Comparing the effect of various pipe materials on biofilm formation in chlorinated and combined chlorine-chloraminated water systems

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Abstract

To compare the effect of various pipe materials on biofilm formation, surface water was used as the test water source; plastic-based pipe materials (polyvinyl chloride-PVC, unplasticised polyvinyl chloride-UPVC, medium density polyethylene-MDPE) and cement-based pipe materials (cement and asbestos cement) are commonly used in drinking water distribution systems in South Africa as test pipe materials. Disinfection was performed using *ca* 2.5 $mg \cdot \ell^{-1}$ initial chlorine followed by *ca* 1.5$mg \cdot \ell^{-1}$ monochloramine. The evaluation of the process relied on attached coliforms and heterotrophic plate count bacteria.

General data indicated the colonisation of all test pipe materials by micro-organisms under the chlorination process within the first 20 min and over the remainder of the study period. The addition of monochloramine to the chlorinated water system (24 h after chlorination) resulted in the removal of coliforms and heterotrophic bacteria attached to pipe materials. Less than 1 $cfu \cdot cm^{-2}$ viable bacterium (except for PVC) was observed on the surface of test pipes between 48 and 168 h. However, the factor of time cannot be ignored in determining the effect of pipe materials on biofilm formation in potable water systems. Bacterial regrowth occurred on the surface of all pipe materials between 168 and 672 h. The capability of bacterial regrowth occurring on the surface of test pipe materials during this period was linked to the depletion of the concentration of monochloramine residual.

Statistical evidence showed that the generic type of pipe materials greatly influenced the density of bacteria in laboratory-scale systems. Cement-based materials significantly supported less fixed bacteria than plastic-based materials (at $p<0.05$ and $p<0.01$). No significant difference in attached bacterial counts was found between the same generic types of pipe materials. This study suggests the use of cement and asbestos cement pipes for the distribution of chlorine-monochloramine treated water. Statistical evidence also showed that all physico-chemical parameters (temperature, pH, turbidity, dissolved organic carbon, total nitrogen, sulphate) had no significant effect on bacterial number at $p<0.05$, implying that the presence of an effective monochloramine residual in the chlorinated water system remains one of the most important factors in controlling the effect of pipe materials on biofilm formation.

Keywords: pipe materials, biofilms, chlorine, monochloramine

Introduction

The purpose of a water distribution system is to deliver to each consumer safe drinking water that is adequate in quantity and delivery pressure and acceptable in terms of taste, odour and appearance. The management of water quality in distribution systems is a major technological challenge to the water industry. Vigilance for any contamination and microbial degradation must be maintained. This is complicated by the very nature of the distribution system that is a dynamic network of mains, which are now available in a diverse range of materials (Block et al., 1993a). Pipe materials for water supply and distribution can generally be classified into one of three generic types: cementitious, metallic and plastic. A wide range of pressure pipe materials is available within these categories, and such materials are used in varying proportions across the countries of the world. Each of these materials has shown its technical advantages, but may also have technical and or economic limitations (Lion et al., 1988). The first stage in selecting pipe materials is a definition of the proposed application. This would require a knowledge of the operating conditions, including the hydraulic requirements (flow, pressure), aggressiveness of water (pH, alkalinity), external and internal corrosivity, microbial contamination, soil loading, handling and joining under different topography, etc. (Lion et al., 1998).

It is well known that micro-organisms can colonise any surface in contact with water. Bacterial growth in a drinking water distribution system mainly occurs on the internal surface of the pipes. Detachment of bacteria from this biofilm may thus affect the water quality. Previous investigators have shown that bacterial growth occurring on pipe walls depends on different factors: concentrations of disinfectant (Momba et al., 1998; Momba and Binda, 2002), water temperature (Kaye and Nagy, 1999; Zacheus et al., 2000), pipe materials (LeChevallier et al., 1990) and concentration of biodegradable dissolved organic carbon (BDOC) which is the main substrate allowing bacterial growth in drinking water (Block et al., 1993; LeChevallier et al., 1993; Servais et al., 1995; Servais, 1996). The characteristics of the material composing pipes may greatly influence the densities of bacteria fixed in a distribution system. Studies have pointed out that the roughness of the material used for the distribution of potable water contributes to bacterial attachment (Pedersen, 1990; Percival et al., 1998). Pedersen (1990) compared biofilm development on stainless steel and PVC surfaces exposed to flowing municipal drinking water. After 167 d he measured a number of micro-organisms growing on the surface. Although there was no difference in the number of cells on the hydrophobic electron polished stainless steel and the hydrophobic PVC, the author reported that rougher stainless steel had 1.4 times more micro-organisms than electro-polished steel. Momba and co-

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