

## Executive Summary

There is a legal requirement for water companies to minimise disinfection by products (DBPs) in drinking water, as set out by regulation 26(2)(a) of the Water Supply (Water Quality) Regulations 2016 (as amended) in England and the Water Supply (Water Quality) Regulations (Wales) in Wales.

Carbonaceous and chlorinated DBPs are considered of greatest relevance because of the widespread use of chlorination.. The regulations define a maximum of 100 µg/L for four chlorinated and brominated THMs in supplied drinking water. In addition there is a standard for bromate at 10 µg/L which can be formed during ozonation of water containing bromide.

Other compounds that may be regarded as DBPs are products from Advanced Oxidation Processes (AOPs) but the identity of these compounds is not well reported and they are not specified in the regulations. AOPs typically involve the generation and use of the hydroxyl radical ( $\bullet\text{OH}$ ) as a strong oxidant to destroy compounds that cannot be oxidised by conventional oxidants such as oxygen and chlorine. Most commercial ultraviolet (UV)/oxidation processes involve generation of  $\bullet\text{OH}$  through UV photolysis of conventional oxidants, including hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) and ozone ( $\text{O}_3$ ) (Murray and Parsons, 2004).

A previous project carried out on behalf of Defra (DWI702317) identified nine priority DBPs that were of potential relevance and have the potential to form when water is treated using AOPs. The focus here is on these nine compounds. (2-methoxy-4,6-dinitrophenol, 3,5-Dinitrosalicylic acid, 2-Hydroxy-5-nitrobenzoic acid, 4-Hydroxy-3-nitrobenzoic acid, 4-Nitrocatechol, 2-nitrohydroquinone, 4-nitrobenzene-sulfonic acid, 4-Nitrophthalic acid, 5-Nitrovanillin).

The aim of this study was to confirm whether these DBPs are formed under controlled conditions and if so whether these DBPs can be effectively removed by GAC post AOP. The project developed analytical methodologies for the nine DBPs, completed a bench scale study assessing their removal by GAC and reported on the conditions which favoured their formation during AOP. The outcomes include a method of analysis with limits of 1 ng/l for seven of the compound and 25 ng/l for the remaining two.

The bench scale study involved experiments with synthetic water samples spiked with natural organic matter, nitrate and alkalinity. These were exposed to photolysis as well as UV/hydrogen peroxide with low and medium pressure lamps. Samples of treated water collected from the post filter stage of 11 water treatment works (real waters) were treated with UV/hydrogen

peroxide. Finally, the real waters were spiked with two of the AOP-DBPs that were formed during the AOP experiments to determine their removal using GAC.

Results from the photolysis experiments showed that none of the doses with either of the lights produced any of the nine DBPs at levels greater than the limits of detection. The AOP experiments showed that none of the nine DBPs of interest were detected at levels greater than 1 ng/L when using a medium pressure lamp. The results using the low pressure lamp did reveal formation of two of the compounds at levels close to or below the limit of detection. These were: 5.314 ng/L 4-Nitrophthalic acid. For this compound the LOD was 25 ng/L; and 1.233 ng/L 3,5-Dinitrosalicylic acid. For this compound the LOD was 1 ng/L. 3,5-Dinitrosalicylic acid was not found in the duplicate sample so the result was not repeatable. The conditions of these experiments were taken forward to carry out experiments on treated water samples collected from water treatment works.

For the real water experiments, only one of the experiments yielded any of the nine DBPs under investigation. Water 6 produced 3.527 ng/L 4-Nitrophthalic acid which is below the LOD of 25 ng/L for this compound. The conditions for this experiment were 500 mJ/cm<sup>2</sup> UV dose, 10 mg/L H<sub>2</sub>O<sub>2</sub> dose. The duplicate did not show that this result was repeatable. The GAC Experiments revealed that levels present after treatment by GAC were below the limits of detection for both compounds.

The study has shown that the nine DBPs do not form at significant levels during treatment by AOPs under a range of conditions. At the levels formed for two of the compounds, these were able to be removed by GAC at contact times (5 and 10 minutes EBCT) lower than those generally used in industry. The risk posed by these chemicals is minimal in the range of source waters investigated. As a precaution these N-DBPs should perhaps be measured in final waters where AOPs are implemented and once their operation has been established. It is not known if tests for these compounds are offered commercially and consideration should be given to the risk of the presence of these compounds as part of the drinking water safety planning process.