An overview of biofilm formation in distribution systems and its impact on the deterioration of water quality

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Abstract

The impact of biofilms present in water distribution systems on the microbial quality of potable water is reported in this review. The issues covered include the composition of bioflims, factors governing their formation and the effect and significance of biofilms on the microbial quality of drinking water. The review addresses the main factors governing the formation of biofilms such as the types of disinfectants and residual concentrations, resistance of bacteria to disinfectants, the influence of piping material and the effect of temperature. Methods for the enumeration of bacteria in biofilms as well as emerging technologies for *in situ* monitoring of biofilms are discussed. Suggested control measures for managing and controlling the problem of biofilm formation in potable water distribution systems to ensure potable water of an acceptable microbiological quality are dealt with.

Introduction

Deterioration of drinking-water quality during storage or in distribution systems remains one of the major difficulties experienced by potable water suppliers. It is an established fact that the distribution system is often vital in determining the final quality of potable water. Pathogenic and toxigenic microbiological agents in drinking water have long been known to cause disease and death in consumers (Craun, 1986). The health risks associated with these pathogens range from viral and bacterial gastroenteric diseases to infections such as hepatitis A and giardiasis. The International Drinking Water Supply and Sanitation Decade (1981 to 1990) was preoccupied with the construction and expansion of water supplies, and it is only in its latter part that more attention was given to the investigation, protection and control of the installations which supply drinking water (Lloyd and Bartram, 1991).

While water produced in the treatment plant may be of high biological quality, the treated water may be subject to conditions in the distribution network that adversely affect it. The reasons why bacterial numbers increase during distribution are not yet fully understood but two of the main factors have been studied in detail:

- The first factor is usually referred to as mechanical failure. Bacteria can be introduced into the distribution network from external sources by a number of means such as open reservoirs, breakages due to new pipeline construction that may disturb the existing distribution system, mains breaks (which may become an increasing problem as the distribution system ages) and the reduction of the water flow pressure in the system resulting in back siphonage (Rossie, 1975).
- The second factor refers to the situation where the increase of bacteria is due to internal regrowth or aftergrowth of bacteria and the associated formation of bioflims. Several investigators have shown that the multiplication of micro-organisms in biofilms along the distribution systems results in the deterioration of the bacteriological quality of drinking water, the development of odour or colour as well as the acceleration of the phenomenon of corrosion within the pipework (Nagy and Olson, 1985).

Biofilm on surfaces exposed to drinking water in distribution systems may well be the main source of planktonic bacteria since up to 1 000 sessile micro-organisms may be present for each planktonic cell which is detected. The occurrence of biofilms or encrustations that harbour various types of micro-organisms has been described extensively (Van der Kooij and Zoetemann, 1978; LeChevallier et al., 1987). The most alarming results are the presence and multiplication of pathogenic and opportunistic pathogens such as *Pseudomonas, Mycobacter, Campylobacter, Klebsiella, Aeromonas, Legionella* spp., *Helicobacter pylori* and *Salmonella typhimurium* occurring within the biofilms (Engel et al., 1980; Wadowsky et al., 1982; Burke et al., 1984; Armon et al., 1997; Mackey et al., 1998).

This review will focus on biofilms in water distribution networks and will cover issues such as biofilm composition, factors affecting the formation of biofilms, techniques for the investigation of biofilms in distribution systems as well as the deterioration of the water quality and the associated health risks. Suggested measures for controlling the problem of bacterial regrowth or biofilm formation in potable water distribution systems will be presented.

The nature of biofilms in water distribution systems

The process contributing to the increase in microbial numbers, not related to mechanical failure, between the point of entry into the distribution system and the final point of consumption is described by the terms “regrowth”, “aftergrowth” and “breakthrough”. The term regrowth is used when bacteria injured during the treatment process start to multiply after recovering from a form of reversible injury. The term aftergrowth consequently denotes growth of micro-organisms native to a water distribution system and the term

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Received 11 November 1998; accepted in revised form 23 August 1999.