

Assessment of Water Contamination by Insecticides from the N'Djamena Region to Lake Chad (Republic of Chad, Africa)

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Abstract— This study investigates surface water and groundwater contamination by insecticides in the region extending from N'Djamena to Lake Chad (Republic of Chad). Thirteen water samples—collected from rivers, wells, one borehole, and municipal tap water—were analyzed using Stir Bar Sorptive Extraction and gas chromatography–mass spectrometry. Among the 18 insecticides tested, permethrin and cypermethrin were the most frequently detected compounds, with concentrations exceeding multiple international environmental and drinking water standards. Surface waters, especially Lake Chad, showed high levels of permethrin (up to 95 ng/L), while cypermethrin was detected in groundwater and tap water samples at concentrations up to 100 ng/L. Although other insecticides were mostly below detection limits, the results indicate localized but significant pesticide contamination, likely related to agricultural practices and vector control campaigns. This 2005 dataset provides a valuable baseline for future assessments of pesticide pollution in the Lake Chad basin.

Keywords— Water contamination, N'Djamena region, Lake Chad, Insecticides.

I. INTRODUCTION

Insecticides are extensively applied in agriculture to enhance crop productivity and protect against pests. However, their intensive and often poorly regulated use has raised growing concerns regarding environmental pollution and associated health risks (Aktar et al., 2009; Zhang et al., 2011). Once released into the environment, insecticides can be transported from agricultural fields to adjacent ecosystems via surface runoff, leaching, and infiltration processes, ultimately contaminating surface water and groundwater (Keesstra et al., 2012; Fenner et al., 2013). Their persistence, mobility, and potential for bioaccumulation make them significant pollutants in aquatic systems (Stehle and Schulz, 2015).

In Chad, the use of insecticides in agricultural zones within the Chari and Logone river basins, in the peri-urban areas of N'Djamena, and during public health campaigns, has raised concerns about water resource contamination (PGPP, 2022). In April 2005, a field survey was conducted to investigate the presence of selected insecticides in both surface and groundwater in the N'Djamena region (Cooper, 2005) and to evaluate their potential environmental and public health implications.

II. MATERIAL AND METHODS

We collected a total of six surface water samples from the Chari River, Logone River, and Lake Chad (Fig. 1), five well water samples, one borehole sample from various locations within the city of N'Djamena, and one sample from the municipal water distribution system (Fig. 2).

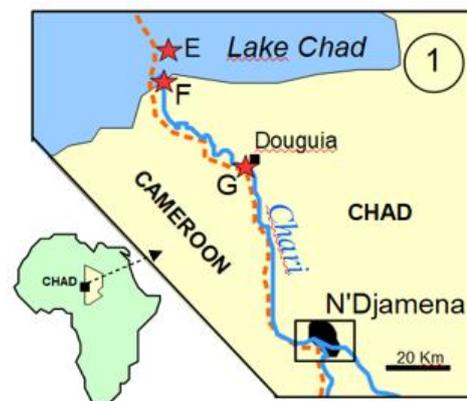


Fig. 1. Location of the analyzed water samples from Lake Chad and the Chari River. E: Lake Chad, 1 km offshore. F: Mouth of the Chari River, 1 km upstream from the lake. G: Chari River at Douguia. Inset: Location of Fig. 2

Most water samples were filtered using 0.45 μm mixed cellulose Millipore filters through a pressure vessel with a Millipore Swinnex filter holder. The filtered samples were stored in pre-cleaned high-density polyethylene (HDPE) bottles, kept cool, and protected from light in an insulated cooler.

Pesticide extraction was carried out on the same day as sampling at the Geology Laboratory, Faculty of Exact and Applied Sciences, University of N'Djamena, using the Stir Bar Sorptive Extraction (SBSE) technique. This method was previously validated by The Bouisson-Bertrand Institute Laboratory (Nîmes, France). Extraction involved magnetic stirring using TWISTER™ stir bars, each coated with 24 μL of polydimethylsiloxane (PDMS) as the sorptive phase. The procedure consisted of placing 50 mL of water to be analysed

(filtered or unfiltered) into a 250 mL Erlenmeyer flask, adding 1 mL of methanol and a TWISTER™ stir bar, followed by magnetic stirring for 1 hour. After extraction, the stir bar was rinsed with distilled water, and then stored in a sealed glass vial at +4 °C.

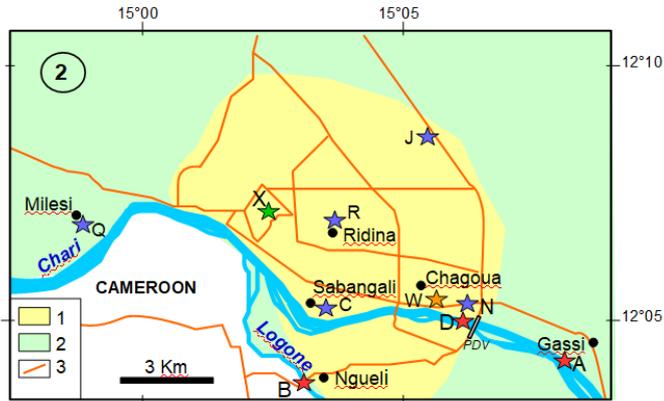


Fig. 2. Location of the analyzed water samples collected in N'Djamena. Red star: surface water. Blue star: well. Orange star: borehole. Green star: tap water. A: Chari River at Gassi. B: Logone River at Ngueli. C: Well at Sabangali. D: Chari River at the double-lane bridge (PDV). J: Well near the city bypass. N: Well near the double-lane bridge. Q: Well at Milezi. R: Well at Ridina. W: Borehole Pahimi. X: Tap water from the guesthouse "Les Flamboyants" (formerly ORSTOM). 1: Urbanized area in 2005. 2: Peri-urban area. 3: Main roads.

Pesticide analysis was performed at the Bouisson-Bertrand Institute Laboratory using an Agilent gas chromatograph equipped with a Thermal Desorption Unit–Cooled Injection System (TDU-CIS), an HP-5 capillary column (30 m length, 0.25 mm internal diameter, 0.25 µm film thickness), and an Agilent 5973i mass selective detector. Quantification was achieved by comparing sample chromatograms to methanolic standard solutions of the target insecticides, after the addition of 50 mL of bidistilled water and followed by the same procedure. The limit of detection was estimated at 5 ng/L, and the limit of quantification at 10 ng/L.

III. RESULTS AND DISCUSSION

Pesticide concentrations in the analyzed samples are presented in Table 1.

A. Surface Water

Among the 18 targeted insecticides, only permethrin was detected in surface waters (Table 1). Upstream of N'Djamena, in the Chari (sample A; Fig. 2) and Logone Rivers (sample B; Fig. 2), concentrations were between the limit of detection (5 ng/L) and the limit of quantification (10 ng/L). Downstream of N'Djamena, higher levels were recorded, reaching 12 ng/L at the mouth of the Chari River, 1 km upstream of Lake Chad (sample F; Fig. 1) and 15 ng/L at Douguia (sample G; Fig. 1). The highest concentration, 95 ng/L, was observed in Lake Chad, 1 km offshore (sample E; Fig. 1).

These concentrations greatly exceed international environmental quality standards (EQS) for permethrin, including the European Union annual average EQS (AA-EQS) of 0.27 ng/L and the maximum allowable concentration (MAC-EQS) of 7 ng/L for aquatic life (SCHEER, 2022). They also

surpass the Canadian guideline of 4 ng/L for the protection of aquatic organisms (CCME, 2006) and the freshwater Predicted No Effect Concentration (PNEC) of 10 ng/L set by the European Chemicals Agency (ECHA, 2024). These findings indicate significant contamination, particularly in Lake Chad, and raise concerns regarding potential impacts on aquatic fauna, especially invertebrates that are highly sensitive to pyrethroids.

No other insecticides were detected, including cypermethrin, known for its high aquatic toxicity. All measured concentrations for cypermethrin were below the detection limit of 5 ng/L. However, this detection threshold remains above both the Canadian provisional guideline of 4 ng/L (CCME, 2006) and the European Union MAC-EQS (0.6 ng/L) and AA-EQS (0.08 ng/L) for cypermethrin (EU, 2013). Therefore, the absence of detection cannot be interpreted as the absence of ecological risk, particularly for sensitive species.

These results indicate significant exposure to permethrin in the surface waters of the Lake Chad basin, likely due to intensive pesticide use in the peri-urban agricultural zones of N'Djaména.

B. Groundwater

Three insecticides were detected in groundwater samples: chlorpyrifos, permethrin, and cypermethrin. The other Insec were below the detection limit (5 ng/L).

Chlorpyrifos was found at 15 ng/L in the Milezi well (sample Q; Fig. 2). This low concentration remains well below international drinking water guideline values: Canada (90 µg/L; Health Canada, 1986), New Zealand (70 µg/L; MoH, 2000), the United States (20 µg/L; EPA, 2000), Australia (10 µg/L; NHMRC, 2000), the European Union (0.1 µg/L; EU, 2020), and the WHO (0.03 µg/L; WHO, 2004).

Permethrin was detected at 40 ng/L in the Milezi well (sample Q; Fig. 2) and 30 ng/L in the well near the new bridge (sample N; Fig. 2). In the Sabangali well (sample C; Fig. 2) and the Pahimi borehole (sample W; Fig. 2), permethrin was detected but not quantified (concentration between 5 and 10 ng/L). Permethrin drinking water standards vary considerably between countries: 100 µg/L in Australia (NHMRC, 2000), 20 µg/L in New Zealand (MoH, 2000), and 300 µg/L according to WHO (2004). The concentrations detected in samples Q and N are below all of these values, except for the general EU pesticide limit of 0.1 µg/L (100 ng/L), which applies uniformly to all pesticides regardless of toxicity (EU, 2020). However, this EU threshold reflects a maximalist risk management policy and is not widely used in practice, particularly in developing countries, where WHO guidelines are often preferred.

Cypermethrin was found at 145 ng/L in the Sabangali well (sample C; Fig. 2), located in an area of intensive market gardening where the Cypercal formulation (containing 100 g/L of cypermethrin) is widely used. It was also detected at 200 ng/L in a tap water sample from the Flamboyants guest house (sample X; Fig. 2). These values exceed the parametric limit of 100 ng/L established by the European Union (EU, 2020) and adopted in many countries, for individual pesticides in drinking water. Although the World Health Organization has not set a guideline value specifically for cypermethrin—owing to its low water solubility and high affinity for sediments—its presence at

such levels raises concerns regarding potential risks to human health.

TABLE 1. Insecticide concentrations. Concentrations are expressed in nanograms per liter of water (ng/L). N.D.: Not detected (detection limit estimated at 5 ng/L). DNQ: Detected but not quantifiable (5 ng/L < concentration < 10 ng/L). f: filtered sample; nf: unfiltered sample. References as in Figs. 1 and 2. A, B, D, E, F, and G: surface water. C, J, N, Q, R, W, and X: groundwater.

references	A	B	D	E	F	G	C	J	N	Q	R	W	X
	f	f	f	f	f	f	f	nf	f	f	nf	nf	nf
Propoxur	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbofuran	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbaryl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethoate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diazinon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methyl parathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fenitrothion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorpyrifos	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND
Ethyl parathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Triazophos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lindane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lambda- cyhalothrine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Permethrin	DNQ	DNQ	DNQ	95	12	15	DNQ	ND	40	30	ND	DNQ	10
Cypermethrin	ND	ND	ND	ND	ND	ND	145	ND	ND	ND	ND	ND	200
Fenvalerate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Deltamethrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

These results reveal localized but significant contamination of groundwater resources in N'Djamena, especially by cypermethrin. This contamination likely originates from the same agricultural activities responsible for surface water pollution in the region.

IV. CONCLUSION

This study provides one of the earliest documented assessments of pesticide contamination in surface and groundwater in the N'Djamena–Lake Chad region. The results highlight the presence of significant levels of pyrethroid insecticides, particularly permethrin and cypermethrin, with concentrations in some samples exceeding international environmental quality standards and drinking water limits. Although the dataset is limited and based on samples collected in 2005, it establishes a valuable historical baseline for future monitoring and risk assessment. These results highlight the need to strengthen pesticide regulations to reduce environmental and health risks in the N'Djamena–Lake Chad region.

REFERENCES

[1] Aktar, M. W., Sengupta, D., and Chowdhury, A. (2009). Impact of pesticides use in agriculture: Their benefits and hazards. *Interdisciplinary Toxicology*, 2(1), 1–12. <https://doi.org/10.2478/v10102-009-0001-7>

[2] CCME (2006). *Canadian Water Quality Guidelines for the Protection of Aquatic Life: Permethrin*. In: *Canadian Environmental Quality Guidelines, 1999*, updated 2006. Canadian Council of Ministers of the Environment, Winnipeg. <https://ccme.ca/en/chemical/161>

[3] Cooper J.F. (2005). Campagne d'échantillonnage (avril 2005) en vue de l'évaluation de la pollution par les pesticides dans la région de N'Djaména au lac Tchad. Rapport inédit, Département de Géologie, Université de N'Djaména, République du Tchad.

[4] EPA (2000). Drinking water standards and health advisories. U.S. Environment Protection Agency. Office of Water 4304. EPA 822-B-00-001 (2000).

[5] Health Canada (1986). *Guidelines for Canadian Drinking Water Quality: Supporting Document – Chlorpyrifos*. Ottawa, Ontario: Environmental Health Directorate, Health and Welfare Canada.

[6] EU (2013). Directive 2013/39/UE du Parlement européen et du Conseil du 12 août 2013 modifiant les directives 2000/60/CE et 2008/105/CE en ce qui concerne les substances prioritaires dans le domaine de la politique de l'eau. *Journal officiel de l'Union européenne*, L 226, 24.8.2013, p. 1–17. <https://eurlex.europa.eu/legalcontent/FR/TXT/?uri=CELEX:32013L0039>

[7] EU (2020). Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast). *Official Journal of the European Union*, L 435, 1–62. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020L2184>

[8] Fenner, K., Canonica, S., Wackett, L. P., and Elsner, M. (2013). Evaluating pesticide degradation in the environment: Blind spots and emerging opportunities. *Science*, 341(6147), 752–758.

[9] Health Canada (1986). *Guidelines for Canadian Drinking Water Quality: Supporting Document – Chlorpyrifos*. Ottawa, Ontario: Environmental Health Directorate, Health and Welfare Canada.

[10] Keesstra, S. D., van Dam, O., Verstraeten, G., and van Huissteden, J. (2012). The influence of land use and climate change on sediment and water delivery in the periglacial region of Europe. *Land Degradation & Development*, 23(5), 507–523.

[11] MoH (2000). Ministry of Health, NZ. Drinking-water standards for New Zealand (2000). www.moh.govt.nz

[12] NHMRC (2000). National Health and Medical Research Council. Australian drinking water guidelines. Agricultural and Resource Management Council of Australia and New Zealand. Commonwealth of Australia (1996).

[13] PGPP (2022). Plan de gestion des pestes et pesticides (PGPP) Tchad. Programme de renforcement de la résilience à l'insécurité alimentaire et nutritionnelle au Sahel (P2-P2RS, PPCI-Sahel, 2020-2025).

[14] SCHEER. (2022). *Draft Environmental Quality Standards for Permethrin and Cypermethrin under the Water Framework Directive*. Scientific Committee on Health, Environmental and Emerging Risks, European Commission.

[15] Stehle, S., and Schulz, R. (2015). Agricultural insecticides threaten surface waters at the global scale. *Proceedings of the National Academy of Sciences*, 112(18), 5750–5755. <https://doi.org/10.1073/pnas.1500232111>

[16] WHO (2004). *Guidelines for Drinking-water Quality*, 3rd edition. Geneva, World Health Organization.

- [17] Zhang, W., Jiang, F., and Ou, J. (2011). Global pesticide consumption and pollution: With China as a focus. *Proceedings of the International Academy of Ecology and Environmental Sciences*, 1(2), 125–144.