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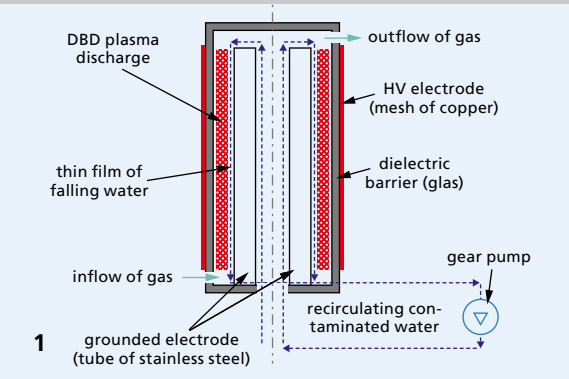

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1 *Schematic structure of a plasma reactor for water treatment.*
2 *Drinking water is often polluted.*

PLASMA PROCESS FOR WATER PURIFICATION

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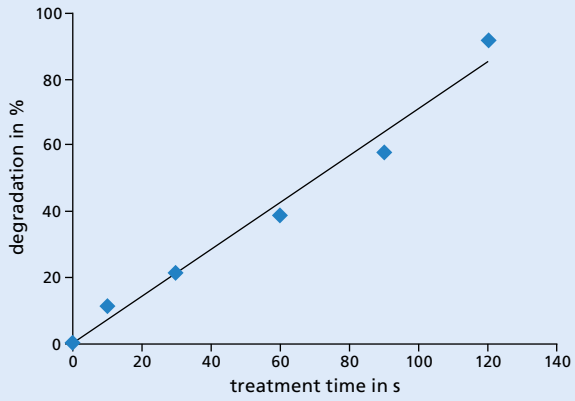
Baseline situation

In many parts of the world, drinking water has become a scarce commodity. Along with the increase in water consumption, this is also due to a progressive contamination of wastewater with pollutants that are difficult to remove and greatly complicate reprocessing to drinking water. In addition to improving water management, efficient methods for wastewater recycling including a quaternary treatment unit are increasingly gaining importance.

Conventional wastewater treatment

Pollutants contained in the wastewater are conventionally removed in centralized sewage treatment plants by mechanical separation of the solid content (primary treatment stage), followed by biological and physico-chemical methods such as precipitation (secondary and tertiary stages). Increasingly, however, such substances pose problems that are hardly accessible by chemical and biological means. These include drug residues, pesticides, herbicides and chemicals in industrial wastewater. These substances can be removed in the so-called quaternary treatment step by means of advanced oxidation processes (AOP) using oxidizing agents such as ozone and hydrogen peroxide as well as UV radiation. However, these cleaning methods generally require chemical additives that are considered hazardous substances, which must be applied in a suitable dosing scheme and disposed of properly.



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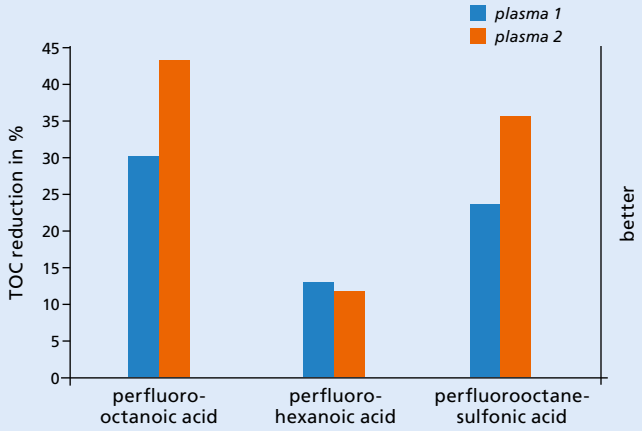

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Plasma processes for water purification

The use of plasma processes is an environmentally friendly and cost-effective alternative. By applying an electrical current, ions, highly-reactive short-lived radicals and short-wave radiation are generated in the plasma from the ambient air and atmospheric oxygen, and break down the wastewater constituents. Hence, the use of additional chemicals and their disposal is not required because the reactive particles are generated only during discharge and react rapidly with pollutants disolved in water due to their high reactivity.

Novel plasma reactors

At the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, we develop different concepts for plasma processes. To make the process efficient, an effective transfer of highly reactive species formed in the plasma and the plasma radiation into the polluted water must be ensured. To achieve this, the plasma is in direct contact with the water, as displayed in the system shown in Fig. 1. Here, the water falls by gravity via an electrode. The plasma forms between the water surface and a counter-electrode, which is located outside of the reactor. In the plasma, hydroxyl radicals are formed, inter alia, which pass into the water and decompose the dissolved pollutants to mineralization with their high oxidation potential. In addition, free radicals form in the water secondary to the shortwave UV radiation, which is also generated in the plasma. An advantage of this method is that the treated water surface is continually renewed and therefore, unlike conventional UV-cleaning, does not pollute glass components of the radiation sources and reduce the efficiency of the systems. Solarization of optical components plays no role here either.

Energy consumption is often used for the purpose of AOP process evaluation, which is required for discoloration of methylene blue by an order of magnitude [1]. Using the plasma method shown as an example, 4 g/kWh is attained. This value is almost one order of magnitude better than that achieved using UV-H_2O_2 treatment with methylene blue [2]. 90 percent of cyanide was degraded within 2 minutes (Fig. 3) [3]. In addition, significantly more complex molecules such as various perfluorinated surfactants (electroplating and textile industry) can be degraded by means of plasma (Fig. 4).

Future prospects

In contrast to the established advanced oxidation processes, the plasma process for water decontamination uses no barrier between the plasma and the medium to be cleaned. It is therefore virtually maintenance-free and characterized by a long service life.

Our service offerings

- Investigation of contaminant degradation using different plasma processes on a bench scale
- Determination of degradation efficiency
- Characterization of degradation products
- Process scaling

We are pleased to carry out this work on behalf of customers or as part of funded projects.

References

[1] Malik, M. A. (2010) Water purification by plasmas: Which reactors are most energy efficient?, Plasma Chem. Plasma Proc. 30: 21–31

[2] Siemens Industry (2011) New actinometry procedure for industrial UV applications, http://www.industry.siemens.com/topics/global/en/fairs/siww/water-convention/Documents/09_Poster_New-Actinometry-Procedure.pdf

[3] Hijosa-Valsero, M.; Molina, R.; Schikora, H.; Müller, M.; Bayona, J. M. (2013) Removal of priority pollutants from water by means of dielectric barrier discharge atmospheric plasma, Journal of Hazardous Materials 262: 664–673

3 *Degradation of 1 mg/L of cyanide in water by plasma treatment.*

4 *Degradation of organofluorine surfactants by means of plasma processes. The figure shows TOC reduction (total organic carbon).*