As water scarcity, rising energy costs, and stricter environmental regulations continue to challenge societies worldwide, managing wastewater has become more important than ever. A new EU regulation (Directive 2024/3019) now requires an additional, fourth stage of treatment to remove stubborn pollutants like pharmaceuticals and industrial chemicals that slip through standard treatment processes. These substances, such as painkillers and chemical additives, can harm both ecosystems and human health, even in tiny amounts.

To tackle this, we urgently need better methods to remove these pollutants, especially by improving how we treat wastewater. Given the global water crisis, it’s crucial to add a new stage to wastewater treatment that focuses on removing these harmful substances. Advanced oxidation processes (AOPs) have shown promise but are expensive due to high energy costs. However, sulfate radical-based AOPs (SR-AOPs), which use a substance called PMS, could make the process more efficient and versatile. Using solar energy could make these methods more cost-effective and sustainable. Specifically, using sunlight in a special type of reactor called a Compound Parabolic Collector (CPC) could cut costs and support eco-friendly development. However, most research on this technology has been done using artificial, or in sunny Mediterranean countries using natural sunlight, not in temperate climates like Poland, which has fewer sunny days. Studies often use pure water, which doesn't reflect real-world conditions, making the data less reliable. Additionally, these studies frequently overlook the potential toxicity of by-products formed during the process, which could be more harmful than the original pollutants. It's also important to test the technology under various conditions, including different seasons and weather, to see how it performs.

The goal is to understand how sunlight, temperature, and water composition affect the process, and whether it can be used reliably in less sunny climates. The study will also check if the breakdown products are safe for the environment by conducting toxicity tests on different aquatic organisms. In addition, a Life Cycle Assessment (LCA) will evaluate how sustainable and environmentally friendly this technology really is, considering energy use, emissions, and potential to support a circular economy.

The results obtained can provide information on processes that utilize sunlight, while ensuring environmental safety. Additionally, these findings could guide the development of water purification and wastewater treatment technologies, specifically for the removal of organic micropollutants from environmental aquatic matrices. Moreover, these results can serve as a preliminary step for broader analyses of AOPs technologies on a larger scale and their potential development in countries with a temperate transitional climate, such as Poland.