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THE COMPARISON OF THE EFFICIENCY OF LOW-PRESSURE MERCURY VAPOUR LAMP AND XENON EXCIMER LAMP IN THE VUV PHOTOLYSIS OF SULFONAMIDE ANTIBIOTICS

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Abstract

VUV radiation (λ < 200 nm) generates reactive HO• and H• directly from the water without addition of any oxidizing agents. Two VUV light source was investigated and compared for the removal of sulfonamide antibiotics, as hazardous substances, from aqueous solution. The low-pressure mercury vapour lamp, emits 254 nm UV and 185 nm VUV light, is a commonly used to produce high-purity water. The other light source was a Xenon excimer lamp, which emits 172 nm VUV light. Although the photon flux of 172 nm VUV light was about five times higher than that of 185 nm VUV light, the formation rate of H_2O_2 in pure water was 40 times higher in the case of Xe excimer lamp. Transformation rate of antibiotics (sulfamethazine, sulfamethoxypyridazine, sulfachloropyridazine, sulfadimethoxine) were investigated and compared in the case of their four-components solutions. The effect of three different matrices (tap water, purified industrial wastewater and biologically treated domestic wastewater) were examined on the transformation rate of organic substances. The higher photon flux of 172 nm light did not cause much better efficiency, and proved to be more sensitive for the matrix parameters than UV/VUV_{185nm} radiation. It can be explained by the extreme inhomogeneity of 172 nm radiated solution.

Keywords: VUV photolysis, Sulfonamide, AOP

1 INTRODUCTION

Advanced Oxidation processes (AOPs) applied to oxidize harmful organic substances, which are difficult to degrade by traditional biological water treatment methods. VUV photolysis, one of the AOPs, is based on high-energy (wavelength <200 nm) radiation, which is able to cause the dissociation of water molecules and produce HO• and H•. During VUV photolysis, the reactive species are formed directly from the photolysis of water without any addition of oxidizing agents.

The molar absorbance of water highly depends on the wavelength: 185 nm photons are absorbed within 11 mm thin water layer, while 172 nm VUV photons are absorbed within 0.04 mm. This extreme inhomogeneity has several consequences.

2 EXPERIMENTAL

For the 172 nm radiation (VUV_{172nm}) Xe_2^* excimer light source was used. The lamp (Radium Xeradex™, 130 mm long, 46 mm diameter, 20 W) was centred in a high purity silica quartz envelope. For the UV/VUV_{185nm} (254 nm/185 nm) radiation a low-pressure mercury vapour (LP) lamp (227 mm arc length, produced by LightTech) was used. This lamp's envelope was made of synthetic quartz.

Separation of the aromatic components in the treated solutions was performed by Agilent 1100 type HPLC equipped with diode array detector (DAD). For the sulfonamides (sulfamethazine (SMT), sulfamethoxypyridazine (SMP), sulfachloropyridazine (SCP), sulfadimethoxine (SDM)) analysis, Lichrospher 100, RP-18; 5 µm column was used, thermostated at 30 °C, with 1.0 mL min^{-1} flow rate of eluent, and 20 µL sample was injected.

3 RESULTS AND DISCUSSION

During the VUV_{172nm} photolysis of Milli-Q water, HO• and H• are formed as primary species. Without organic substances, the recombination of HO• radicals result in the formation of H_2O_2. In the presence of dissolved O_2, another way is the recombination of less reactive HO_2• and O_2•⁻ (Figure 1.) In 172 nm radiated water about 40 times more H_2O_2 formed than in $UV/VUV_{185\,nm}$ radiated one, despite, that the ratio of photon fluxes is around 5 ($VUV_{172\,nm}$: 3×10^{-6} mol_{photon} s^{-1}; $VUV_{185\,nm}$: $5\text{-}7\times10^{-7}$ mol_{photon} s^{-1}). In O_2-free solution, H_2O_2 is formed in significant concentration only in the case of VUV photolysis, its value is almost a quarter of the value measured in O_2-saturated solution.

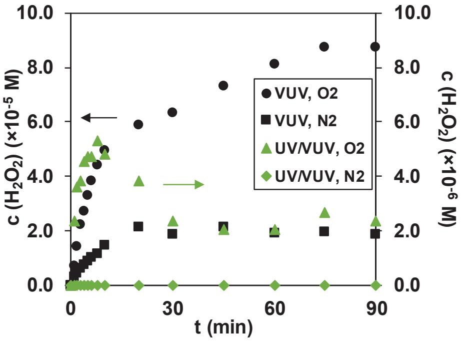


Figure 1. The concentration of H_2O_2 versus the time of irradiation in the case of UV/VUV_{185nm} and VUV_{172nm} photolysis

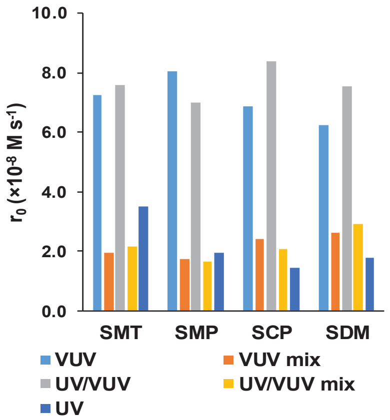
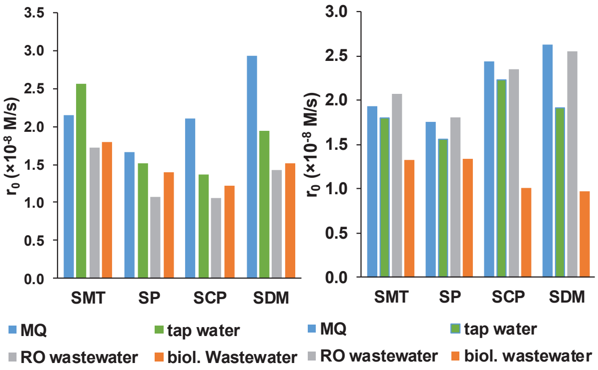


Figure 2. The transformation rates of one-component (2.0×10^{-5} M) containing solutions and four-component (2.0×10^{-5} M of each sulfonamide) solutions

As Figure 2. shows, UV photolysis has significant contribution to the transformation in UV/VUV_{185nm} radiated solutions. In the case of four-component mixtures, the transformation rate of each sulfonamide was reduced to 40–25% (Figure 2.), which can be explained by competition for HO• radicals. Despite the significantly higher photon flux, similar transformation rates were measured in solutions radiated with 172 nm light and in those radiated with 254/185 nm light. The volume of the treated solutions was the same (500 mL).

AOPs are generally used as post-treatment method in water treatment, thus it is important to investigate the effect of different type of water matrix on the transformation of harmful substances. Three different type of matrices were investigated in this study: tap water having high ionic content (conductivity: 627 □S cm^{-1}) and low organic content (COD: 0.79 mg L^{-1}), RO purified industrial wastewater (COD: 0.11 mg L^{-1}) and biologically treated domestic wastewater (conductivity: 1258 □S cm^{-1} COD: 6.9 mg L^{-1}) (Figure 3.).



a b

Figure 3. The effect of matrices UV/VUV (a) and VUV (b) photolysis

During UV/VUV photolysis, tap water had a positive effect in the case of SMT, while it has a negative effect in the case of SCP and SDM). In the case of VUV photolysis its effect is negligible. The RO-treated industrial water has no effect in the case of VUV_{172nm} photolysis, while biologically treated one strongly decreased the transformation rates. This is mainly due to the higher COD value and relative high HCO_3^- (103.4 mg L^{-1}) concentration.

Electrical Energy per Order (E_{EO}) were calculated and compared in each case. When biologically treated domestic water was used as matrix, the E_{EO} values were significantly higher for Xenon-excimer lamp.

The higher photon flux of 172 nm light did not resulted in much better efficiency, and proved to be more sensitive for the matrix parameters than UV/VUV_{185nm} radiation. It can be explained by the extreme inhomogeneity of 172 nm radiated solution.

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