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Exploring the applicability of differential absorbance to simultaneously quantify and control microbial inactivation and DBPs formation

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Abstract. Chlorination is effective in inactivating microorganisms. However, its interaction with natural organic matter (NOM) and inorganic ions leads to the formation of disinfection byproducts (DBPs). Surrogate parameters, such as the differential absorbance at 272 nm (DA272), have shown potential for monitoring NOM degradation and DBP formation. This study aims to evaluate the applicability of DA272 as a control tool for both microbial inactivation and DBP control. The results demonstrate a strong correlation between DA272 and the microbial inactivation ratio and suggest that specific DA272 thresholds can be established to ensure both effective disinfection and DBP control within the treatment plant.

Keywords: Chlorination; disinfection by-products; inactivation ratio; differential absorbance.

1. Introduction

Microorganisms' inactivation is mandatory to guarantee water safety. Among disinfection strategies, chlorination is the most widely used due to its low cost and its ability to guarantee residual chlorine throughout the pipeline (Manoli et al., 2019). To achieve the desired inactivation an adequate Ct value [mg*min*L^{-1}], that is the product between the oxidant residual concentration and the exposure time, is required. Regarding chlorination, the USEPA (1991) determined the Ct values needed to achieve Giardia cysts and viruses log inactivation based on water characteristics (T, pH) and residual chlorine concentration. To meet the desired microbial control at a plant, the inactivation ratio (IR), that is the ratio between the calculated Ct of the plant and the corresponding Ct calculated by the USEPA, should be equal or greater than 1 (USEPA, 2020). With the new European Directive (EU) 2020/2184 on drinking water, some DBP species, such as Total Trihalomethanes (TTHMs) and Total Haloacetic acids (THAAs), are now regulated. Therefore, water treatment plants need to comply with both microorganisms' inactivation and DBP limits. Differential absorbance at 272nm (DA272) is a surrogate indicator of DBP species formation and chlorine decay (Roccaro et al., 2008). As the chlorination proceeds, the absolute value of DA272 increases because natural organic matter (NOM) chromophores are increasingly destroyed by chlorine, with ensuing formation of the DBPs. Therefore, the DA272 is a fundamentally important parameter that keeps track of the NOM evolution and its interactions with the oxidant (Korshin et al., 2002). Given the strong correlation between DA272 and chlorine decay, such a surrogate parameter could be potentially used to optimize chlorination operations and improve DBPs formation control (Roccaro et al., 2008).

2. Materials and methods

The experimental dataset used in this study is taken from Roccaro et al. (2008) and (Roccaro & Vagliasindi, 2009). Chlorination experiments were conducted using water samples collected from the inlet (December and March) and outlet (March) of the Ancipa water treatment plant in Sicily, characterized by a pH of 7, 3 and 2 mg/l of DOC, respectively. For the December inlet samples, chlorination was performed at three temperatures—3°C, 20°C, and 34°C—using initial chlorine doses of 0.25, 0.5, 0.75, 1.0, 1.5, and 2.0 mg Cl_2 per mg DOC. Reaction times ranged from 10 minutes to 7 days. In March, the fractionated effluents from XAD-8 and XAD-4 resin columns, along with the unfractionated samples (i.e., raw water), were chlorinated with 0.75 and 1.5 mg Cl_2 per mg DOC, with reaction times ranging from 10 minutes to 3 days. TTHMs, DA272, and IR were measured and calculated on each sample at varying chlorine dosages and contact time.

3. Results and discussion

Achieving microorganisms' inactivation (IR=1) and keeping the TTHMs formation below its drinking water standard (30ug/L in Italy) is challenging. In this study, IR

and TTHMs values were expressed as a function of DA272. Figure 1 shows that DA272 correlates well with both IR and TTHMs values. All the DA272 values ranging between the value corresponding to IR=1 ($DA272_1$) and that of TTHMs=30ug/L ($DA272_2$) would allow achieving both the desired objectives (see square dots in Figure 1). In turn, whenever ($DA272_1$, IR=1) is lower or equal to ($DA272_2$, TTHMs=30ug/L) both the objectives are met (see green square dots in Figure 1). It is the case of the water treated by XAD-4 resin (green square dots in Figure 1). A similar result can be observed for the water treated using XAD-8 resin, as demonstratet in Figure 1 (see violet square dots). When ($DA272_1$, IR=1) is higher than the condition of ($DA272_2$, TTHMs=30ug/L) the objectives are not met. It is the case of the untreated (raw) waters (denoted by red square dots in Figure 1). By applying this approach, site-specific DA272 thresholds can be established to ensure effective disinfection while maintaining TTHMs within standard limits. In conclusion, DA272 offers a robust, fundamentally sound and informative parameter, making it a valuable tool for water treatment process monitoring and control.

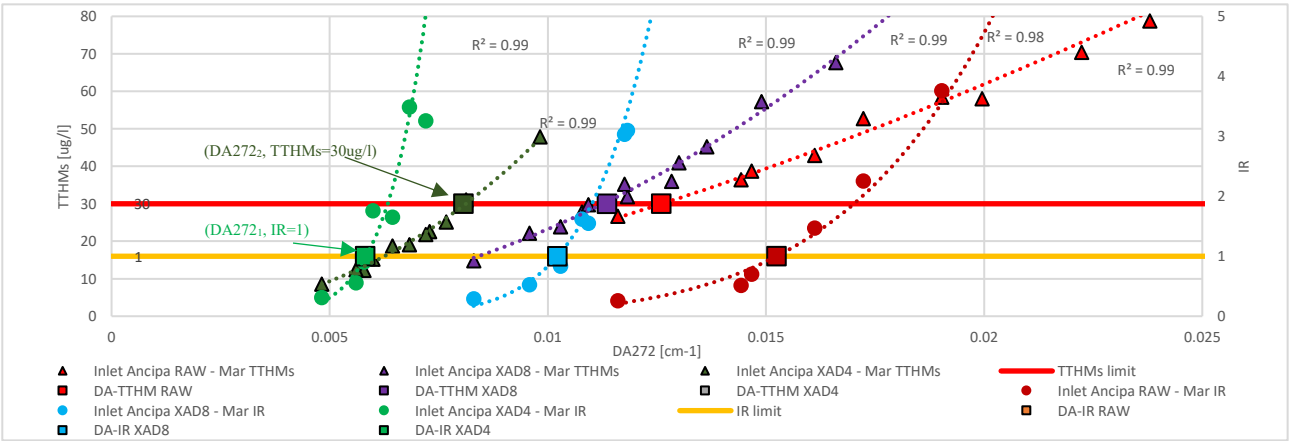

Figure 1. DA272 correlation with IR and TTHMs at varying water quality (raw and treated waters)

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