Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 455 (P-5), 2025, pp. 243–244
DOI: 10.25171/InstGeoph_PAS_Publs-2025-140
40th International Polar Symposium – Arctic and Antarctic at the Tipping Point, 4–7 November 2025, Puławy, Poland

ARCTIC-O_3: Ozonation as a Wastewater Treatment Strategy for Sensitive Ecosystems: A Polish Case Study for Arctic Applications

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Abstract

The Arctic environment is one of the most vulnerable regions on Earth, facing increasing pressure from human activities such as tourism and settlement expansion. These fragile ecosystems, uniquely adapted to extreme conditions, are highly sensitive to disturbances caused by pollution. Among the most pressing challenges is the discharge of untreated wastewater into the environment, which introduces organic pollutants, nutrients, and emerging contaminants, such as antibiotics and antibiotic resistance genes (ARGs) (Khan et al. 2020; Phoon et al.2020). Addressing these challenges requires innovative, scalable, and cost-effective solutions tailored to the harsh Arctic conditions.

Polar regions, including Longyearbyen in Svalbard, are experiencing growing environmental pressure due to increasing tourism, which leads to potential ecosystem degradation and pollution from untreated wastewater. Approximately 285,000 m³ of untreated wastewater is discharged annually into the local fjord, posing unknown ecological risks. A previous project, entitled "Influence of wastewater on the bacterioplankton community and its characteristics in Adventfjorden, Svalbard", financed by the Research Council of Norway (Svalbard Science Forum), revealed the presence of antibiotics and ARGs in wastewater effluents. These findings highlighted the urgent need for solutions to address wastewater contamination in such fragile environments.

Building on these findings, the ARCTIC-O_3 project explores ozonation as a treatment method to reduce the environmental impact of untreated wastewater (Lim et al. 2022). It aims to evaluate the effectiveness of ozonation in removing organic, biogenic, and micropollutant contaminants, including antibiotics and ARGs, in regions where conventional biological treatment is impractical (Chu et al. 2020; Hou et al. 2019; Czech 2012; Feng et al. 2016). By addressing challenges like low temperatures and permafrost, the project seeks to offer a practical solution for protecting sensitive Arctic ecosystems.

Different ozone doses are being tested to study the effectiveness of wastewater treatment in reducing faecal contamination, removing pharmaceuticals, and affecting the presence of antibiotic resistance. Firstly, the tests are being carried out on the pilot treatment plant in Jastrzębia Góra, Poland, to optimise the ozone dosage and assess the balance between reducing pollutants and energy costs. Secondly, the chosen approach will be tested on wastewater samples from Longyearbyen to consider the actual biochemical content of the wastewater. Ultimately, this will hopefully lead to the development of an effective, economically viable wastewater treatment solution for sensitive Arctic environments.

Preliminary results of the ARCTIC-O_3 project demonstrate that a satisfactory reduction of fecal indicator bacteria (E. coli reduction of 99.9%, equivalent to a 2-log reduction) can be achieved at an ozone consumption of approximately 200 mg/L. The ozonation process can be operated through two distinct modes of action: (a) intensive ozonation which achieves the desired bacterial reduction in a shorter time by applying higher ozone concentrations, and (b) lower ozone flow which reaches the same reduction over a longer treatment period, using reduced ozone flow rates. The economic feasibility of each mode is going to be evaluated based on the ozone consumption costs and operational efficiency. The final decision is based on the integration of chemical and microbial results, ensuring the chosen method is both effective and economically viable for sensitive Arctic environments.

Acknowledgments. The project was funded by the Argentum Triggering Research Grants program as part of the Gdansk University of Technology Initiative of Excellence Research University.

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Received 3 September 2025
Accepted 20 October 2025