Assessment of the UV/TiO_2 oxidation process (Deliverable 2.4.1.5)

The natural organic matter (NOM) is a direct problem in drinking water due to colour and taste. Indirectly, NOM is a problem because it reacts with the most commonly used disinfectants, chlorine, to form disinfection by-products (DBP's). In addition, NOM acts as a food source for bacterial regrowth in potable water distribution systems, and it reduces the efficiency of many water treatment operations. Lately there has been a focus on removal of organic micro-pollutants as well. Hence there is need for new technology and processes that can remove dissolved species at low concentrations, which is the basis for the research presented here on advanced oxidation processes (AOP).

Importance Importance

Advanced oxidation processes (AOP) are chemical oxidative processes, which can be applied to drinking water treatment to oxidize pollutants. A part of them generates hydroxyl radicals ($HO^{\bullet}$) which is the second strongest known oxidant (2.8 V) after fluorine. It is able to oxidize and mineralize almost every organic molecule, yielding CO_2 and inorganic ions. The UV/TiO_2 photocatalytic process is among the most studied AOP and has been shown to have a potential for effectively treating NOM. Literature results report up to 80 % removal of TOC and 98 % of colour using UV/TiO_2, and with a remaining organic matter concentration which was easily biodegradable. Vacuum ultra-violet (V-UV) lamp can be used for water and air treatment. This kind of lamp permits the photolysis of water and is a very interesting and powerful source of $HO^{\bullet}$ radical and consequently represents considerable application potential. Combining V-UV and photocatalysis have shown to be very efficient. In this work we have used a unit with immobilized TiO_2 (to avoid a separation step) irradiated with a low pressure mercury lamp emitting at two wavelength 254nm and 185nm for treatment of NOM containing water. Combining V-UV and photocatalysis have shown to be very efficient. In this work we have used a unit with immobilized TiO_2 (to avoid a separation step) irradiated with a low pressure mercury lamp emitting at two wavelength 254nm and 185nm for treatment of NOM containing water.

Approach

Experiments were conducted in batch mode using an annular reactor (M300 water purifier®) provided by Wallenius Water AB. In order to investigate the importance of the different processes involved during the degradation of NOM by this system, different configurations combining two types of reactors (with and without immobilised TiO_2) and two types of 15W low pressure mercury lamps (emitting only at 254nm or both at 254nm and 185nm) have been used.

Result

The M300 water purifier unit originally designed for ballast water treatment and disinfection, using a combination of Vacuum-UV (V-UV) and UV/TiO_2, has shown to be effective for the removal of NOM from water. Within this unit, the V-UV is the most efficient process in comparison to the photocatalysis and photolysis. However, a number of parameters have to be adjusted for an optimal degradation. The degradation has shown to be pH, oxygen, carbonate and flow dependent:

- The degradation rate is higher with increasing with oxygen concentration due to improved oxidation of NOM, since oxygen is involved in the formation of different oxidizing species, and since it reduces recombination between charges.
- The NOM concentration affects its degradation rate since NOM acts as a radical scavenger and thereby reducing the apparent rate constant.
- The degradation rates are higher at higher pH which could be attributed to two main reasons; 1) higher hydroxyl anion concentration leading to higher formation of $HO^{\bullet}$; and 2) more appropriate configuration of NOM for the oxidation by the $HO^{\bullet}$.
- Carbonate scavenger effect has been investigated at different pHs (acid, neutral and basic). The scavenger effect is more important at high pH, because carbonate consume hydroxyl radicals easier than bicarbonate.

At a NOM removal efficiency of about 90% the treatment costs of the process was about 4 times higher than what is considered as suitable for practical applications. However, by improving the process design and reducing the required treatment efficiency it is believed that the treatment cost could be reduced down to competitive levels.

More information

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