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学 位 論 文 要 旨
Dissertation Abstract

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学位論文題目：
Title of Dissertation

Energy Saving Technology Development for the Treatment of Reverse Osmosis Concentrate Using a Rotating Advanced Oxidation Contactor（回転円板型促進酸化装置を用いた逆浸透濃縮排水の省エネルギー型処理技術の開発）

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Reverse osmosis (RO) is a well-established and widely used technology for wastewater reclamation. With the purification of the treated wastewater, the RO process produces a concentrate which reported to be about 15–20 % of the influent volume. The RO concentrate contains concentrated levels of rejected pollutants originating from the source water. The emerging pollutants persistent in wastewater, such as pharmaceuticals and personal care products, have raised awareness of the environmental risk of the direct discharge of the RO concentrate. In addition, with the increase in global water demand, the scale of RO plants has been getting larger for several decades. Therefore, it is necessary to develop suitable technology to treat RO concentrates before discharging them into receiving water or recycling for other purposes. In this thesis, the removal of organic matters especially PPCPs in RO concentrate from a municipal wastewater reclamation facility has been researched.

Firstly in Chapter 2, the synthesized TiO_2-high silica zeolite (HSZ-385) composites powder was applied for the treatment of crotamiton, a scabicide and antipruritic agent persistent during biological treatment processes and frequently detected in secondary effluent in Japan. Crotamiton was rapidly adsorbed by HSZ-385 from the secondary effluent, and the other components of the secondary effluent little affected crotamiton adsorption. Even though the TiO_2-zeolite composites showed lower adsorption rates than that of HSZ-385, similar crotamiton adsorption capacities were revealed using both test materials. The photocatalytic decomposition of crotamiton was significantly inhibited by the water matrix at low initial concentrations. The TiO_2-zeolite composites rapidly adsorbed crotamiton from secondary effluent, and then the crotamiton was gradually decomposed under ultraviolet (UV) irradiation. Importantly, when using TiO_2-zeolite composites, coexisting material in the secondary effluent did not markedly inhibit crotamiton removal at low initial crotamiton concentration. The behaviors of the main intermediates during treatment demonstrated that the main degradation intermediates of crotamiton were also captured by the

composites. This provides a promising mechanism to mitigate secondary pollution caused by the harmful degradation intermediates.

Secondly in Chapter 3, the two powdered materials TiO_2 and HSZ-385 have been effectively immobilized into a paper-like composite sheet, which is easy to handle and recover the photocatalyst and adsorbent during the treatment process. The removal of the antipruritic agent crotamiton from RO concentrate was studied using the TiO_2/zeolite composite sheet. Excellent adsorption performance of crotamiton by the TiO_2/zeolite composite sheet has been found without obvious inhibition by other components in the RO concentrate. With application of UV irradiation, crotamiton was simultaneously removed by adsorption and photocatalysis. The photocatalytic decomposition of crotamiton in the RO concentrate was significantly inhibited by the water matrix at high initial crotamiton concentrations, whereas rapid decomposition was realized at low initial crotamiton concentrations. Similarly, the major degradation intermediates of crotamiton were also adsorbed by the composite sheet.

In Chapter 4, a novel rotating advanced oxidation contactor (RAOC) equipped with the composite TiO_2-zeolite sheet was used to the treatment of RO concentrate. The removal of organic matters was studied as well as the variation of biodegradability of the RO concentrates. We analyzed the concentration of 53 PPCPs in the raw RO concentrate and 48 PPCPs were detected at a concentration range of N.D.—1560 ng/L. The anti-inflammatory drug ketoprofen showed the highest concentration of 1560 ng/L in the RO concentrate, and the concentration of crotamiton ranked the third (670 ng/L). Under UV irradiation, the removal efficiency of the majority of the PPCPs were removed up to over 80% after 12h treatment by the RAOC, even though the adsorption process is not quite effective for 8 PPCPs ($<$ 50%). The adsorption process of the RAOC showed no improvement to the biodegradability of the RO concentrate. With UV irradiation applied, the RAOC improved the biodegradability of the RO concentrate with the degradation of organic matters. And after 6 h treatment by the UV applied RAOC, the BOD_5/COD_{cr} ratio decreased with the degradation of the produced biodegradable products. The TOC and COD_{cr} decreased by 24.5 % and 28.0 % after 12 h treatment, respectively. Judging from the improved biodegradability, after a short time UV applied RAOC treatment, the residual organic matters in the RO concentrate can be easily removed by a post biological process.

Furthermore in Chapter 5, removing the antipruritic agent crotamiton from RO concentrate with or without a coagulation pretreatment have been studied using the RAOC. The polyaluminum chloride (PAC) coagulation of the RO concentrate showed higher efficiency at pH 5 in terms of reducing TOC, A_{365}, and A_{254}, and the coagulation efficiency improved with an increase in PAC dosage from 0 to 6 mmol Al/L. The RAOC performed well in adsorbing crotamiton

without obvious inhibition by other components in the RO concentrate, and the majority of the crotamiton was removed after 6 h, which resulted in the purification of the treated solution. With UV irradiation applied to the RAOC, crotamiton was simultaneously removed through adsorption and photocatalysis. The behavior of the main degradation intermediates of crotamiton during treatment showed that the degradation intermediates were also captured by the composite sheet. Coagulation followed by the RAOC process was effective in the removal of the organic matter in the RO concentrate as well as the photocatalytic degradation of crotamiton.

In addition in Chapter 6, a solar light irradiated RAOC treatment was used for the treatment of RO concentrate with or without the coagulation pretreatment. The energy consumption indicated that electric energy per order for TOC removal was evaluated with/without PAC coagulation pretreatment applied before the RAOC treatment of RO concentrate.