Non-thermal plasma treatment of landfill leachate for detoxification of hazardous pollutants

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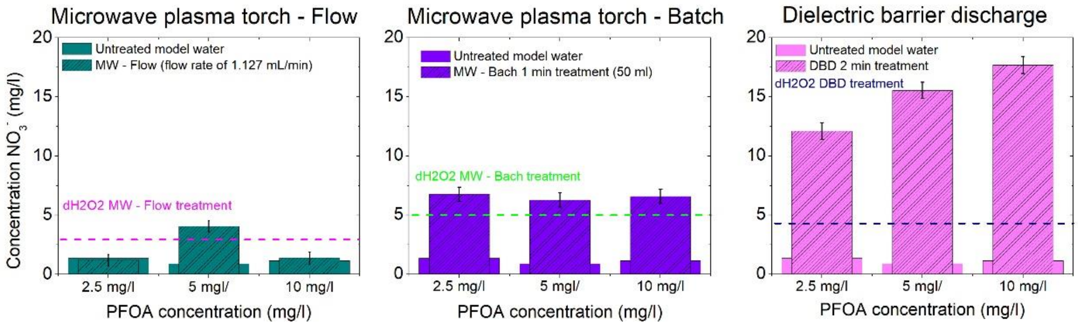
Novel plasma sources find their place from industry to biomedicine – including ecology and environmental protection, sustainable agriculture, food processing and safety, microbiological control, etc. Low-temperature plasma has made a significant impact on society over the past half-century. The development of low-temperature plasma technologies presents a new opportunity to improve the quality of life and open new areas for advanced research. A new opportunity for the application of plasma technology appears in the efforts on waste and wastewater management. One of the main problems of long-term storage of solid waste from urban daily activities is the production of leachate – a highly concentrated organic and nitrogen-rich liquid [1]. The leachate from solid waste landfills contains high concentrations of various organic and inorganic recalcitrant compounds, most of which are highly toxic. The treatment of this complex mixture of contaminants of environmental concern, including per- and polyfluoroalkyl substances (known as PFAS) is a challenge for waste/wastewater management and conventional technologies usually have low efficiency. Cold atmospheric plasma (CAP) sources of various types operating at atmospheric pressure usually produce a non-equilibrium plasma that can be used for the successful degradation of complex organic compounds [2].

This study is focused on the possibility of reduction in PFAS concentrations in model water and leachate contaminated with Perfluorooctanoic acid (PFOA) after treatment with plasma. In the treatment of wastewater and sludge with a high content of various pollutants, it is of particular interest how the additional contaminants affect the degradation of PFAS. The competitive reactions to the PFAS defluorination occurring during the treatment need to be investigated. Determining the dependence between the concentrations of contaminants such as NOx and the suppression in degradation of persuasive compounds will not only help to increase the degradation ratio but also to understand the mechanisms of PFAS degradation. It was previously reported that the process was strongly impacted by the presence of NO_2 and NO_3 due to scavenging of H and e-aq [3].

Three plasma sources (Surface-wave-sustained Argon plasma torch, underwater discharge and dielectric barrier discharge) operating at various discharge conditions have been used to produce the plasma in order to describe the effect of the plasma treatment of model water contaminated with PFOA and leachate contaminated with PFAS. In surface-wave-sustained Argon plasma torch, the plasma is produced by a microwave plasma torch sustained by an electromagnetic surface wave at 2.45 GHz in Argon at atmospheric pressure and input wave power of 100 W. The microwave plasma torch can operate in two treatment regimes – the designed experimental setup allowed the achievement of a continuous flow process of treatment (flow rate of 1.127 mL/min) and a batch treatment. The dielectric barrier discharge (DBD) with liquid electrode generates plasma discharge above water surface at high frequency power supply with frequency of 11 kHz which operates at voltage of 16 kV and mean power is 36 W. The underwater diaphragm discharge used in this study consist of camera separated by a dielectric membrane in two containers. The high frequency (15 kHz) voltage of 5 kV is applied to the electrode in the camber denoted by "+" and the electrode denoted by "–" is grounded. The obtained concentrations of reactive oxygen and nitrogen species in the treated water in the presence of PFOA have been investigated, as well as changes in the concentration of PFOA during plasma treatment depending on the presence of other pollutants in variable concentrations. The case of obtaining shorter chain PFAS as a consequence of the treatment is considered.



(a) (b) (c)

Fig. 1: Concentration of NO_3^- in model water contaminated with PFOA treated by microwave plasma torch in water flow configuration (a), microwave plasma torch in batch configuration and treatment time 1 min (b) (MW power 100 W, Argon flow 3 l/min) and dielectric barrier discharge and treatment time 2 min (c). The dashed lines correspond to NO_3^- concentration in treated distilled water without added contaminants.

When dealing with multicomponent systems, such as highly polluted wastewater together with the plasma as a complex system of reactive species, electrons and UV, changes in the concentration of the various constituents must be carefully monitored. The possibility of reducing toxic pollutants during plasma treatment is promising, but obtaining new no less toxic compounds in high concentration as products of PFAS degradation is also a possible outcome.

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