Cold Plasma for Water Treatment: A Technical Report Based on Patent Literature

Abstract (Summary)

This report analyzes patent literature concerning the application of cold plasma technology for water treatment. The inventions detailed address various challenges in water purification, disinfection, and wastewater treatment, offering alternatives to traditional methods like chlorination, UV radiation, and chemical treatments. The core focus lies in utilizing cold plasma to generate reactive species for oxidizing organic pollutants, eliminating pathogens, and producing sterile water. The applications span diverse areas, including drinking water disinfection, industrial wastewater treatment, agricultural irrigation, and portable water purification systems.

Background and Challenges

Traditional water treatment methods often face limitations in addressing emerging contaminants, high energy consumption, chemical usage, and the generation of harmful byproducts. Chlorination, while effective, can produce disinfection byproducts. UV radiation may be ineffective against certain contaminants. Ozone treatment can be costly. These challenges drive the need for innovative, efficient, and environmentally friendly water treatment technologies. Cold plasma technology emerges as a promising alternative, offering non-chemical disinfection and pollutant degradation capabilities.

Technical Fields of Invention

The inventions discussed in this report fall within the following technological areas:

- **Water Disinfection:** Utilizing cold plasma to eliminate bacteria, viruses, and other pathogens in water (US10604422B2, US11053140B2, EP4001220C0, US12116292B2, US11939243B1, WO2023160811A1).
- **Wastewater Treatment:** Applying cold plasma for the degradation of organic pollutants and complex hydrocarbons in wastewater (WO2021258229A1, WO2011021515A1, WO2023250193A1).
- **Plasma Generation:** Developing efficient and compact cold plasma generators for water treatment applications (EP3272715A4, WO2023160811A1).
- **Fertigation:** Using plasma to generate soluble nitrogen-bearing species for in-situ fertilizer production in irrigation water (US9475710B2).
- **Water Treatment Systems:** Integrating cold plasma technology into comprehensive water treatment systems for various applications (WO2017086499A1, US11939243B1, WO2023250193A1).

Inventions Related to Cold Plasma for Water Treatment

1. Integrated Water Disinfection Systems:

- **Novelty and Objectives:** These inventions focus on integrating cold plasma disinfection directly into water containers, providing a portable and non-chemical solution for water purification. The objective is to address the

limitations of traditional methods against emergent contaminants in remote or disaster areas.

- **Unique Components:** These systems typically include a water container, a high voltage power source, electrodes submerged in the water, a power source controller, and an activation device (US10604422B2, US11053140B2).
- **Technical Problems Solved:** These inventions solve the problem of emergent contaminants that traditional methods may fail to sanitize. They improve upon existing methods by providing a portable, non-chemical disinfection solution.

  (Relevant)

2. Decentralized Plasma Discharge Apparatus:

- **Novelty and Objectives:** This invention aims to provide a mobile, energy-efficient, and high-throughput water treatment system that overcomes the drawbacks of chlorination and other disinfection methods.
- **Unique Components:** The core of the invention is a plasma reactor comprising a liquid pump that recirculates liquid flow between a first liquid outlet port and a first liquid inlet port, wherein the first liquid inlet port supplies liquid water to a liquid drop or a droplet generator (US12116292B2).
- **Technical Problems Solved:** This invention eliminates metal electrode erosion and contamination by producing plasma discharge between liquid electrodes.

  (Relevant)

3. Cold Plasma Generators for Plasma-Activated Water (PAW):

- **Novelty and Objectives:** These inventions focus on creating compact, customizable, safe, and low-cost systems for generating plasma-activated water (PAW) to disinfect water systems.
- **Unique Components:** These systems utilize a dielectric barrier discharge (DBD) plasma generator with a shapable electrode formed by an insulated electrical wire (WO2023160811A1).
- **Technical Problems Solved:** These inventions address the limitations of existing water decontamination methods that suffer from low efficiency and high energy consumption.

  (Relevant)

4. Wastewater Reclamation Systems with Cold Plasma:

- **Novelty and Objectives:** These inventions aim to provide a cost-effective solution for municipal and industrial wastewater facilities to reuse effluent for irrigation, groundwater recharge, and various industrial processes.
- **Unique Components:** The core of the invention is a wastewater reclamation system comprising a primary screening system, a nano-bubbler, a depository, an electrostatic device, a cold plasma unit, a solid separation

system, a carbon filter with expanded graphene, pumps and conduits, sensors, and a controller (WO2023250193A1).

- **Technical Problems Solved:** These inventions address the need for systems that meet stringent requirements for organic matter, complex hydrocarbons, and pharmaceuticals breakdown.

(Relevant)

5. Water Treatment Device with Integrated Electrode and Ceramic Structure:

- **Novelty and Objectives:** This invention aims to improve energy efficiency in plasma generation and enhance the efficiency of dissolving active species generated by the plasma in water.
- **Unique Components:** The core of the invention is a water treatment device comprising first and second electrodes and a ceramic structural body for introducing gas to generate plasma and active species, wherein the ceramic structural body and at least one electrode are integrated (EP3272715A4).
- **Technical Problems Solved:** This invention addresses the problem of high energy consumption and poor active species dissolution in conventional devices.

(Relevant)

6. Flow-Through Hydrodynamic Plasma Reactor:

- **Novelty and Objectives:** This invention aims to provide a reliable device and method for purifying water from bacteriological and chemical contaminants, addressing the shortcomings of existing water purification devices such as complexity, high energy consumption, and limited effectiveness.
- **Unique Components:** The core of the invention is a system for flow-through-hydrodynamic-plasma-reactor-based water treatment, comprising a housing, a channel within the housing, an electrically conductive flow body installed in the channel, an electrode located within the channel between the flow body and the exit, a pulse generator and a plurality of magnets positioned on an outer surface of the housing (US11939243B1).
- **Technical Problems Solved:** This invention utilizes cold plasma generated within fine bubbles in a turbulence zone to produce reactive oxygen species (ROS) for oxidizing contaminants.

(Relevant)

Applicability and Uses

The inventions described have broad applicability across various sectors:

- **Drinking Water Disinfection:** Portable water bottles (US10604422B2, US11053140B2) and decentralized systems (US12116292B2) provide safe drinking water in remote areas or during emergencies. (Relevant)
- **Wastewater Treatment:** Cold plasma systems can be integrated into municipal and industrial wastewater treatment plants to remove organic

pollutants and meet stringent discharge requirements (WO2021258229A1, WO2023250193A1). (Relevant)

- **Agricultural Irrigation:** Plasma-treated water can be used for fertigation, providing soluble nitrogen species for plant growth (US9475710B2). (Relevant)
- **Aquaculture:** Plasma water treatment devices can maintain water quality in aquariums by removing contaminants and foam (WO2017086499A1). (Relevant)
- **Industrial Applications:** Cold plasma can be used for treating industrial wastewater, cooling tower water, and process water in various industries.
- **Sterile Water Production:** The technology can be used to produce sterile water with improved bactericidal effect (EP3272715A4). (Relevant)

Conclusion

The patent literature reveals a growing interest in cold plasma technology for water treatment. The inventions address critical challenges in water purification, disinfection, and wastewater treatment, offering innovative solutions that are efficient, environmentally friendly, and cost-effective. The diverse applications of cold plasma in water treatment highlight its potential to revolutionize water management practices across various sectors.

Citations

- US10604422B2 (Relevant)
- US11053140B2 (Relevant)
- EP4001220C0 (Relevant)
- US12116292B2 (Relevant)
- WO2021258229A1 (Relevant)
- WO2011021515A1 (Relevant)
- US9475710B2 (Relevant)
- WO2017086499A1 (Relevant)
- EP3272715A4 (Relevant)
- US11939243B1 (Relevant)
- WO2023160811A1 (Relevant)
- WO2023250193A1 (Relevant)

Contexts: WO2021258229A1 :: METHOD AND SYSTEM FOR THE DIRECT AND ECONOMICAL ACCELERATED OXIDATION OF DOMESTIC WASTEWATER, LIQUID INDUSTRIAL WASTE, OTHER WASTEWATER AND DRINKING WATER IN SITU\n
US10604422B2 :: Water container with integrated plasma disinfection\n
US11053140B2 :: High voltage (plasma) based water disinfection method and system for water containers\n
EP4001220C0 :: WATER PURIFIER AND WATER PURIFICATION SYSTEM\n
US12116292B2 :: Plasma-based water treatment apparatus\n
WO2011021515A1 :: WATER TREATMENT APPARATUS\n
US9475710B2 :: Very high frequency (VHF) driven atmospheric plasma sources and point of use fertigation of irrigation water utilizing plasma production of nitrogen bearing species\n

WO2017086499A1 :: WATER TREATMENT DEVICE USING PLASMA\n EP3272715A4 :: WATER TREATMENT DEVICE, WATER TREATMENT METHOD, STERILE WATER PRODUCTION DEVICE, AND STERILE WATER PRODUCTION METHOD\n
US11939243B1 :: Device, system, and method for flow-through-plasma-hydrodynamic-reactor-based water treatment\n US7767167B2 :: Dielectric barrier discharge cell with hermetically sealed electrodes, apparatus and method for the treatment of odor and volatile organic compound contaminants in air emissions, and for purifying gases and sterilizing surfaces\n WO2019040991A1 :: A METHOD FOR THE TREATMENT OF EUKARYOTIC MICROORGANISMS\n
WO2006123258A3 :: WATER PURIFICATION AND TREATMENT DEVICE AND METHOD FOR DESALTING OR PURIFYING WATER\n WO2023160811A1 :: COLD PLASMA GENERATOR AND APPLICATIONS COMPRISING SAME\n
WO2023250193A1 :: PROCESS AND METHOD FOR TERTIARY WASTEWATER TREATMENT\n
, WO2021258229A1 :: METHOD AND SYSTEM FOR THE DIRECT AND ECONOMICAL ACCELERATED OXIDATION OF DOMESTIC WASTEWATER, LIQUID INDUSTRIAL WASTE, OTHER WASTEWATER AND DRINKING WATER IN SITU\n
US10604422B2 :: Water container with integrated plasma disinfection\n US11053140B2 :: High voltage (plasma) based water disinfection method and system for water containers\n EP4001220C0 :: WATER PURIFIER AND WATER PURIFICATION SYSTEM\n US12116292B2 :: Plasma-based water treatment apparatus\n WO2011021515A1 :: WATER TREATMENT APPARATUS\n US9475710B2 :: Very high frequency (VHF) driven atmospheric plasma sources and point of use fertigation of irrigation water utilizing plasma production of nitrogen bearing species\n
WO2017086499A1 :: WATER TREATMENT DEVICE USING PLASMA\n EP3272715A4 :: WATER TREATMENT DEVICE, WATER TREATMENT METHOD, STERILE WATER PRODUCTION DEVICE, AND STERILE WATER PRODUCTION METHOD\n
US11939243B1 :: Device, system, and method for flow-through-plasma-hydrodynamic-reactor-based water treatment\n
WO2006123258A3 :: WATER PURIFICATION AND TREATMENT DEVICE AND METHOD FOR DESALTING OR PURIFYING WATER\n WO2023160811A1 :: COLD PLASMA GENERATOR AND APPLICATIONS COMPRISING SAME\n
WO2023250193A1 :: PROCESS AND METHOD FOR TERTIARY WASTEWATER TREATMENT\n