Drinking Water Biofilms

Drinking water distribution systems (DWDS) are responsible for the conveyance of drinking water from a centralised treatment works to the customers tap. Despite water utilities in the UK producing a very quality of water to their consumers, microbiological regulatory failures do still occur to do regrowth of microorganisms within DWDS.

The majority of microorganisms found within the DWDS are known to exist in communities attached to the inner surface of the pipe forming a biofilm. It has been previously estimated that 95% of the overall biomass is attached to pipe walls, while only 5% resides in the water itself (Flemming et al., 2002).

Biofilms are a particular concern to water utilities as:
- They can act as the transient or long term habitat of faecal indicator organisms and potentially pathogenic bacteria
- Pose a threat to water aesthetics when they detach.

Assimilable Organic Carbon

Although it has been demonstrated that microbial communities occur ubiquitously at the DWDS pipe interface, we lack applicable understanding of the microbial communities existing in biofilms. In particular it is not extensively known how biofilm communities are impacted upon by the concentration of assimilable organic carbon (AOC), and indeed how the attached microorganisms themselves impact upon this abiotic parameter.

Total organic carbon (TOC) consists of particulate and dissolved organic carbon (DOC), with AOC being the fraction of the DOC pool that is assimilated by aquatic organisms for growth (See Figure 2). The AOC fraction is small varying between 3 and 500 μg/l representing 0.1-8.5% of the DOC pool (Van der Kooij, 1984).

Application of AOC Method

AOC sampling was initially applied to 20 Scottish Water drinking water systems to provide a broad array of AOC concentrations, before four systems were sampled in more detail (treatment work and distribution) to determine spatial and temporal variations in AOC concentration. AOC sampling was initially applied to 20 Scottish Water drinking water systems to provide a broad array of AOC concentrations, before four systems were sampled in more detail (treatment work and distribution) to determine spatial and temporal variations in AOC concentration.

Biofilm Analysis

By using coupon sampling devices (see Figure 5) installed within an operational drinking water system, it is possible to study the in situ formation of mixed species biofilms in an environment accurately imitating the wall boundary hydraulic conditions, nutrient supply and microbial inoculation occurring in the field.

References


How Do We Measure AOC?

Sample Collection
Pasteurisation / Filtration
Inoculation
Incubation
Enumeration

AOC Method Development

As no direct, chemical measurement of the AOC concentration exists, the bioassay approach is used to estimate the concentration of AOC by analysing its effect on the bacterial inoculum. The AOC concentration, expressed as acetate-carbon equivalents, is calculated from the linear relationship between AOC concentration and maximum growth of a bacterial strain(s) in carbon limited water from inoculation to stationary phase.

To date, a thorough assessment of the AOC methodology has been undertaken, including the use of indigenous test organisms, alterations to sample preparation and incubation (time and temperature) and alternative enumeration techniques including the use of spread plate count and flow cytometry (see Figure 3). Optimal growth of AOC test strain Pseudomonas fluorescens strain P-17 occurs at an incubation temperature of 15°C.

Figure 1: Photograph of biofilm accumulation on the pipe wall of a distribution main

Figure 2: Fractions of carbon found within drinking water

Figure 3: BD Flow Cytometer

Figure 4: AOC concentrations found within 20 drinking water systems (AOC was sampled both raw and treated water)

Figure 5: PWG coupons including a) outer coupon and b) removable insert. Adapted from Fish, 2015)