

Combinations of UV, VUV, and H₂O₂ Treatments Facilitating the Biological Removal of NOM from Drinking Water

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Summary

Natural organic matter (NOM) is a problem in drinking water for a number of reasons. Two of the more significant ones are that it interferes with water treatment processes (e.g., designed for the removal of solids, micropollutants, or pathogens), and reacts with commonly used chemical disinfectants to form disinfection by-products which may be detrimental to human health. Most conventional water treatment processes for the removal of NOM merely concentrate it, potentially creating a disposal problem. Ozone is widely used to oxidise disinfectant by-product precursors to biologically labile compounds which can be removed by biofiltration. This process has high capital and operating costs, and for waters with a high bromide content may be unsuitable due to formation of bromate, a toxic by-product.

The main objective of this work was to investigate combinations of ultraviolet (UV) radiation at 254 nm, vacuum ultraviolet (VUV) radiation at 185 nm, and hydrogen peroxide (H₂O₂) to directly mineralise NOM and facilitate the biological removal of the remainder. In the process, it was anticipated that more knowledge on the structure and characteristics of NOM would be generated which would be useful to the scientific community and water treatment practitioners. A reactor was designed and constructed to house the low pressure mercury vapour lamps and their effects on two highly coloured surface water samples were investigated.

The photooxidation treatments used were found to be effective for the removal of NOM. NOM was effectively mineralised by hydroxyl radicals generated by UV/VUV alone, UV/VUV/ H₂O₂, and UV/ H₂O₂, but not by UV alone. However, UV alone created the most

biodegradable NOM (up to 30% of the raw water DOC) and in combination with biological treatment was effective for NOM removal. The biodegradable fraction of the NOM after treatment by the other processes was the same as or less than that of the raw water (approximately 15%).

The chlorine reactivity of the NOM treated by small UV doses either remained the same as or was slightly increased when compared to the raw water. Larger doses decreased the chlorine reactivity. Subsequent biological treatment further reduced the chlorine reactivity, resulting in a higher quality and more bio-stable water. Low molecular weight (LMW) carbonyl compounds were analysed before and after biological treatment and found to account for a measurable portion (for some samples up to 70%) of the difference in chlorine demand of irradiated samples before and after biological treatment.

The presence of hydrogen peroxide and nitrite in irradiated samples was tested because of their toxicity. Low levels of hydrogen peroxide formed (e.g., 0.8 mg.L⁻¹ and 0.2 mg.L⁻¹ formed in Myponga water when irradiated using UV/VUV and UV alone, respectively) in irradiated samples. Nitrite concentrations increased in natural water samples when 254 nm radiation was used (after 8 hours or 450 J.cm⁻², 8 µM had formed in Myponga water). When 254 and 185 nm radiation were used the concentrations initially increased, reached a maximum (6 µM), and then decreased on further irradiation. This indicated hydroxyl radical preferentially oxidised NOM when it was present initially, rather than nitrite. Both species were detected in concentrations above the European Guidelines (0.1 mg.L⁻¹ and 2 µM for H₂O₂ and NO₂⁻ respectively) indicating that, if in the unlikely event that they persist after biological treatment, they may be problematic.

Photooxidation should be followed by a biological treatment step to reduce the input electrical energy, create a biologically stable water, improve the water quality (reduction in DOC concentration and chlorine demand), and remove oxidation by-products (e.g., LMW carbonyl compounds, nitrite, and hydrogen peroxide).

The treatment of Myponga water with UV/VUV irradiation supplemented with 10 mg.L⁻¹ of H₂O₂ followed by biological treatment had an electrical energy input of similar order of magnitude (8 kJ.L⁻¹) for equivalent NOM removals to those quoted in the literature for

ozone/biofiltration (2 kJ.L^{-1}), indicating that after more research and development work this process may become commercially viable.

Lastly, the kinetics of the photooxidation (at $\geq 254 \text{ nm}$) of chromophoric NOM could be approximated by a simple depolymerisation model. This follows from the laws of photochemistry, which suggest smaller molecules will initially accumulate in the system since they react more slowly than larger molecules because their molar absorptivity is less. If the interpretation and modelling assumptions made are sound and the behaviour is neither unique to, nor a coincidence of, the samples used then it suggests chromophoric NOM is more structured than widely believed.