Synergetic Treatment of Pesticide Contaminated Drinking Water by Combined RO Separation and Electrochemical Degradation

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This project studied the electrochemical removal of the pesticide transformation product 2,6-dichlorobenzamide (BAM) in Danish drinking water produced from groundwater at two different anode materials. The influence of the electrolyte composition on the degradation kinetics and pathways of BAM was clarified. Although chloride is present in small concentrations in the groundwater, persistent chlorinated intermediates were not found. The quantity of intermediate products with and without chloride was at the same level or lower compared to inert electrolyte. Integrating electrochemical removal with RO pretreatment significantly reduced the overall energy consumption of the process by 95%; 0.96 kWh/m³ compared to 18.5 kWh/m³ (EO alone).

Pesticides and pesticide residues are the most important micropollutants found in Danish groundwater aquifers and responsible for large quantity of groundwater currently being unusable for drinking water production. One very good example is the pesticide transformation product (PTP) 2,6-dichlorobenzamide (BAM) that is a daughter product of the commonly used pesticide dichlorobenil. Of the total number of groundwater aquifers that are included in the Danish groundwater monitoring programme, 50% have been found to be contaminated with pesticides and PTPs, and in 18.8–20.2% of these cases, the primary contaminant was BAM.

Electrochemistry offers a potentially efficient alternative to AC adsorption – a well-known water treatment technique with pros and cons - for pesticide removal at Danish water works. In recent years, electrochemical oxidation (EO) technology has developed from fundamental research on synthesis of new electrode materials aimed at high oxidation power, resistance and durability and laboratory studies of treatment efficiencies of various polluted aqueous matrices into commercial available products. However, concurrent to the incipient market dissemination of the technology, much more research is still needed in order to fully understand the effect of the technology on the water matrices and the produced effluents. One challenge is elucidating contaminant degradation pathways and identifying degradation intermediates (DIs) with the aim of ensuring discharge of an environmentally safe and healthy effluent.

This project demonstrated that BAM can indeed be removed from Esbjerg tap water (DK) by an EO treatment process. Detailed model solution studies in inert and electroactive electrolyte solutions elucidated the degradation pathways and the quantity of DIs formed during the treatment at two electrode materials; Ti/Pt-IR and Nb/BDD. Especially the presence of chloride in groundwater, although in small amounts, has caused initial concerns related to harmful byproduct formation, but our study revealed that even though the degradation pathways was much more complex in a chloride rich electrolyte (Figure 1), the quantity in DIs were at the same level or lower than in inert sodium sulphate electrolytes (Figure 2). All DIs formed during the treatment where removed at prolonged treatment times and complete TOC removal was obtained.
Figure 1. Proposed degradation pathway for BAM in chloride medium. The scheme distinguishes between main and secondary routes. The compounds formed in the secondary routes were only detected with GC/MS after increasing the concentration 100x with SPE and in intensities much lower than the compounds of the main routes. [1]

Figure 2. Quantitative DI plots. (a) Nb/BDD sulphate, (b) Ti/Pt-Ir sulphate, (c) Nb/BDD chloride, (d) Ti/Pt-Ir chloride. The difference between the BAM and the TOC curves represents the remaining organic carbon, which is the DIs. The integrated areas are plotted in the subplots. [1,2]

Another significant challenge for large-scale use of EO in water treatment is high energy consumptions, and for EO to become accepted as best available technique, the amount of energy consumed in the process must be reduced. In this study, the energy consumption of the pesticide removal was remarkably reduced by introducing pre-separation of BAM by a RO membrane followed by EO treatment of the concentrate prior to re-mixing with the clean water permeate. Using a RO membrane operated at a water recovery of 90%, the total energy consumption of the process consumed 95% less energy (0.96 kWh/m³) compared to the stand-alone EO treatment (18.5 kWh/m³) (Figure 3).

Figure 3. Total energy of both membrane and electrochemical oxidation to obtain a 1-log removal of BAM in one cubic meter of groundwater. Tap water represents the scenario without the membrane, where all the water undergoes electrochemical treatment, whereas it is only 20% and 10% of the water in the XLE 80% and XLE 90% recovery scenarios.[3]

The reduction in energy consumption was found to be a result of primarily two factors; (1) a smaller volume of water was in need in the energy intensive EO treatment, and (2) the high rejection of chloride by the RO membrane increased the rate of degradation through mediated active chlorine oxidation in the membrane retentate. The investigation showed that combining RO filtration with EO of the contaminants in the concentrate provides a promising strategy for the dissemination of EO in larger scale and actual use for protection of the environment.

References
