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Global dataset of pesticide pollution and environmental quality standards for risk assessment (2010–2020)

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Abstract

Pesticides are widely used in agriculture, and their residues are frequently detected across the environmental medium, becoming a pressing global problem that affects the ecosystem and public health. Here, we present a comprehensive dataset covering pesticide residues and regulatory standards in three major environmental media (air, soil, and water), compiled from nearly 700 publications and official databases reporting data between 2010 and 2020. Analysis shows that pesticide data are mainly concentrated in China, Europe, and the United States, and current environmental quality standards can cover the current monitored pesticide species. This unified resource can support future multimedia exposure modeling, regulatory threshold comparison, and geographic prioritization of pesticide risk.

Background and Summary

Pesticides are described as a series of chemicals used in agriculture to protect from pests and improve crop productivity, including insecticides, herbicides, and fungicides[1,2]. While pesticides protect crops, they can also enter environmental compartments (e.g., air, water, and soil)[3–5] and cause harmful effects on non-target organisms[6–8]. These compartments serve as primary exposure pathways for both humans and ecosystems[9]. Numerous studies have reported that environmental pesticide residues can inhibit or directly kill organisms like bees[10,11], earthworms[12,13], and fish[14,15], and may be accumulated in organisms through the food chain[16], ultimately disrupting the ecology. Pesticide pollution can also be embedded in international trade at the global scale[17,18]. Multiple epidemiological studies indicate that long-term human exposure to environmental pesticides is associated with the increased incidence of immune disorders[8,19], endocrine diseases[20–23], hematological disorders[24,25], or cancers[26–28]. Climate change is expected to exacerbate pesticide-related environmental impacts by altering pest dynamics, application patterns, and chemical persistence[29]. Overall, pesticide pollution in air, water, and soil is a global environmental and public health concern.

To protect the environment and human health, nations have promulgated environmental quality standards (EQSs) for pesticides in environmental compartments as the maximum allowable concentration that will not cause adverse effects[30]. In addition, many field studies and national monitoring programs have quantified the pesticide residues in air, water, and soil[31–34]. However, these efforts differ in reporting methods and concentration units, which creates heterogeneity in data collection and reporting. These fragmented data make it difficult to provide a large-scale overview of pesticide pollution and limit the ability to identify critical polluted regions, posing challenges for cross-media and cross-regional risk assessment. Therefore, it is necessary to compile a globally harmonized dataset of observed pesticide concentrations in each environmental compartment. Additionally, integrating datasets of environmental standards would facilitate comparisons between current pesticide concentrations and national safety thresholds to identify exceedance. This is essential for strengthening pesticide monitoring and control, and for developing targeted public health policies.

This work presents a curated global dataset of reported pesticide concentrations in ambient air, surface freshwater, groundwater, marine water, and soils, coupled with regulatory environmental quality standards collected between 2010 and 2020. The dataset is designed to support environmental exposure and risk assessments, facilitate international regulatory comparisons, and serve as a foundation for evaluating pesticide fate and transport. Moreover, the dataset can provide sampling location information, which can support future efforts to build or refine a national pesticide residue monitoring network. By integrating existing resources, this dataset fills the gap in existing data through integration and enhances our understanding of global pesticide contamination.

Methods

Data collection

For pesticide contamination data, we retrieved literature studies from Web of Science, Scopus, and Google Scholar to extract data. The searches were conducted using combinations of the keywords “pesticide monitoring”, “air or water or soil pollution”, and individual pesticide names. The publication period was limited to 2010-2023, and the search language was restricted to English. In addition, official monitoring databases or regulatory agency reports were searched using terms such as “air/water/soil pollution monitoring website.” Known databases are shown in Table 1. Data from our previous global assessments of pesticide contamination in air[34] and surface water[35] were additionally integrated to supplement the dataset.

This dataset also systematically compiles environmental quality standards (EQSs) for pesticides in air, surface water, groundwater, and soil. These environmental compartments were selected because they represent the main pathways for pesticide exposure with widely established standards globally. We collected data from official government websites, such as the U.S. Environmental Protection Agency (USEPA), United Nations Environment Programme (UNEP), and China Ministry of Ecology and Environment (China MEE), as well as from previously published studies[30,36].

Table 1. Major databases for environmental pesticide monitoring.

Database Name	Media	URL
Stockholm Convention Data Warehouse	Air, Water	https://www.pops-gmp.org
Water Quality ICM, 2022	Water	https://sdi.eea.europa.eu/catalogue/srv/api/records/bdeadea2-cfaf-4724-b002-816d71c7e361
National Water Monitoring Program for Pesticides Data	Water	https://data-donnees.ec.gc.ca/data/sites/assess/national-water-monitoring-program-for-pesticides-nwmpp-data/?lang=en
Database SLU Agricultural water	Water	https://jordbruksvatten.slu.se/pesticider_start.cfm
The Water Quality Portal	Water	https://www.waterqualitydata.us/
Toxic Sites Identification Program	Soil	https://www.contaminatedsites.org/

Inclusion and Exclusion criteria

We included studies that reported measured (not modeled) pesticide concentrations with accompanying metadata for the period 2010-2020 and excluded reviews and meta-analyses. It should be noted that we only considered residential soils for soil contamination studies. This is because, compared with the periodic exposure of agricultural workers to crop land, residents are exposed to pesticide residues in residential soils over long and continuous periods. When the soil type was not specified in the study, soil samples were assumed to be from residential areas. In cases where the soil type was not explicitly specified, samples were assumed to be residential soil. For each eligible publication, we recorded key data information, including sampling location, sampling date, pesticide name, and reported values and units. When pesticide concentrations were presented in a graphic, values were extracted using tools like WebPlotDigitizer. EQSs were accepted if issued by a government agency or cited in peer-reviewed work.

A total of 20160 publications were initially retrieved for screening. After removing duplicates based on titles, we reviewed the full texts by applying the inclusion and exclusion criteria described above. This ultimately resulted in 698 eligible publications, including 62 for air, 578 for water, and 58 for residential soil.

Data harmonization

We categorized environmental compartments into the following groups: (i)Air: with sub-categories for urban or rural, etc. (ii) Water: surface freshwater, groundwater, ocean, and (iii) residential soil. In this way, the data were compiled into a structured database. In addition, to facilitate computational applications, concentration units were standardized across media: (i) air in $\mu g/m^3$, (ii) water in μg/L; and (iii) soil in μg/kg dry weight (dw). For accurate pesticide identification and retrieval, each pesticide was assigned a unique Chemical Abstract Service Registration Number (CAS No.) using CAS Databases. EQSs were systematically organized according to jurisdiction, medium, pesticide, and endpoint (e.g., human health, aquatic life)[30,36,37]. To ensure data quality, data from official databases, such as Waterbase (Water Quality ICM, 2022), were processed using both code and Excel functions, depending on the task. The steps involved include[38]: (i) Filtering data collected between 2010 and 2023; (ii) removing non-environmental medium data; (iii) excluding data that did not meet the required criteria, for example, non-pesticide compounds. This step involved cross-referencing compounds with databases like Pesticide

Properties DataBase (PPDB)[39], Pesticide Action Network (PAN)[40], and PubChem[41] to confirm whether they were pesticides; (iv) removing duplicate entries and illogical data (e.g., minimum concentrations greater than maximum concentrations); (v) calculating the annual maximum, median, and mean concentrations for each monitoring site, pesticide compound, and sampling year. Finally, the cleaned data were converted into a standardized format and saved as CSV files for further analysis and sharing.

Geographical sampling location

Based on the approach of Sun[42] and Wu[43], the following procedures were applied: (i) for sampling sites with coordinates, latitude and longitude were directly extracted; (ii) for publications that only provided site maps without explicit coordinates, approximate locations were identified visually using Google Maps; (iii) for locations lacking coordinates but with explicit descriptions, latitude and longitude were obtained by searching the names on Google Maps; and (iv) for sampling sites with vague location descriptions, the central coordinates of the smallest administrative unit encompassing the sampling area were used. When site types were involved, classification was conducted following the ESA LUCAS land cover modalities (first-level classes)[44].

Data format and availability

Data are provided in csv format per environmental medium, with each record containing the following fields: sampling location, year, source, pesticide name, CAS No, value (Minimum/Maximum/Median/Mean), and reference. EQSs are organized in a structured file with metadata including issuing agency, chemical ID, threshold value, and endpoint.

Data Records

This study presents a dataset comprising nearly 1660000 observations of pesticide residue concentrations in the environmental compartments (2010-2020), covering 92 countries, together with >20000 records of pesticide environmental quality standards from 81 regulatory bodies[45]. This dataset is available on the Figshare[45] with the name "PestiGlobal: A Comprehensive Dataset on Pesticide Pollution and Standards" version 5. It can be accessed via the following URL: https://doi.org/10.6084/m9.figshare.30271873 (2026). Eight files are included in the dataset, and their overview is as follows:

(1) "Airborne pesticide contamination.csv" (last updated: 2026-02-25; file size: 2.66 MB) contains a total of 9472 records of pesticide concentrations in air, and it includes 35 variables.

(2) "Surface freshwater pesticide contamination.csv" (last updated: 2026-02-25; file size: 184.32 MB) contains a total of 685653 records of pesticide concentrations in surface freshwater, and it includes 30 variables.

(3) "Groundwater pesticide contamination.csv" (last updated: 2026-02-25; file size: 0.50 MB) comprises a total of 1560 records of pesticide concentrations in groundwater, and it includes 29 variables.

(4) "Groundwater (continued).csv" (last updated: 2026-02-25; file size: 236.12 MB) comprises a total of 956308 records of pesticide concentrations in groundwater, and it includes 28 variables.

(5) "Seawater pesticide contamination.csv" (last updated: 2026-02-25; file size: 1.26 MB) contains a total of 4233 records of pesticide concentrations in seawater, and it includes 30 variables.

(6) "Residential soil pesticide contamination.csv" (last updated: 2026-02-25; file size: 0.25 MB) includes a total of 823 records of pesticide concentrations in residential soil, and it includes 30 variables.

(7) "EQSs.csv" (last updated: 2026-02-25; file size: 1.80 MB) contains a total of 22273 records of standard values across multiple environmental compartments. This file includes 14 variables.

(8) "Abbreviation.csv" (last updated: 2026-02-25; file size: 0.01 MB) documents abbreviations used across the dataset. These are organized in a table grouped by the applicable data columns.

All variable descriptions for these datasets are detailed in Supplementary File (Table S1).

Data Overview

This dataset compiles pesticide concentration across multiple environmental media, including air, water (surface freshwater, groundwater, and seawater), and residential soils, covering more than 70 countries worldwide. Airborne pesticide data are mainly derived from literature and established monitoring networks, while water data largely originate from national and regional monitoring databases. Residential soil data are comparatively sparse and primarily sourced from published studies and contaminated site inventories. Here, we simply describe the geographical coverage and the summary statistics of pesticide concentration. Firstly, the geographical distribution of sampling sites is shown in Figure 1. The highest density of sampling sites is observed in Europe, the United States, and China, reflecting the availability of long-term monitoring programs and published literature in these regions (Fig. 1). For pesticide concentration, the dataset reveals a strong imbalance between the number of detected pesticides and those with established environmental quality standards (EQSs). While hundreds of pesticides are routinely detected in air, water, and soils, regulatory thresholds are available for only a limited subset, mainly legacy and persistent compounds. This discrepancy highlights a regulatory gap between current environmental monitoring and existing standards, underscoring the need for comprehensive data integration to support future risk assessment and policy development (Fig. 2).

Technical Validation

To ensure objectivity during the initial collection period, all team members strictly followed the same inclusion and exclusion criteria throughout the literature selection process. All records were subjected to a secondary review to prevent omissions. After data entry, two researchers independently cross-checked the records based on predefined quality control checklists:

1. Pesticide confirmation: the compounds were cross-checked against the PPDB, Pesticide Action Network (PAN), and PubChem websites to confirm their classification as pesticides. Non-pesticide compounds or environmental contaminants were removed from the dataset.
2. Duplicate verification: For entries exhibiting high similarity (e.g., identical metadata, concentration data, and research teams), they need to be removed to prevent duplication.
3. Geographical validation: For coordinates reported in the literature, the provided latitude and longitude were verified using Google Maps to confirm consistency with the corresponding site names and locations
4. Logical check: For data from the same publication or official database[46], data with logical inconsistencies (e.g., negative pesticide concentration, the maximum smaller than the minimum) were removed to ensure data accuracy.

Usage notes

This work provides the first global compilation (2010-2020) integrating pesticide residues measured in environmental compartments with their corresponding standard values. This dataset contributed to a more complete understanding of the occurrence and regulatory status of pesticide residues across different regions. Its core applications are mainly reflected in three aspects: first, supporting the parameter optimization of multimedia exposure models to improve the accuracy of exposure risk assessment; second, facilitating comparison of regulatory thresholds across countries to identify consistencies in global pesticide management systems; and third, aiding geographic prioritization of pesticide risk by enabling identification of contamination hotspots. Furthermore, this resource can be integrated with other databases for analyses. For example, pesticide usage data[47] can be combined to explore potential associations with pesticide contamination levels. In addition, the structure of this dataset allows customized segmentation and synthesis by pesticide categories, environmental compartments, or geographic region, facilitating adaptation to diverse research objectives.

Users of this dataset should be aware of potential sampling biases in the literature compilation. This compilation only included English-language data and did not fully capture studies from non-English-speaking countries. Future versions will incorporate more localized data sources through collaborative networks to improve global representativeness. Additionally, due to uneven geographic coverage of sampling sites and differences in sampling periods, caution is warranted when assessing pesticide contamination in data-scarce regions. Finally, given the temporal coverage of the dataset, users may consider integrating it with new database releases. For example, the Land Use and Coverage Area frame Survey (LUCAS) 2022 topsoil data from the European Commission[48] is expected to be released in 2026. This dataset will provide pesticide residue data from approximately 33000 sites from 2022. Once available, this data will offer more comprehensive information for updating the current dataset.

Data availability

The data is deposited on Figshare (https://doi.org/10.6084/m9.figshare.30271873).

Code availability

All analyses are conducted using ArcGIS (10.8) and Origin (2024). No specific custom code has been produced during the collection of this dataset.

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Contribution statement

Huang: Writing – review & editing, Writing – original draft, Methodology, Software, Data collection, Data curation.

Li: Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Ethics declarations

Competing interests

The authors declare no competing interests.

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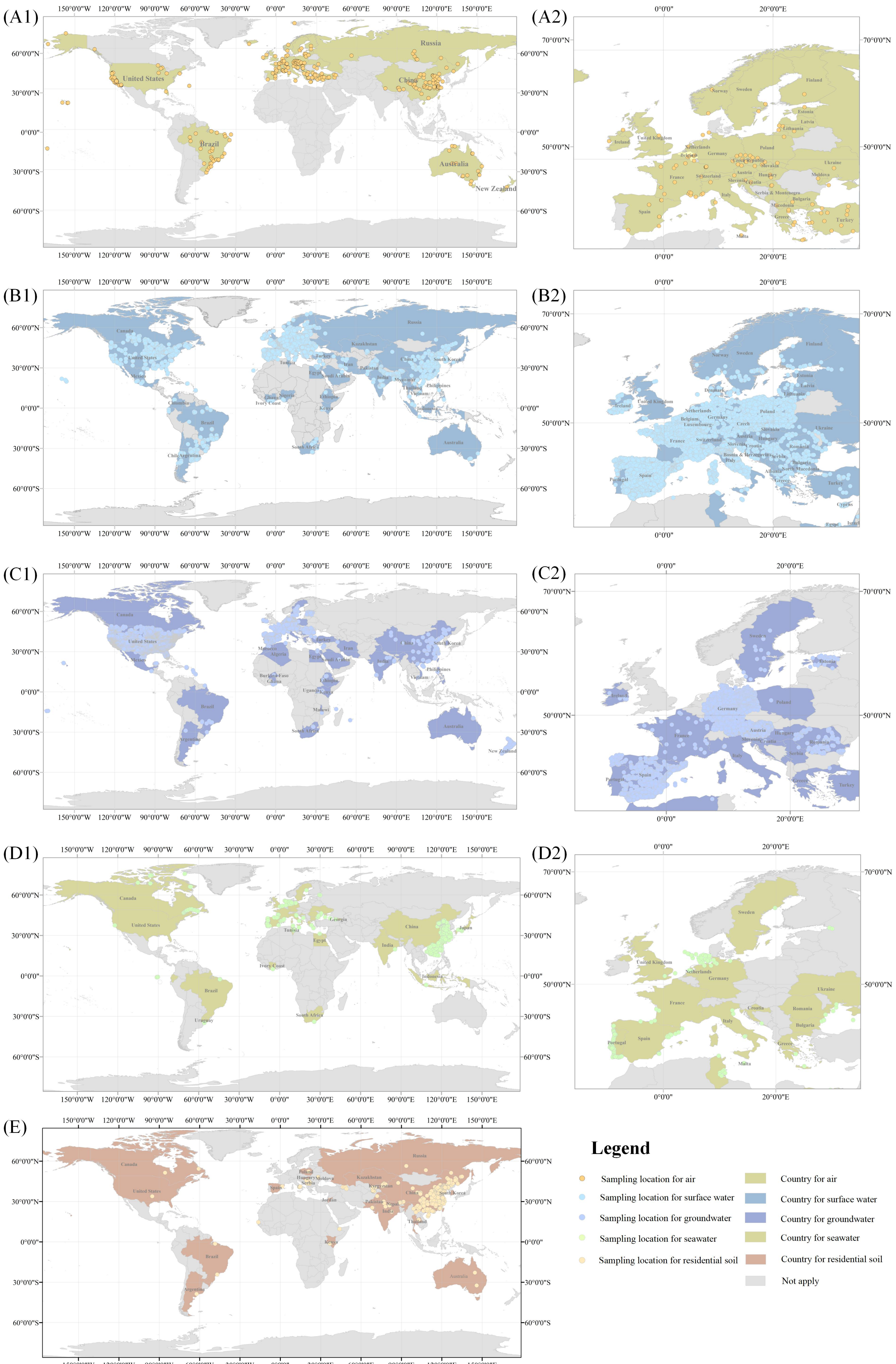
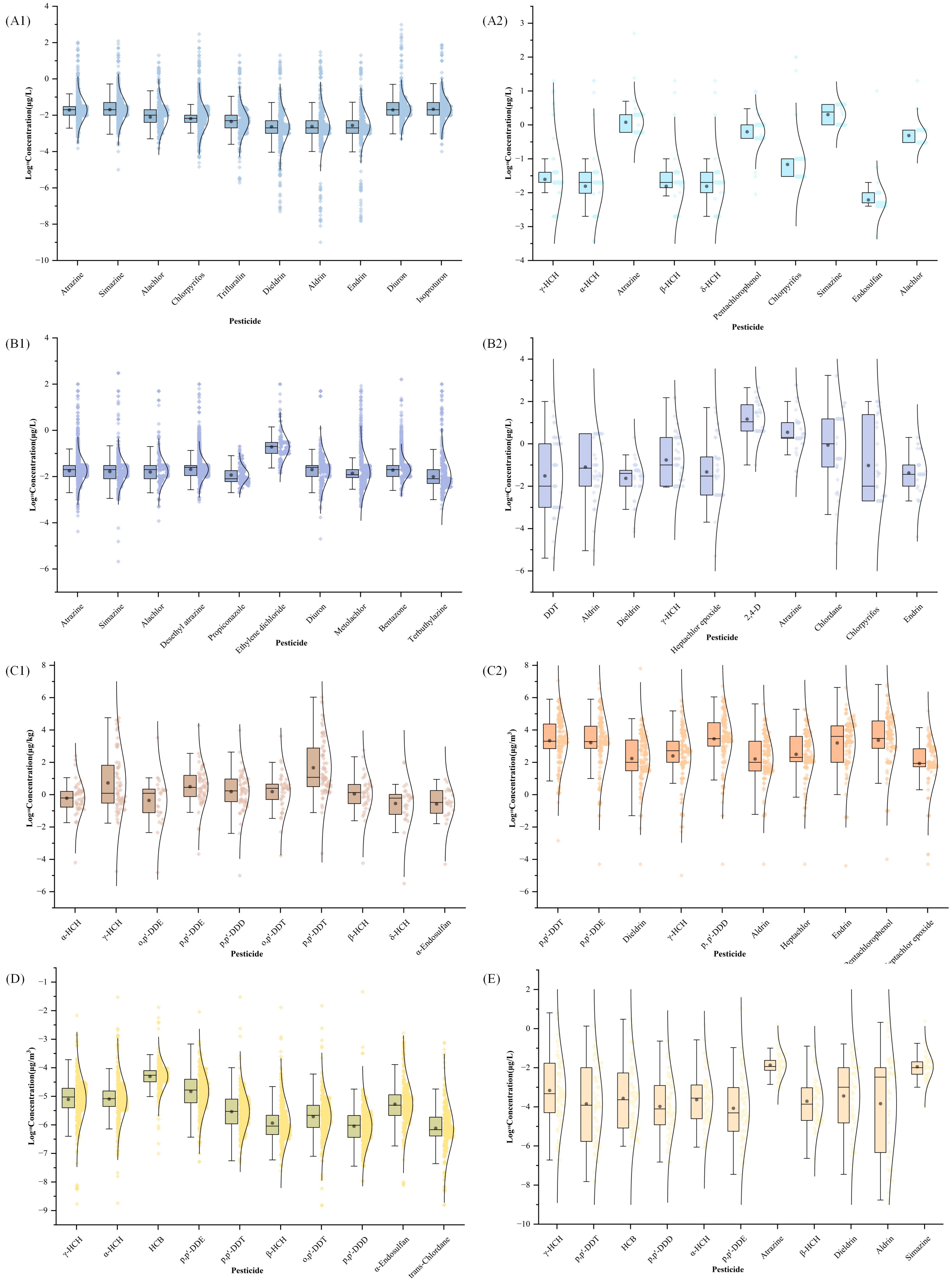
Figure legends

Fig. 1. Geographic distribution of pesticide monitoring sites. (A1–A2) Air; (B1–B2) Surface freshwater; (C1–C2) Groundwater; (D1–D2) Seawater; (E) Residential soil (global and European scales).

Fig. 2. Occurrence and regulatory coverage of the ten most frequently monitored pesticides. (A1–A2) Surface freshwater (occurrence and regulation); (B1–B2) Groundwater (occurrence and regulation); (C1–C2) Residential soil (occurrence and regulation); (D) Air (occurrence only); (E) Seawater (occurrence only).


(A1)
(A2)
(B1)
(B2)
(C1)
(C2)
(D1)
(D2)
(E)
Legend
Sampling location for air
Sampling location for surface water
Sampling location for groundwater
Sampling location for seawater
Sampling location for residential soil
Country for air
Country for surface water
Country for groundwater
Country for seawater
Country for residential soil
Not apply


(A1)
Log10Concentration(μg/L)
Atrazine
Simazine
Alachlor
Chlorpyrifos
Trifluralin
Dieldrin
Aldrin
Endrin
Diuron
Isoproturon
Pesticide
(A2)
Log10Concentration(μg/L)
γ-HCH
α-HCH
Atrazine
β-HCH
δ-HCH
Pentachlorophenol
Chlorpyrifos
Simazine
Endosulfan
Alachlor
Pesticide
(B1)
Log10Concentration(μg/L)
Atrazine
Simazine
Alachlor
Desethyl atrazine
Propiconazole
Ethylene dichloride
Diuron
Metolachlor
Bentazone
Terbuthylazine
Pesticide
(B2)
Log10Concentration(μg/L)
DDT
Aldrin
Dieldrin
γ-HCH
Heptachlor epoxide
2,4-D
Atrazine
Chlordane
Chlorpyrifos
Endrin
Pesticide
(C1)
Log10Concentration(μg/kg)
α-HCH
γ-HCH
o,p'-DDE
p,p'-DDE
p,p'-DDD
o,p'-DDT
p,p'-DDT
β-HCH
δ-HCH
α-Endosulfan
Pesticide
(C2)
Log10Concentration(μg/m3)
p,p'-DDT
p,p'-DDE
Dieldrin
γ-HCH
p, p'-DDD
Aldrin
Heptachlor
Endrin
Pentachlorophenol
Heptachlor epoxide
Pesticide
(D)
Log10Concentration(μg/m3)
γ-HCH
α-HCH
HCB
p,p'-DDE
p,p'-DDT
β-HCH
o,p'-DDT
p,p'-DDD
α-Endosulfan
trans-Chlordane
Pesticide
(E)
Log10Concentration(μg/L)
γ-HCH
p,p'-DDT
HCB
p,p'-DDD
α-HCH
p,p'-DDE
Atrazine
β-HCH
Dieldrin
Aldrin
Simazine
Pesticide