Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 455 (P-5), 2025, pp. 269–271
DOI: 10.25171/InstGeoph_PAS_PubIs-2025-148
40th International Polar Symposium – Arctic and Antarctic at the Tipping Point, 4–7 November 2025, Puławy, Poland

Toolik Lake Sediment Record as a PAHs and Other Pollution Accumulation Proxy in Permafrost Region of Alaska

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1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs), despite not being listed in the Stockholm Convention (2001) on persistent organic pollutants (POPs), share several characteristics with the classic POPs and are distributed in the environment worldwide. They are environmentally persistent and toxic (Jiao et al. 2009); they act as carcinogens and mutagens (International Agency for Research on Cancer 1983).

Permafrost regions have been affected by climate warming resulting in intensification of the water cycle and changes in aquatic biogeochemistry. In those regions, lake bottom sediment sequences provide knowledge on short- and long-term environmental changes, including natural, man-made (coal and oil combustion) and mixed (wildfires) sources of PAHs in environment. Furthermore, observed intense flux of selected metals (O'Donnell et al. 2024; Malcata Martins et al. 2025) into aquatic environment show possible vulnerability of freshwater to leaching and remobilization of chemical compounds accompanying permafrost thaw.

Our research objectives focus on temporal changes in polycyclic aromatic hydrocarbon (PAHs) and selected metals and metalloids and the possible influence of environmental and human activity factors on it, including the recent climate change.

2. RESEARCH AREA AND METHODS

The study was performed in the Toolik Lake (68°38'00"N, 149°36'15"W; Area = 150 ha, $depth_{max}$ = 26 m), located 20 km north of the Brooks Range in Alaska (Fig. 1). The lake is located in the continuous permafrost zone, in moraine sediments, and was formed 12000 years ago as a kettle hole. In this study, lake sediment cores were collected in September 2023 with the use of UWITEC gravity core sampler for soft bottom sediments with plexiglas pipes Ø = 90 mm, at the deepest site of the main basin fed by the inlets (T1 core), and the second small basin separate from the main part of lake (T2 core). The cores were divided in the field and 30 samples were taken from the core T1 of the total length of 0.63 m, and 33 samples from the core T2 of the total length 0.67 m. Samples were stored in the cooler in zip-lock bags during transport into laboratory in Poland.

We analysed (PAHs) concentrations in sediment extracts in dichloromethane. 16 EPA PAHs concentrations were determined with a Nexis GC-2030 gas chromatograph, coupled to a GCMS-QP2020 NX mass spectrometer (Shimadzu, Japan). Strict QA/QC procedures were followed, and recoveries of 75–84% were achieved. Organic matter (OM) content (percentage) was determined by loss-on-ignition (LOI) method at 400°C for 4 h, to avoid removing clay minerals alongside organics in the process. Concentrations of selected metals and metalloids and non-metals with inductively coupled plasma – mass spectrometry.

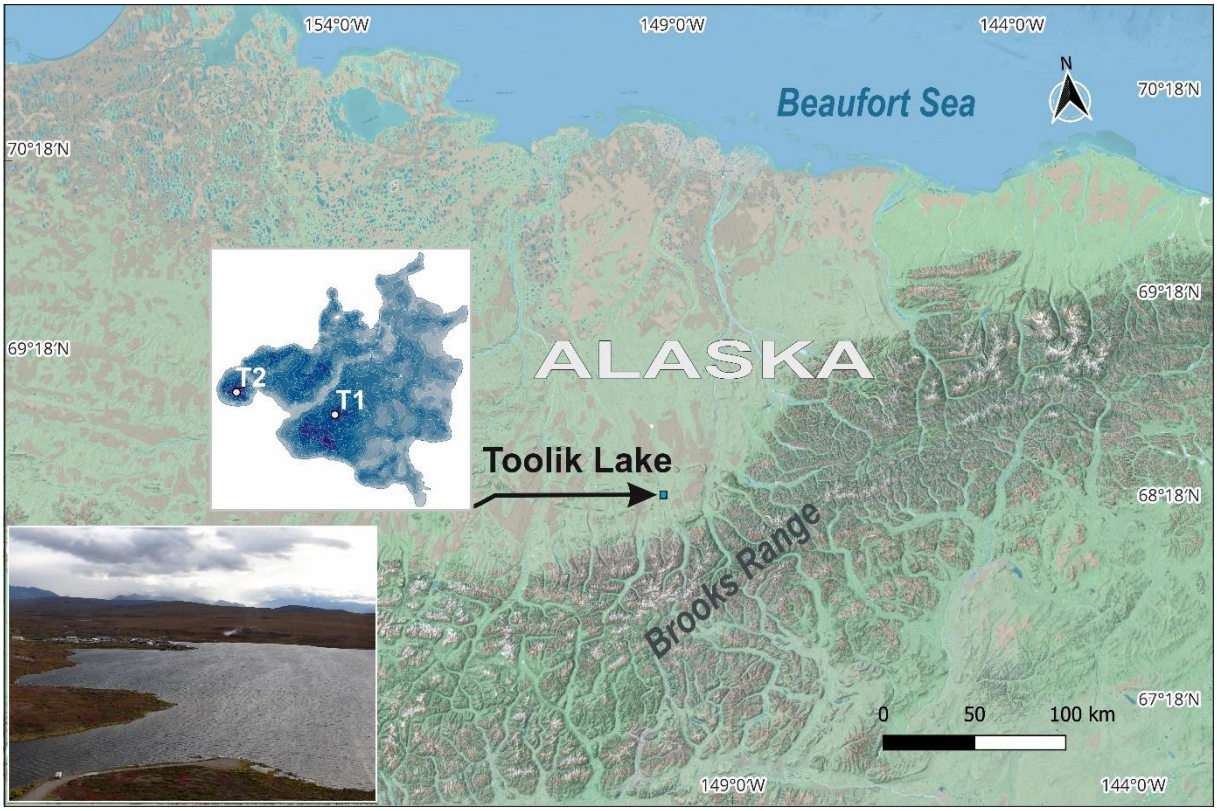

Fig. 1. Toolik Lake and sampling sites T1 and T2 locations (Map data ©2023 TerraMetrics, bathymetry based on Stuckey et al. (2019)).

3. RESULTS AND CONCLUSIONS

OM content was at a moderate level (median in core T1 at 17.1%, in core T2 at 24.8%) and OM variability with depth reached 5.6% and 3.7% (interquartile range, IQR) in core T1 and T2, respectively, excepting a single purely organic layer T2-21. PAHs varied along the cores, with a visible increase in core T2 and decrease in T1 toward the top. Predominant congeners at both

sites were phenanthrene, naphthalene, and benzo[a]pyrene. Non-parametric coefficients of variation (IQR divided by median) were 23.7%, 46.7%, and 109.6% for naphthalene, phenanthrene, and benzo[a]pyrene in core T1, respectively, while in core T2 they reached 49.1%, 59.1%, and 41.4% for the respective compounds. Concentration increases occurred for selected metals towards the top, more noticable in T1, located in the main lake basin, which is fed by the Toolik Inlet– the largest tributary of Toolik Lake (watershed area 46.6 km^2). Simultaneously, selected elements exhibited sharp concentration peaks in the deeper sections of the cores, especially core T2. Temporal changes in PAHs, metals and metalloids concentrations reflected possible influence of environmental and human activity, including the recent climate change.

Acknowledgments. This study was funded by the National Science Centre of Poland (NCN), PER2Water project (no. 2021/41/B/ST10/02947).

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Received 15 September 2025
Accepted 20 October 2025