NJ Department of Environmental Protection
Division of Science and Research

A Factsheet: Plasma Based Treatment Technologies for PFAS and 1,4-Dioxane in New Jersey Drinking Water and Regional Waste water Treatment Plants

March 2025

Report Authors and Affiliations:
Selman Mujovic, PhD., Purafide

Factsheet Prepared by:
Zahid Aziz, Ph.D., NJDEP Division of Science and Research

What was the purpose of the study?

Emerging contaminants such as Per- and Polyfluoroalkyl Substances (PFAS) and 1,4-dioxane are linked to potential health concerns, including cancer, reproductive issues, thyroid problems, and other health risks. Both PFAS and 1,4-dioxane are synthetic chemicals that have been widely used in various applications, including consumer products, industrial processes, and firefighting foam. They have been detected in water sources, including drinking water, groundwater, and surface water.

1,4-dioxane is a persistent compound that can resist biodegradation and chemical oxidation, making it difficult to remove using traditional treatment methods. Similarly, proven and readily available treatment techniques for PFAS are limited. Currently, three effective treatment processes are in use for PFAS removal from water: granular activated carbon, ion exchange resins, and high-pressure membrane systems. However, these treatments generate concentrated secondary waste streams high in PFAS without proper and environmentally sound disposal solutions.

This study used novel plasma-based treatment technologies to improve our understanding of mechanisms to break down PFAS and 1,4-dioxane into inert components. Further, the study sought to develop an environmentally friendly and cost-effective process for the destruction and ultimate removal of these contaminants from water, rather than simply filtering the contaminants.

Plasma-based water treatment is a promising technology that uses ionized gas to break down PFAS and 1,4-dioxane in water. Plasma water treatment was tested on wastewater, leachate-impacted groundwater, and landfill leachate. It is hoped that, if successful, plasma can be used in a device to create a Point of Entry Treatment (POET) system, which would be installed at the entry point to a building or home and treat all water entering the building.

What was the general approach to this study?

Purafide developed the Plasma Water Reactor (PWR), which uses an innovative design to enhance plasma generation while minimizing energy consumption for the breakdown of some PFAS and 1,4-dioxane. Plasma can simultaneously oxidize and reduce organic compounds and other contaminants including PFAS and 1,4-dioxane by producing a mixture of hydroxyl radicals and aqueous electrons. Additionally, the plasma process produces no residual waste and requires no chemical additions. Purafide performed bench-scale studies in their laboratory using the PWR under various operating conditions to estimate the treatment effectiveness and relative cost. The experiments with the PWR system demonstrated that considerable destruction of the target contaminants, regardless of the source of the water samples. It was observed that the PWR showed substantial destruction of perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorononanoic acid (PFNA), and 1,4-dioxane, unlike other conventional methodologies.

Overall, what did the studies show?

The study:

- tested the effectiveness and cost of treating PFOA, PFOS, PFNA, and 1,4-dioxane in water using plasma;
- demonstrated variable reaction rates and removal efficiency across contaminants and water types. Overall, plasma achieved good PFAS destruction even with background interferences;
- documented formation of shorter-chained PFAS, indicating destruction of regulated longer chain PFAS such as PFOA, PFOS, and PFNA. Theoretically, PFAS and other contaminants would be completely destroyed with a sufficient treatment time, leading to formation of harmless products such as carbon dioxide, elemental fluorine, and water;
- showed high destruction efficiency of over 90% for PFOA, and PFOS, at a range of high concentrations (Figure 1; 90.0 – 0.40 μg/L; ppb observed in leachate-impacted groundwater and landfill leachate) but did not quantify destruction at lower concentrations given the limited treatment time. However, reductions in PFOS and PFNA were observed in the landfill leachate sample which had relatively lower average initial concentrations of 444 and 137 ng/L (ppt) and were reduced to 11.35 and 4.45 ng/L respectively, which are below the maximum concentration limit of 13 ng/L in drinking water;

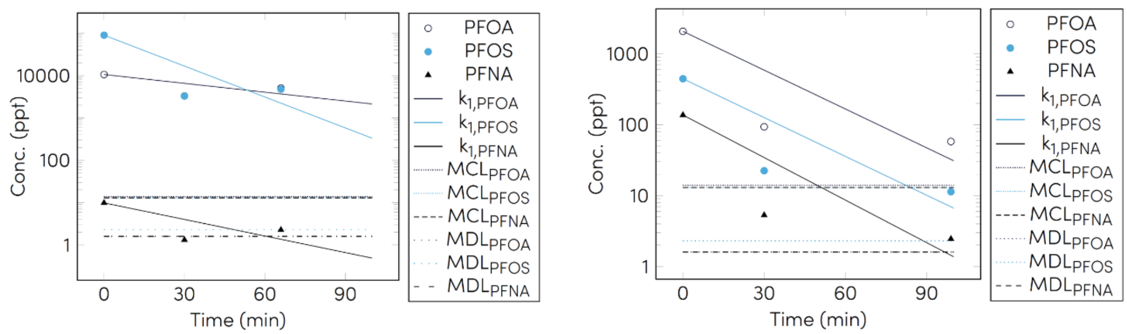

Figure 1: Plasma-based destruction of regulated PFAS in leachate-impacted groundwater (Left) and in landfill leachate (Right)

- estimated costs for treating leachate-impacted groundwater and landfill leachate samples to reduce selected PFAS below maximum concentration limits. Cost ranged from $32 to $240 for leachate-impacted groundwater and $14 to $69 per thousand gallons for landfill leachate, respectively. Costs significantly decreased for samples with initially lower concentrations, such as landfill leachate. Based on previous experience however, Purafide believes that costs are independent of initial concentration; rather, it is the source (leachate, groundwater, etc.) that determines the treatment time and ultimate cost;
- showed reduction of 1,4-dioxane in wastewater with an average initial concentration of 1.50 µg/L (ppb) to concentrations below the New Jersey Ground Water Quality Standard (0.40 µg/L) and the method detection limit (0.16 µg/L).
- showed less significant 1,4-dioxane reduction in leachate-impacted groundwater (2800.0 µg/L average initial concentration) and landfill leachate (89.0 µg/L average initial concentration), with only 27% removal for treatment times of up to 90 minutes. It is worth mentioning that Purafide observed higher rates of destruction of 1,4-dioxane in other leachate samples when exposed to longer treatment times, but these samples were not part of this study;
- discussed how the PWR system may serve as a POET treatment system and/or be integrated with other technologies in industrial and waste management facilities.

How will DEP use the data?

The study shows that the breakdown of some PFAS chemicals and 1,4-dioxane by plasma-induced reactions may lead to a cleaner, more sustainable approach to contaminant removal and water clean-up. In the long term, this technology could create a dynamic, cost-effective plasma-based treatment system for PFAS and 1,4-dioxane in drinking and wastewater samples. The results of the investigation are useful for understanding the mechanisms of PFAS and 1,4-dioxane breakdown and destruction and could lead to improvements in the water quality control strategies and treatment methods developed by NJDEP.

Please review the full report for more detailed information at https://hdl.handle.net/10929/145703

Funding for this study was provided by NJDEP and managed under NJ DEP contract 23-SR-19628.

Who to contact with further questions?

For more information on this report, feel free to contact Zahid Aziz (Zahid.Aziz@dep.nj.gov).

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