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Accumulation of pesticides in the sediments of Lake Labo: Relationships with organic matter and ecological risks (Lôh-Djiboua, Centre-West, Ivory Coast)

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Abstract

The accumulation of pesticides in the sediments of Lake Labo (Ivory Coast) is a major environmental issue, linked to the region's intensive agricultural practices. This study aims to assess their contamination, its link with organic matter and the associated ecological risks, thus filling a gap in local data on these processes in humid tropical ecosystems. Thirty sediment samples, taken according to a standardized protocol, were analyzed using the QuEChERS method and loss on ignition, with pesticide quantification by gas chromatography and risk assessment using Environmental Quality Standards. The results reveal significant threshold exceedances for monuron (17.80 ± 21.00 µg/kg), aldicarb (8.83 ± 11.00 µg/kg) and methabenzthiazuron (11.53 ± 13.00 µg/kg), particularly in sediments rich in organic matter (10-11%). Total load was 0.11387 ± 0.33600 mg/kg, with marked spatial variability. These results underline the urgency of strengthening pesticide monitoring and regulation in tropical agricultural areas, while opening up prospects for studies integrating degradation metabolites and long-term ecotoxicological impacts.

Keywords: Pesticides, Sediment, Organic matter, Ecological risks, Lake Labo.

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1. Introduction

Aquatic sediments play a crucial role in ecosystem dynamics, acting both as pollutant reservoirs and as historical indicators of environmental contamination (Hashmi *et al.,* 2020; Sanad *et al.,* 2025). In agricultural regions such as Lôh-Djiboua in Ivoiry Coast, the intensive use of pesticides for food and cash crops raises major concerns about their accumulation in aquatic environments, particularly in sediments (Prajapati *et al.,* 2022). The latter, due to their high affinity for organic matter (OM), can retain persistent compounds such as triazines or substituted ureas, posing long-term ecological risks via their potential release into the water column or their bioaccumulation in the trophic chain (Roche and Tidou, 2009). Previous studies have highlighted the capacity of sediments to reflect the history of contamination, as demonstrated by Hamoutene (2023) and Tapie *et al.,* (2018), who warn of frequent exceedances of environmental standards in tropical ecosystems. However, despite these advances, gaps persist in the understanding of the interactions between OM and pesticides, particularly in humid tropical climate contexts where conditions accelerate both soil degradation and pollutant dispersion (Ahipo, 2024; Bene *et al.,* 2024). Furthermore, the lack of environmental quality standards (EQS) for some compounds, such as pesticide metabolites, limits monitoring capabilities, a challenge already identified in similar basins in West Africa (Victor *et al.,* 2023). Faced with these challenges, this study aims to: (1) Quantify pesticide accumulation in the sediments of Lake Labo, (2) Evaluate their relationship with OM content and (3) Estimate ecological risks based on available EQS. By relying on standardized methods (QuEChERS, LOI) and rigorous statistical analyses, this research will contribute to sustainable management of aquatic resources in a context of intensive agriculture, while proposing avenues to strengthen local regulatory frameworks.

2. Materials and methods

2.1. Study Area

Our study took place in the Lakota department, in the heart of the Lôh-Djiboua region, in west-central Ivory Coast **(Figure 1)**. We targeted six villages: Akabreboua, Gazolilié, Dahiri, Gniakpalilié, Nassalilié and Grand-Déboua, with a particular focus on the Gazolilié dam, located between the villages of Gazolilié and Dahiri (coordinates: 5°54'38" N, 5°41'38" W) (**Figure 2**). This dam, a natural area of 3,390.26 m² with a depth exceeding 15 meters, collected sediment samples to assess their quality and impact on aquatic ecosystems. These data, combined with socio-economic analyses, allowed a comprehensive approach to the agricultural, environmental and health challenges of the region. The climate is humid tropical, with average temperatures of 25 to 30°C and abundant rainfall from April to October, favoring food and cash crops. However, despite the fertility of the ferralitic soils, these are rapidly degrading under the effect of intensive agriculture and erosion, particularly around the dam (Ahipo, 2024; Bene *et al.,* 2024).

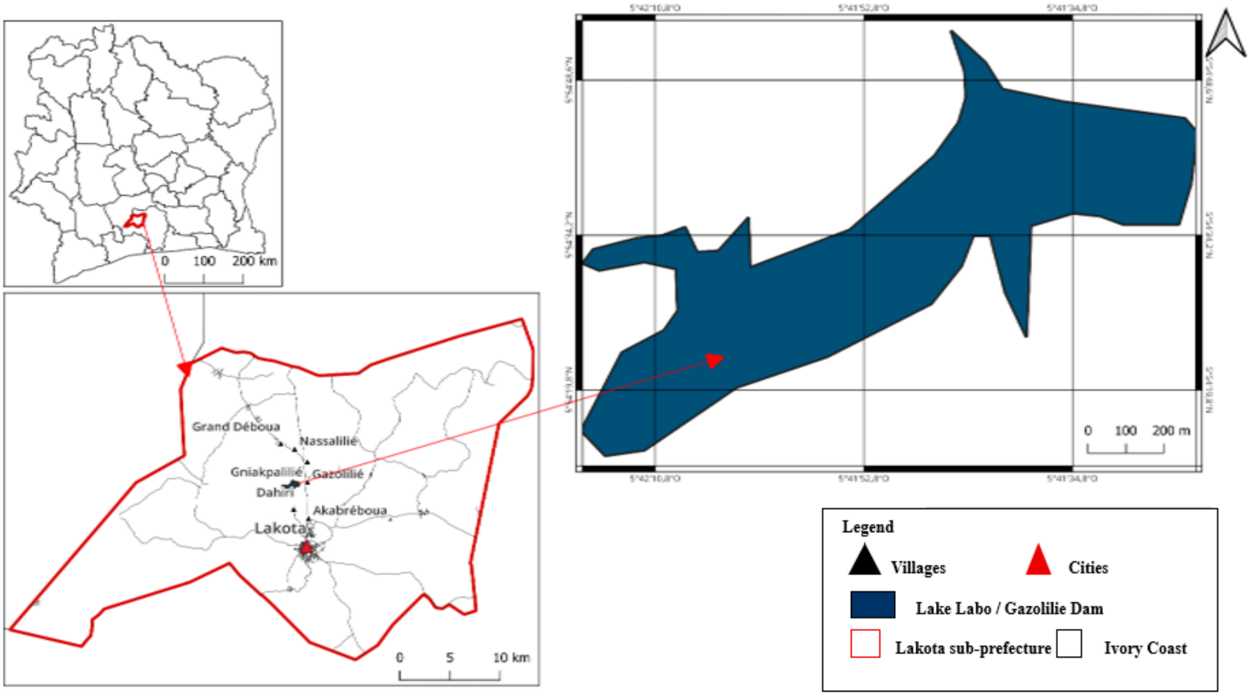

Figure 1: Location of the study area.

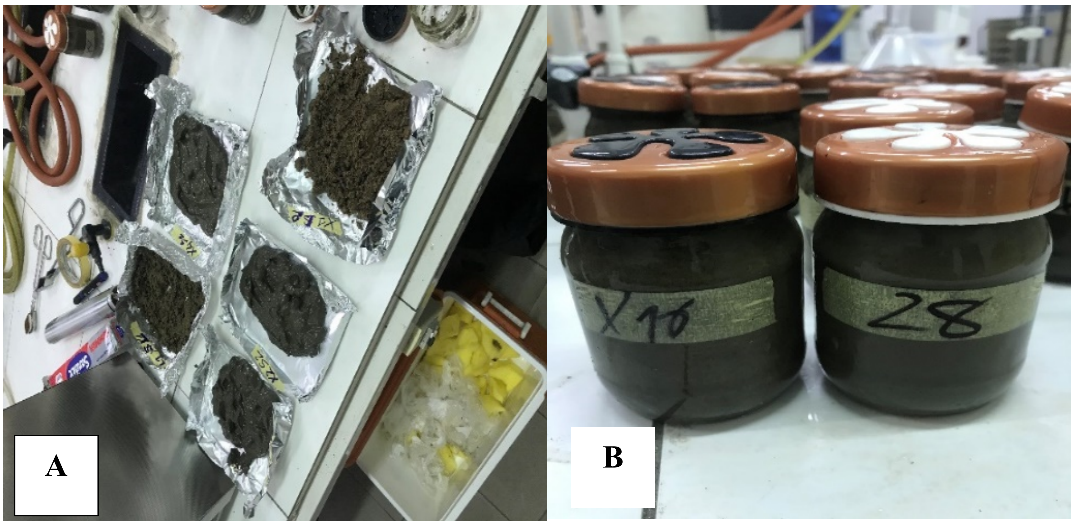

Figure 2: Map of the sediment.

2.2. Reagents and Solvents

For sediment analysis, the QuEChERS method was applied using acetonitrile (Merck) as the extraction solvent, supplemented with a mixture of $MgSO_4$ (for dehydration) and NaCl (for phase separation). Further purification was performed with PSA (for the removal of acids and sugars) and ENVI-Carb™ (for the reduction of pigments and interferences).

2.3. Sediment matrices

The sediments of Lake Labo are key indicators of pollution, acting both as traps for insoluble pesticides, heavy metals, and persistent organic compounds, and as historical archives of contamination (Koukougnon *et al.,* 2022). Their study allows tracing the evolution of pollution over the long term, as shown by Hashmi et al. (2020) and Arisekar et al. (2019). Our research focuses on the accumulation of pesticides in these sediments and their potential release into the water column.

2.4. Sediment Sampling Protocol

From July 14 to 16, 2024, we collected 30 sediment samples from the reservoir using a Van Veen grab, a specialized tool for bottom deposits. The samples were distributed over five distinct areas (Littoral 1, Sublittoral 1, Deep Zone, Sublittoral 2, and Littoral 2), with precise GPS location **(Figure 3)**. Each sample was placed in 200 g glass vials, labeled, and transported on ice to preserve their integrity. In the laboratory, the sediments were dried at 40°C for four days, crushed, and then sieved to less than 63 µm to isolate the fine fraction, the most relevant for analysis. The prepared samples were then stored at room temperature at the Oceanographic Research Center (ORC) pending analysis.

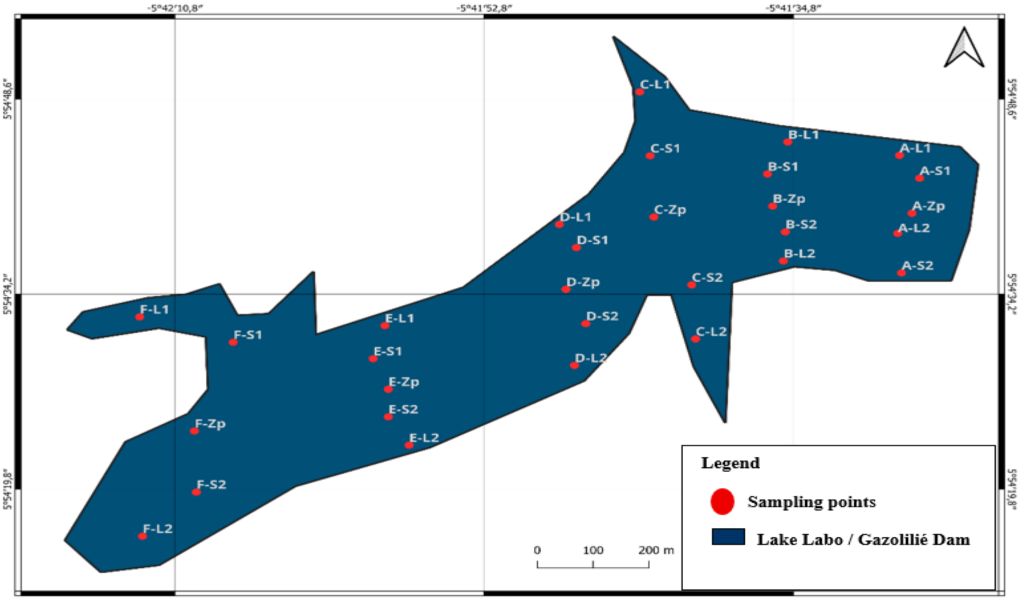

Figure 3: Sediment sampling points in the Lake Labo.

2.5. Target Pesticides

The study targeted 64 pesticides selected through a triple approach: (1) surveys of local farmers and retailers to identify commonly used products, (2) cross-referencing with the list of substances approved by the Ivorian Ministry of Agriculture, and (3) consideration of priorities defined by the national food safety agency. The panel included compounds from various chemical families, including both authorized pesticides and substances potentially used illegally **(Table 1)**.

Table 1: List of target pesticides organised by chemical family.

Chemical Families	Active Substances
Triazines	Atrazine, Cyanazine, Desethylatrazine, Desisopropylatrazine, Prometryn, Propazine, Simazine, Terbuthylazine, Terbutryn
Herbicides	Glyphosate (ammonium salt, isopropylamine salt), Glufosinate-ammonium, Hexazinone, Metamitron, Metazachlor, Metolachlor, Oxyfluorfen, Propanil, Triclopyr, 2,4-D amine salt, Paraquat dichloride, Cyhalofop-butyl
Organophosphates	Chlorfenvinphos, Chlorpyrifos-ethyl, Parathion-ethyl, Parathion-methyl
Pyrethroids	Beta-cyfluthrin, Bifenthrin, Cypermethrin, Deltamethrin, Lambda-cyhalothrin
Neonicotinoids	Acetamiprid, Imidacloprid, Thiamethoxam
Carbamates	Aldicarb, Chlorpropham, Methomyl, Thiobencarb
Substituted ureas	Buturon, Chlortoluron, Diuron, Fenuron, Isoproturon, Linuron, Methabenzthiazuron, Metoxuron, Monolinuron, Monuron
Fungicides	Cyproconazole, Difenoconazole, Triadimenol, Vinclozolin, Folpet, Metalaxyl-M, Mancozeb, Copper compounds (oxychloride, oxide)
Others	Fipronil, Indoxacarb, Mandipropamid, Metsulfuron-methyl, TCMTB
Biological	Bacillus subtilis

2.6. Pesticide Extraction and Analysis

The process begins by sampling 5 g of carefully homogenised and accurately weighed sediment, which is placed into a 50 mL centrifuge tube. Next, 10 mL of ultrapure water and 10 mL of acetonitrile are added, and the mixture is shaken vigorously for one minute. After sealing the tube securely, more intense agitation is carried out using a vortex mixer for approximately 5 minutes. This is followed by the addition of a salt mixture composed of 4 g of anhydrous magnesium sulphate (to remove residual water), 1 g of sodium chloride (to aid phase separation), along with 0.5 g of disodium citrate and 1 g of trisodium citrate (to stabilise the pH). The tube is shaken vigorously again for one minute and then centrifuged at 3000 revolutions per minute (rpm) for 5 minutes. A 6 mL aliquot of the supernatant is then transferred to a new polypropylene tube containing 150 mg of PSA (primary secondary amine) and 900 mg of magnesium sulphate (to purify the extract), as well as 45 mg of Envi-Carb (to remove interferences). After a further 2 minutes of shaking and centrifugation at 3000 rpm for 5 minutes, 5 mL of the purified extract is collected. This extract is acidified with 5% formic acid in acetonitrile (10 µL per mL of extract). The final sample is concentrated under a stream of nitrogen. The analysis was carried out by gas chromatography coupled with mass spectrometry (GC/MS, Agilent 8890/5977B). The limits of detection (LOD) and quantification (LOQ) applied were specific to each compound family, with LODs ranging from 0.003 to 0.006 mg/kg and LOQs ranging from 0.009 to 0.018 mg/kg **(Table 2)**. Concentrations (Cp, in µg/kg) were calculated from chromatographic peak areas using the formula:

$$C_p = (S_c \times C_e \times V_f \times F) / (S_e \times M_e \times V_1) \tag{1}$$

Where S_c/S_e represent the peak areas (sample/standard), C_e the standard concentration, V_f/V_1 the extraction/final volumes, M_e the sample mass, and F the dilution factor.

Table 2: Analytical Parameters of the GC-MS Method.

Pesticide	LOD (µg/kg)	LOQ (µg/kg)	Recovery Rate (%)	Reference
Atrazine	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Simazine	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Terbuthylazine	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Cyanazine	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Desethylatrazine	6	18	80-90	Anastassiades, 2003; US EPA, 2006
Desisopropylatrazine	6	18	80-90	Anastassiades, 2003; US EPA, 2006
Propazine	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Terbutryn	6	18	85-95	Anastassiades, 2003; US EPA, 2006
Diuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Linuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Monuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Methabenzthiazuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Isoproturon	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Fenuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Metobromuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Buturon	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Metoxuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Monolinuron	6	18	75-85	Anastassiades, 2003; Magnusson & Örnemark, 2014
Chlorfenvinphos	3	9	70-80	Anastassiades, 2003; US EPA, 2014
Parathion-methyl	3	9	70-80	Anastassiades, 2003; US EPA, 2014; Kankou et al., 2021
Aldicarb	3	9	70-80	Anastassiades, 2003; US EPA, 1992
Metazachlor	3.33	10	80-90	European Commission, 2021
Vinclozolin	3	9	80-90	AOAC, 2007

2.7. Organic Matter Analysis

Organic matter (OM) plays a central role in terrestrial and aquatic ecosystems, influencing the composition of soils and sediments, nutrient availability, and the retention or release of contaminants such as pesticides (Touch *et al.,* 2017; Bensharada *et al.,* 2022). In the context of Lake Labo, assessing the organic composition of sediments is essential to understand their capacity to absorb and retain pesticides, as well as to anticipate their potential transfer to the water column and aquatic organisms (Heiri *et al.,* 2001; Mozaffari *et al.,* 2023). The loss on ignition (LOI) method was selected to quantify

OM in the sediments due to its simplicity and reliability, being widely validated for the analysis of sediments, sludges, and residues (Hoogsteen *et al.,* 2018; Gerenfes *et al.,* 2022). The protocol involves an initial air-drying of the samples, followed by grinding and sieving to homogenise the particle size. A precise mass (5–10 g) is then heated to 550 °C for 4 hours in a muffle furnace, an optimal temperature for oxidising OM without altering inorganic minerals (Sutherland, 1998; Zhang *et al.,* 2014). After cooling in a desiccator, the difference in mass before and after ignition is used to calculate the percentage of OM via the formula:

$$\% \text{ Organic Matter} = (M_1 - M_2) / M_1 \times 100 \tag{2}$$

Where: M_1: initial mass of dry sediment (g); M_2: mass of sediment after ignition (g) at 550°C.

This approach identifies areas of the lake where the OM concentration is high, which governs the mobility and persistence of pollutants. LOI analysis thus provides key insights into the behaviour of pesticides in sediments, clarifying their storage, release, and the associated risks for the aquatic ecosystem (Nakhli *et al.,* 2019; Braun *et al.,* 2020).

2.8. Sediment Quality Standards

The protection of benthic organisms, which are closely dependent on sediments, requires the definition of concentration thresholds for contaminants present in these environments. However, unlike for water, direct ecotoxicological data to establish specific values for each substance in sediments remain limited (Hamoutene, 2023; Amouroux et Brun, 2018). To address this lack of data, a common approach involves translating Environmental Quality Standards (EQS) for water into values applicable to sediments (Hamoutene *et al.,* 2022). A simplified formula has been developed to facilitate this conversion, integrating a fixed component and another related to the organic carbon/water distribution coefficient (Koc) of the pollutant (Tapie *et al.,* 2018):

$$\text{Sediment EQS} = (0.7826 + 0.0217K_{oc}) \times \text{Water EQS} \tag{3}$$

This equation allows for the estimation of the maximum permissible concentration of a contaminant in sediments (in µg/kg dry weight) based on its EQS in water (in µg/L). The K_{oc} reflects the pollutant's affinity for sedimentary organic matter, thereby influencing its bioavailability. Although it is not based on ecotoxicological data specific to benthic species, this method provides a useful reference for assessing ecological risks and guiding sediment management and monitoring strategies. It thus serves as a pragmatic tool in the absence of specific standards, while highlighting the need for further research to refine protection thresholds.

2.9. Statistical Data Processing

Chromatographic data (Agilent 8890/5977B GC-MS) were processed with WILEY/NIST spectral libraries and validated by retention time and spectral matching. Statistical analyses combined: Univariate tests (ANOVA/Tukey for parametric data; Kruskal-Wallis/Wilcoxon for nonparametric data, after verification by Shapiro-Wilk/Levene). Multivariate approaches (PCA on centered-reduced data) in R 4.3.0 and Excel 2019. Correlation networks (Pearson/Spearman), visualized by heatmaps, revealed associations between contaminants and environmental parameters. Values < LOD were replaced by LOD/√2, and samples with >30% missing data were excluded to ensure robustness of the results.

3. Results and discussion

3.1. Pesticide residues detected in sediments

The analysis of sediment samples from Lake Labo revealed a widespread contamination by various pesticides, with a total residue load of 113.87 ± 336.00 µg/kg dry weight. The detected compounds, their mean concentrations, and standard deviations are detailed in **Table 3**. The contamination profile was diverse, encompassing several major chemical families.

Table 3: Pesticide residues detected in the sediments of Lake Labo (concentrations in µg/kg dry weight).

Family/Molecule	Concentration (µg/kg) (Mean ± SD)
Triazines	Atrazine (6.93 ± 16.00); Simazine (5.57 ± 13.00); Terbuthylazine (4.07 ± 17.00); Cyanazine (2.30 ± 15.00); Desethylatrazine (3.37 ± 11.00); Desisopropylatrazine (5.30 ± 11.00); Propazine (5.60 ± 11.00); Terbutryn (5.07 ± 19.00)
Substituted Ureas	Buturon (3.00 ± 10.00); Diuron (6.10 ± 16.00); Fenuron (5.03 ± 12.00); Linuron (6.67 ± 68.00); Monuron (17.80 ± 21.00); Methabenzthiazuron (1.53 ± 13.00); Monolinuron (4.93 ± 35.00); Metoxuron (3.77 ± 15.00); Isoproturon (3.83 ± 22.00)
Organophosphates	Chlorfenvinphos (2.20 ± 8.00); Parathion-methyl (2.30 ± 13.00)
Carbamates	Aldicarb (8.83 ± 11.00)
Other Compounds	Vinclozolin (3.73 ± 18.00); Metazachlor (4.47 ± 60.00)
Total Load	113.87 ± 336.00

Substituted ureas were particularly prominent, with monuron (17.80 ± 21.00 µg/kg) and methabenzthiazuron (11.53 ± 13.00 µg/kg) being detected at the highest concentrations. Triazines formed the most diverse group, including atrazine, simazine, and their degradation products. The presence of these substances confirms that sediments act as a significant long-term sink for persistent organic pollutants, as highlighted in previous studies on West African aquatic ecosystems (Appiah *et al.,* 2020; Djene *et al.,* 2025). The detection of both parent compounds and metabolites, such as desethylatrazine, indicates not only recent inputs but also ongoing environmental degradation processes within the lake's ecosystem, reflecting the intensive agricultural practices in the Lôh-Djiboua region.

3.2. Ecological risk assessment based on Sediment Quality Standards (EQS)

The potential ecological risk was assessed by comparing the measured concentrations with their respective derived Sediment Environmental Quality Standards (EQS), as presented in Table 4. The results revealed significant exceedances of regulatory thresholds for several compounds.

Table 4: Comprehensive ecological risk assessment based on derived Sediment Environmental Quality Standards (EQS) for all detected pesticides.

Pesticide	Measured Concentration (µg/kg)	Derived Sediment EQS (µg/kg)	Exceedance Factor	Risk Level
Substituted Ureas				
Monuron	17.80	2.60	6.8	High
Linuron	6.67	1.81	3.7	Moderate
Diuron	6.10	2.25	2.7	Moderate
Isoproturon	3.83	1.44	2.7	Moderate
Methabenzthiazuron	11.53	ND	ND	ND
Fenuron	5.03	ND	ND	ND
Metoxuron	3.77	ND	ND	ND
Buturon	3.00	ND	ND	ND
Monolinuron	4.93	ND	ND	ND
Triazines				
Atrazine	6.93	1.77	3.9	High
Simazine	5.57	1.47	3.8	High
Terbuthylazine	4.07	1.56	2.6	Moderate
Propazine	5.60	ND	ND	ND
Cyanazine	2.30	ND	ND	ND
Terbutryn	5.07	ND	ND	ND
Desethylatrazine	3.37	ND	ND	ND
Desisopropylatrazine	5.30	ND	ND	ND
Carbamates				
Aldicarb	8.83	0.14	63.1	High
Organophosphates				
Chlorfenvinphos	2.20	3.35	0.7	Low
Parathion-methyl	2.30	ND	ND	ND
Chloroacetanilides				
Metazachlor	4.47	0.73	6.1	High
Other Compounds				
Vinclozolin	3.73	ND	ND	ND

The most critical exceedances were observed for aldicarb (exceedance factor of 63.1), methabenzthiazuron (11.5), and monuron (6.8), indicating a high potential risk to benthic organisms. Compounds such as atrazine, simazine, and metazachlor also showed high exceedance factors (>5). The alarmingly high exceedance for aldicarb, a highly toxic carbamate insecticide, is particularly concerning and warrants immediate regulatory attention. Conversely, the presence of numerous compounds including cyanazine, fenuron, and vinclozolin for which no Sediment EQS could be derived due to a lack of ecotoxicological data, underscores a critical gap in the current environmental risk assessment frameworks (Hamoutene *et al.,* 2023). This highlights an urgent need for research to establish protective thresholds for these unregulated substances, as the pragmatic approach of deriving sediment EQS from water standards, whilst useful for an initial assessment, has limitations and should be refined with site-specific ecotoxicological studies on benthic organisms (Hamoutene *et al.,* 2023).

3.3. Principal Component Analysis of contamination patterns

Principal Component Analysis (PCA) was employed to elucidate the underlying structure of the contamination data and identify potential sources and associations. The biplot (**Figure 4**) illustrates the distribution of samples and the contribution of pesticides to the principal components.

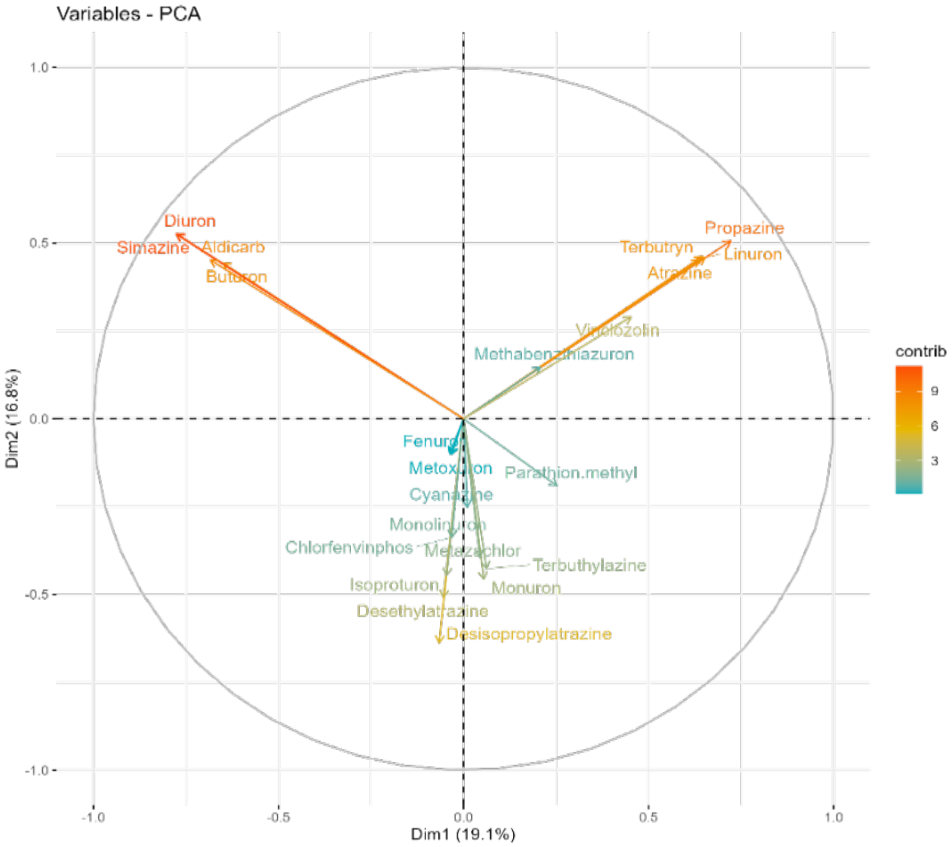

Figure 3: Principal Component Analysis (PCA) biplot showing the distribution of sediment samples and the contribution of detected pesticides to the principal components.

The first five dimensions of the PCA collectively explained 71.3% of the total variance observed in the dataset. The first dimension (19.1%) was strongly correlated with major herbicides such as atrazine and diuron. This pattern is consistent with findings from other agricultural basins (Mwevura *et al.,* 2021) and strongly suggests a common origin linked to runoff from crop fields in the catchment area. The second dimension (16.8%) was primarily influenced by degradation products, including desethylatrazine, and the insecticide aldicarb. This provides crucial information on the transformation pathways of these pesticides within the lake's ecosystem after their application and transport. The remaining dimensions captured more subtle variations, potentially related to less commonly used pesticides or local environmental factors such as soil type and specific microclimatic conditions that influence pesticide transport and fate. This multivariate analysis reinforces the hypothesis that agricultural runoff is the primary vector of contamination, corroborating studies from similar environments in West Africa (Koua *et al.,* 2019; Victor *et al.,* 2023). The clear separation of certain compounds and degradation products in the PCA biplot helps to disentangle the complex mixture of pollutants and can guide targeted source identification and mitigation strategies.

3.4. Influence of organic matter on pesticide distribution

The spatial distribution of pesticide concentrations was analysed in relation to the organic matter (OM) content of the sediments, as detailed in **Table 5**. A clear trend emerged, highlighting the role of OM in sequestering contaminants.

Sediments with higher OM content (10-11%) generally showed a greater abundance and diversity of pesticide residues. For instance, compounds like simazine, diuron, and aldicarb were consistently more prevalent in this group. Specific "hot spots" were identified, such as at Point_4 (11% OM), which showed elevated monuron (0.092 µg/kg), and Point_17 (10.2% OM), with a peak concentration of methabenzthiazuron (0.27 µg/kg). These results unequivocally demonstrate the critical role of sedimentary organic matter as a key regulator of pesticide retention. Organic particles act as effective traps for hydrophobic and moderately polar pesticides, a phenomenon well-documented for compounds with high organic carbon-water partition coefficients (Koc) (N'Guessan *et al.,* 2023; Touch *et al.,* 2017). This strong affinity prolongs the persistence of these pollutants in the ecosystem, creating a long-term reservoir that can potentially be released back into the water column under changing environmental conditions. This dynamic underscores the importance of considering sediment OM content in any risk assessment or management plan for agricultural lakes, as it directly modulates the mobility, bioavailability, and ultimate ecological impact of accumulated pesticides.

This integrated assessment confirms that the sediments of Lake Labo are a significant reservoir for agricultural pesticides, with several compounds, notably aldicarb, monuron, and methabenzthiazuron, posing a high ecological risk. The contamination profile is consistent with the intensive agricultural practices in the Lôh-Djiboua region, and the patterns revealed by PCA strongly point to agricultural runoff as the primary contamination pathway. Whilst the pragmatic approach of deriving sediment EQS from water standards has provided a useful initial risk assessment, it has limitations.

Table 5: Spatial distribution of pesticide concentrations (µg/kg) across sampling points, categorised by organic matter (OM) content.

OM Group	Sampling Point (% OM) and Representative Pesticide Concentrations (µg/kg)
9-10%	Point_3 (9.8%): Fenuron (0.024), Metoxuron (0.035); Point_6 (10%): Desisopropylatrazine (0.021), Monolinuron (0.074), Monuron (0.04), Chlorfenvinphos (0.033); Point_7 (9.5%): Cyanazine (0.044), Terbuthylazine (0.033), Metazachlor (0.025); Point_11 (9.9%): Atrazine (0.043), Propazine (0.039), Terbutryn (0.056), Linuron (0.041); Point_14 (9.7%): Fenuron (0.034), Metoxuron (0.025); Point_16 (9.6%): Fenuron (0.02), Metazachlor (0.024), Aldicarb (0.023), Vinclozolin (0.021); Point_19 (10%): Terbuthylazine (0.023), Monuron (0.29), Metazachlor (0.027), Parathion-methyl (0.023); Point_21 (9.8%): Desisopropylatrazine (0.021), Monolinuron (0.074), Monuron (0.04), Chlorfenvinphos (0.033); Point_23 (9.5%): Atrazine (0.023), Propazine (0.023), Terbutryn (0.024), Linuron (0.022), Vinclozolin (0.021); Point_26 (9.9%): Atrazine (0.023), Propazine (0.029), Terbutryn (0.026), Linuron (0.021), Parathion-methyl (0.023), Vinclozolin (0.027); Point_30 (10%): Desethylatrazine (0.02), Desisopropylatrazine (0.021)
10-11%	Point_1 (10.5%): Fenuron (0.028), Metazachlor (0.021), Aldicarb (0.03), Vinclozolin (0.016); Point_2 (10.2%): Propazine (0.019), Linuron (0.033), Methabenzthiazuron (0.076); Point_4 (11%): Terbuthylazine (0.043), Monuron (0.092), Metazachlor (0.017), Parathion-methyl (0.023); Point_5 (10.4%): Simazine (0.038), Buturon (0.021), Diuron (0.042), Aldicarb (0.015); Point_8 (10.3%): Atrazine (0.033), Propazine (0.029), Terbutryn (0.046), Vinclozolin (0.027); Point_9 (10.7%): Desethylatrazine (0.028), Desisopropylatrazine (0.036), Isoproturon (0.053), Monuron (0.051); Point_10 (10.1%): Simazine (0.023), Buturon (0.021), Diuron (0.036), Aldicarb (0.063); Point_12 (10.6%): Simazine (0.031), Diuron (0.041), Aldicarb (0.063); Point_13 (10.8%): Atrazine (0.058), Linuron (0.035); Point_15 (10.5%): Desethylatrazine (0.03), Desisopropylatrazine (0.036), Isoproturon (0.062); Point_17 (10.2%): Propazine (0.029), Linuron (0.023), Methabenzthiazuron (0.27); Point_18 (10.4%): Fenuron (0.021), Metoxuron (0.025); Point_20 (10.3%): Simazine (0.028), Buturon (0.023), Diuron (0.022), Aldicarb (0.025); Point_22 (10.1%): Cyanazine (0.025), Terbuthylazine (0.023), Metazachlor (0.02); Point_24 (10.7%): Desethylatrazine (0.023), Desisopropylatrazine (0.024), Monuron (0.021); Point_25 (10.9%): Simazine (0.023), Buturon (0.025), Diuron (0.021), Aldicarb (0.023); Point_27 (10.5%): Simazine (0.024), Diuron (0.021), Aldicarb (0.023); Point_28 (10.3%): Atrazine (0.028), Linuron (0.025); Point_29 (10.1%): Fenuron (0.024), Metoxuron (0.028)

As suggested by Hamoutene et al. (2023), this method should be refined with site-specific ecotoxicological studies on benthic organisms to obtain more accurate protection thresholds.

Furthermore, the logistical constraints of this study limited the analysis of a broader range of degradation metabolites, which could provide a more complete picture of the contamination dynamics. The findings highlight the urgent need to strengthen pesticide use regulations and promote sustainable agricultural practices in West Africa. Future research should prioritise the analysis of degradation metabolites, in-situ ecotoxicological evaluations of benthic communities, and watershed-scale modelling of contaminant fluxes to develop effective strategies that balance agricultural productivity with the conservation of vital aquatic ecosystems like Lake Labo.

Conclusion

This study quantified pesticide accumulation in Lake Labo's sediments, identifying concerning exceedances of Environmental Quality Standards for monuron, aldicarb, and methabenzthiazuron, while demonstrating organic matter's critical role in pollutant retention and ecological risk modulation. The integrated chemical and risk assessment approach addresses knowledge gaps in tropical aquatic systems, revealing how agricultural intensification and climate conditions amplify contamination. Findings underscore the urgent need for sediment-specific standards, particularly for unregulated compounds. Future research directions should prioritize: (1) degradation metabolite analysis, (2) in situ ecotoxicological evaluation of benthic communities, and (3) watershed-scale contaminant flux modeling to develop targeted management strategies balancing agricultural productivity and ecosystem conservation in West Africa.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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