

Toxicity assessment of petroleum-derived pollutants in wetlands sediments impacted by Colombia's largest oil refinery

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Abstract

INTRODUCTION: Petroleum industry activities, such as extraction and refining, release toxic pollutants, including polycyclic aromatic hydrocarbons (PAHs) and trace elements (TEs), both characterized by their persistence, bioaccumulation potential, and toxicity in organisms. The largest oil refinery in Colombia is located in the Magdalena Medio region, Santander, a floodplain fed by the Magdalena River, its tributaries and wetlands. Given its ecological relevance, this area faces serious environmental risks due to contamination. **OBJECTIVE:** To quantify PAHs and TEs in wetland sediments around the refinery and evaluate their biological effects using *Caenorhabditis elegans*. **MATERIALS AND METHODS:** Composite sediment samples were collected from 20 points across Zarzal (ZW), San Silvestre (SSW), Llanito (LW), Paredes (PW), and Yarirí (YW) wetlands. Total mercury (T-Hg) was quantified using a direct RA-915M analyzer; 47 TEs, including Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), and Zinc (Zn), by ICP-MS; and PAHs (naphthalene, 1-methylnaphthalene, anthracene, fluoranthene, acenaphthene, pyrene, benzo[a]anthracene, benzo[a]pyrene, phenanthrene, and fluorene) via GC-MS. Aqueous sediment extracts (1:3, sediment : K medium) were tested for lethality, growth, and reproductive effects in *C. elegans* after 24 hours of exposure. **RESULTS:** TEs levels for Hg (0.03-0.12 µg/g), Cd (0.56-3.54 µg/g), Cr (41.91-103.98 µg/g), Cu (17.2-163.8 µg/g), Pb (13.8-28.4 µg/g), and Zn (78.9-406.3 µg/g) showed that Cd, Cr, and Zn exceeded the Probable Effect Level (PEL) at several points, indicating potential adverse biological effects. Among the PAHs analyzed, naphthalene, pyrene, and benzo[a]pyrene were the most prevalent and reached the highest concentrations, with maximum values of 4.56, 5.16, and 4.96 µg/g, respectively. However, exceedances of the PEL were observed for multiple PAHs at up to 12 points. Sediment extracts from ZW, SSW, and PW caused increased lethality in *C. elegans* (up to 11.7%) and growth inhibition (up to 44.3%), while those from PW and YW significantly reduced offspring production by 41.3% and 32.9%, respectively. **CONCLUSION:** Wetlands surrounding the refinery are impacted by persistent pollutants, with biological toxicity in *C. elegans*. These substances, potentially combined with unidentified co-occurring pollutants, may exert synergistic effects that increase toxicity. Strengthened environmental monitoring is essential to protect these ecosystems.

Introduction



Materials and methods

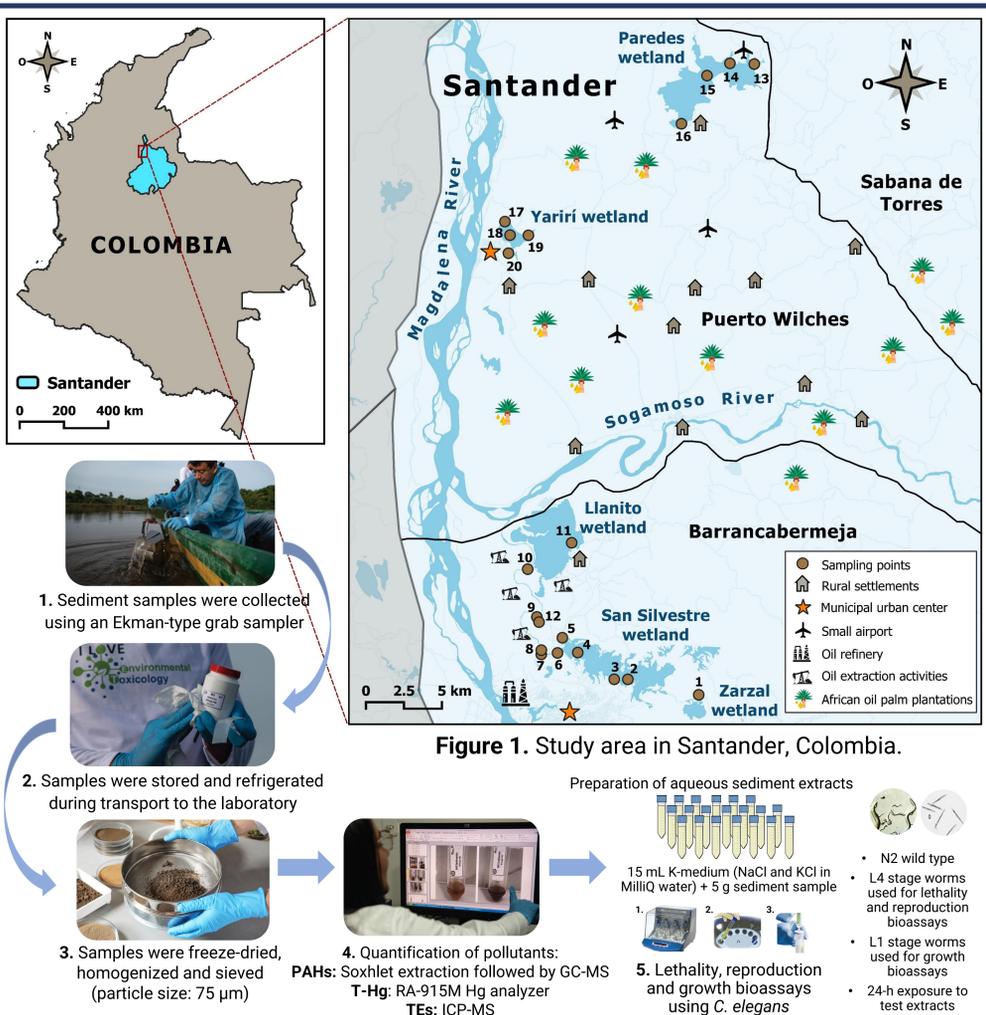


Figure 1. Study area in Santander, Colombia.

Results and discussion

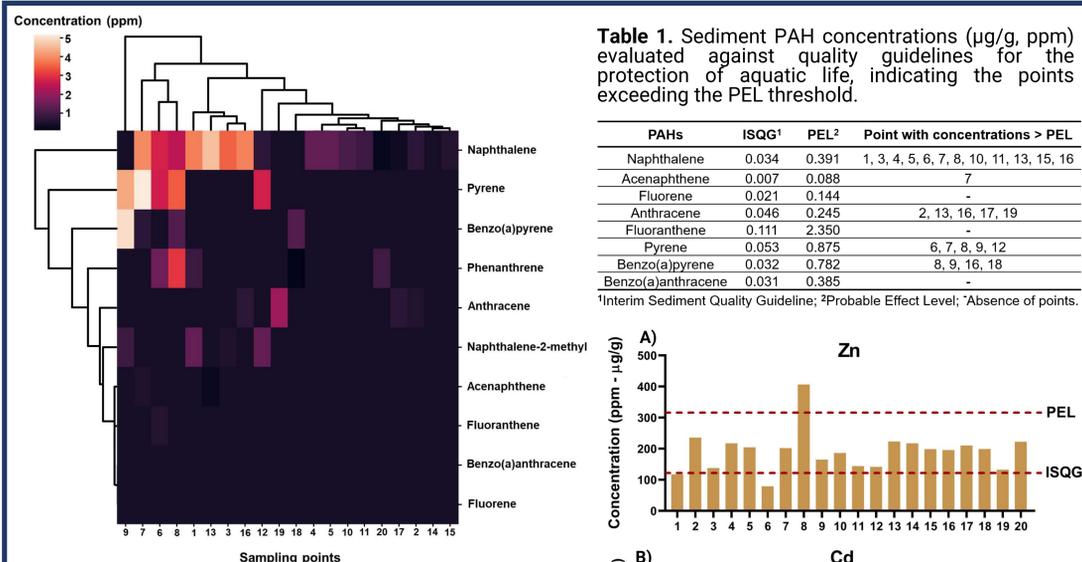


Table 1. Sediment PAH concentrations (µg/g, ppm) evaluated against quality guidelines for the protection of aquatic life, indicating the points exceeding the PEL threshold.

PAHs	ISQG ¹	PEL ²	Point with concentrations > PEL
Naphthalene	0.034	0.391	1, 3, 4, 5, 6, 7, 8, 10, 11, 13, 15, 16
Acenaphthene	0.007	0.088	7
Fluorene	0.021	0.144	-
Anthracene	0.046	0.245	2, 13, 16, 17, 19
Benzo(a)pyrene	0.111	2.350	-
Pyrene	0.053	0.875	6, 7, 8, 9, 12
Phenanthrene	0.032	0.782	8, 9, 16, 18
Benzo(a)anthracene	0.031	0.385	-

¹Interim Sediment Quality Guideline; ²Probable Effect Level; ³Absence of points.

Figure 2. Heatmap of PAH concentrations obtained from sediment samples, clustered by similarity.

Naphthalene, pyrene, and benzo[a]pyrene were the most prevalent and reached the highest concentrations, with maximum values of 4.56, 5.16, and 4.96 µg/g, respectively.

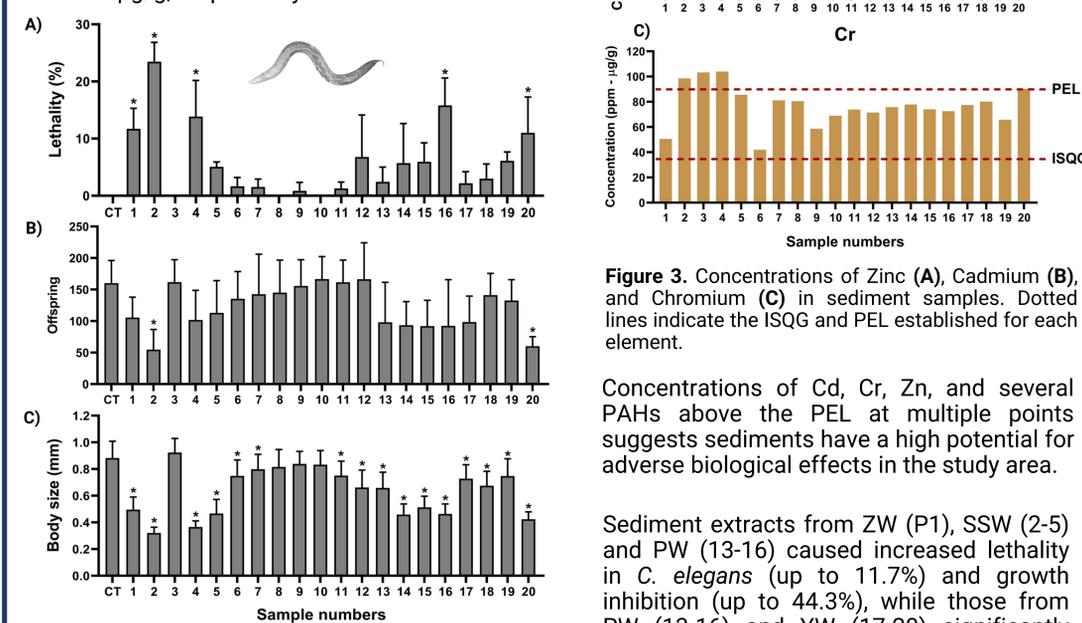


Figure 3. Concentrations of Zinc (A), Cadmium (B), and Chromium (C) in sediment samples. Dotted lines indicate the ISQG and PEL established for each element.

Concentrations of Cd, Cr, Zn, and several PAHs above the PEL at multiple points suggests sediments have a high potential for adverse biological effects in the study area.

Figure 4. Assessment of lethality (A), reproduction (B), and growth (C) using *C. elegans*. *Significant mean difference ($p < 0.05$) compared to the control group (CT).

Sediment extracts from ZW (P1), SSW (2-5) and PW (13-16) caused increased lethality in *C. elegans* (up to 11.7%) and growth inhibition (up to 44.3%), while those from PW (13-16) and YW (17-20) significantly reduced offspring production by 41.3% and 32.9%, respectively.

References

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Conclusions

Wetlands surrounding the refinery are impacted by persistent pollutants, with biological toxicity in *C. elegans*. These substances, potentially combined with unidentified co-occurring pollutants, may exert synergistic effects that increase toxicity. Strengthened environmental monitoring is essential to protect these ecosystems.

Acknowledgments

The Environmental and Computational Chemistry Research Group at the University of Cartagena acknowledges the Environmental Investigation Agency (EIA) for funding this research. We invite you to scan the QR code to watch the documentary "Life at 50°C: Revealing the Toxic Legacy of Colombia's Oil Giant" (BBC World Service Docs), which features findings from this study.

