Findings	Mechanistic interpretation	Text	Narrative summary from study results
Co-exposure / Particle Modification	Surface coating or combined exposure	Coated; Uncoated; Mixed pollutants; Not specified	As reported