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ROZPRAWA DOKTORSKA

Zwiększenie efektywności technologicznej usuwania wybranych mikrozanieczyszczeń z wód

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ABSTRACT

The presence of micropollutants in water poses serious and real threats to human health, especially in a situation of global scarcity of right quality sources of water available for household use. Since the vast majority of micropollutants are xenobiotics, the only possible ways to remove them from the aquatic ecosystem are to identify them, and to eliminate or reduce their emissions, as well as to reduce them in an ad hoc and effective manner through water and wastewater treatment processes. The situation has been monitored by international legislation for many years, one of the effects of which is the enactment of the so-called Water Framework Directive.

Professional literature reports suggest that conventional water treatment processes are insufficiently effective in removing micropollutants. Although micropollutant removal techniques have advanced significantly in recent years and process efficiencies often allow for complete micropollutant removal, this potential is not yet being fully exploited for the treatment of water intended for household use. However, due to increasing water quality standards, this may change in the near future.

The aim of this work was to analyze the effectiveness of micropollutants reduction and improvement of general parameters of water, using selected processes, considered as niche techniques in the context of water treatment technology, and also some classical techniques. The following processes were investigated: coagulation with three different aluminium coagulants and organic flocculants, ultra- and nanofiltration with the use of several commercially available membranes, sorption on activated carbon and ion exchange, as well as selected advanced oxidation processes (AOP) using UV radiation. Preliminary studies were conducted in a laboratory scale, and the resulting data were used for the design and construction of a pilot, modular station, allowing to potentially conduct long-term research on technological systems. Studies on the effectiveness of micropollutants reduction were also conducted on a pilot scale.

The objects of the study were natural river, lake and underground waters differing in their characteristics, especially in the content of natural organic matter. Selected micropollutants were introduced into the waters viz: 4-nonylphenol, 4-octylphenol, anthracene, alachlor, heptachlor and its epoxide, and bis(2-ethylhexyl) phthalate.

Laboratory tests showed that in the coagulation process the coagulant PACl was the most effective in neutralizing colloidal impurities and reducing organic matter. The reduction of micropollutants ranged from 6 - 86% and depended on the content of natural organic matter, whose higher concentration improved the efficiency of the process, as well as on the characteristics of the compounds. Some increase in process efficiency was also observed after the addition of a cationic flocculant. Pilot scale coagulation tests confirmed the results obtained in laboratory tests. In this case, reduction results between 0 - 90% were obtained.

In laboratory tests of the ultrafiltration (UF) process, a BY membrane, characterized by a molecular weight cut-off value of 100 kDa, was selected as optimally effective in terms of reduction of total organic matter and stability of operation expressed by its relative permeability coefficient. A membrane with analogous properties was implemented into the UF module of the pilot station, which was found to be highly effective in reducing the micropollutants tested, with reduction rates ranging from 63 to 100%.

The nanofiltration process had a high organic matter reduction efficiency, and the NF-90 membrane was selected as the most effective membrane through laboratory testing. In pilot scale tests, complete retention of micropollutants was achieved.

Analysis of the sorption and ion exchange processes showed the superiority of the process using S5428 anion exchange resin. Compared to sorption on activated carbon, ion exchange on the anion exchanger was more effective in reducing micropollutants. It was also observed that, in contrast to the ion exchange process, the effectiveness of the activated carbon technology is highly dependent on the organic matter content of the treated matrix as well as of the properties of the substances to be reduced. In a pilot scale study, 100% reduction of all micropollutants tested was achieved by using anionite.

In laboratory studies of photolytic AOPs, based on the reduction of natural organic matter and the absorbance value at λ = 254 nm (Abs_{254}), it was shown that among the UV/O_3, UV/TiO_2 and UV/H_2O_2 systems, the ozone-based system had the highest efficiency. In laboratory experiments, the total mineralization of organic matter was only achieved to a small extent. However, based on the noticeable reduction in Abs_{254} values, it was decided to run the UV/O_3 process at pilot scale after appropriate process modifications. At the pilot scale, a reduction of micropollutants in the range of 32 - 100% was achieved and the efficiency depended on the structure of the individual compounds. Additionally, for the UV/O_3 process, toxicity analysis of the samples before, during and after the experiment was performed. Results were obtained suggesting the occurrence of the so-called hormesis phenomenon, consisting in stimulation of the response of the indicator organism as a result of some, usually small, toxicity of the sample. A weakening of this effect was observed as the oxidation process progressed, which indicated a toxicity reduction.