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Accelerated aging of polyethylene pipe grades in aqueous chlorine dioxide at constant concentration

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Abstract

The impact of disinfected water on the degradation of polyethylene (PE) was investigated with immersion tests of two PE pipe materials in 10 and 5 ppm chlorine dioxide (ClO_2) medium at 60 °C. Aging experiments in 1 ppm ClO_2 at 60, 50 and 40 °C were also carried out to study the effect of different aging temperatures. During conditioning, the pH was kept at 6.8. A specific exposure device with continuous concentration control and adjustment has been applied in order to generate reliable and reproducible aging conditions. Sample characterization applying scanning electron microscopy (SEM), tensile test, dynamic oxidation tests as well as FTIR-spectroscopy indicated accelerated antioxidant consumption and polymer degradation. Material aging at 50 °C and above was found to be much faster than at 40 °C applying 1 ppm ClO_2 concentration. An optimized testing condition for fast material characterization in case of 1 mm thick specimens was found to be a concentration of 1 ppm ClO_2 at 50 °C. The simultaneously increasing material embrittlement and the consumption of active antioxidant molecules imply an apparent unselective reaction of ClO_2 with the polymer and the stabilizers molecules. Moreover, the radical nature and the high reactivity of ClO_2 led to the formation of carbon-chlorine species, which are assumed to originate from degraded antioxidant molecules.

1 Introduction

In drinking water distribution systems various disinfection techniques such as ozonation, ultraviolet radiation, chlorination (HOCl), the addition of chloramines, and ClO_2 have been used for decades to inactivate pathogenic microorganisms [1–3]. Due to their high effectiveness, low implementation and operation cost, chlorination and addition of ClO_2 are the most widely used secondary disinfectants techniques in water treatment. Considering the strong oxidative nature of these chemicals the long-term effect of chlorinated water on pipe materials is a matter of interest. The presence of chlorine-based disinfectants accelerates the consumption of stabilizers and consequently the degradation of the PE. In order to accurately investigate the impact of oxidizing agents on the degradation mechanism of polymers, stable and well-controlled exposure conditions are necessary. As it is defined in ASTM F2023 [4] and ASTM F2263 [5], applying a

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