Understanding the relationship between assimilable organic carbon (AOC) and microbiology within drinking water

Stream

The Industrial Doctorate Centre for the Water Sector

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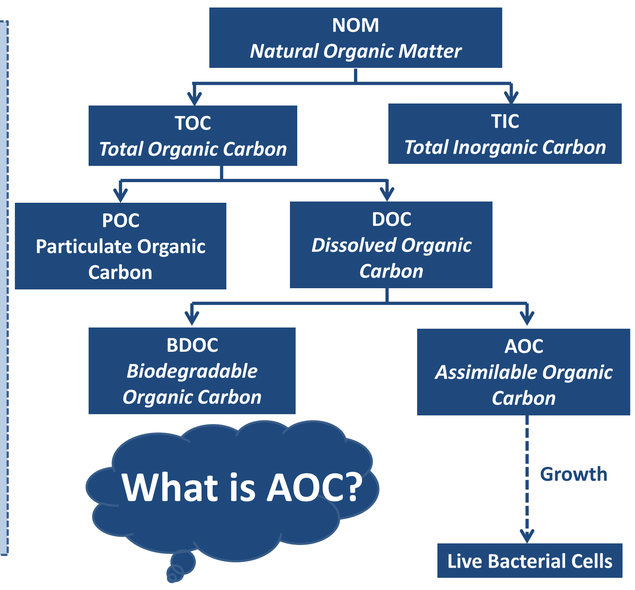
1. Introduction & Aims

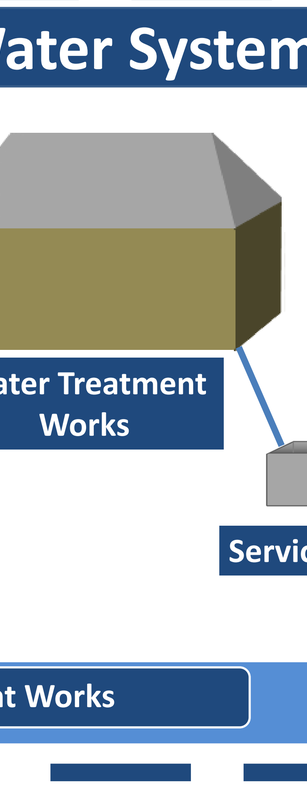
- Management of **drinking water microbiology** is critical to maintaining high quality drinking water from the point of water leaving the treatment works to reaching the customers tap.
- **Assimilable organic carbon (AOC)** is the fraction of carbon most easily consumed by bacteria, resulting in microbial growth.
- Measures of the AOC concentration in drinking water are therefore used as an indication of the degree of regrowth of **heterotrophic bacteria** both at the treatment works and in the distribution system.

Problem Statements

- Despite drinking water leaving water treatment works being of a high standard, **the quality of the water often deteriorates** as it travels through the distribution network.
- Why are microorganisms growing in the network and **generating bacterial failures**? **Insufficient disinfection? Nutrient supply?**
- AOC measurements are generally not conducted by UK water utilities due to the **time consuming nature of plate count enumeration** and the **lengthy incubation period** required for each sample to reach the stationary phase of bacterial growth.



2. Development of AOC Protocol



- The AOC concentration of a water sample can be measured by using the bioassay approach in which a water sample is **pasteurised, inoculated** with a known cell concentration, and **incubated** until the cells reach the **stationary phase** of growth.
- However, the time taken to complete this assay can be up to **14 days.**
- Lab trails were conducted to determine the optimum **incubation temperature, type and volume of inoculum and choice of enumeration technique** to create a **more rapid and reproducible AOC protocol.**
- An AOC methodology was selected that combines the use of **two known strains of bacteria, a larger inoculum volume** and **flow cytometric enumeration.**
- By using *Pseudomonas fluorescens* strain P-17 and *Spirillum* strain NOX instead of a natural microbial inoculum, there is **greater consistency between different batches of stock inoculums.**
- Flow cytometry is a far more rapid enumeration method than standard plates counts, requiring only **2 minutes** per sample.

The Drinking Water System

Aims & Objectives

1. To create a r**apid, standardised AOC method** that can be used for routine drinking water analyses.

2. To sample raw and treated water in a large number of Scottish Water treatment works to determine the **efficiency of AOC removal.**

3. To determine how AOC varies in and between **water distribution systems**. To determine any correlations between the AOC concentration and other drinking water parameters.

3 a. Application of Method: Raw and Treated Water

- The drinking water treatment process is designed to reduce the amount of AOC entering the distribution system.
- AOC sampling was initially applied to **20 Scottish Water treatment works** to provide a broad array of AOC concentrations.
- The **removal rate** of AOC varied between treatment site, depending on the incoming water source and the type of treatment applied. Approximately **40%** of AOC could be removed by a conventional treatment process.
- Borehole systems contained a much lower concentration of AOC and produced treated water than can be classed as **biostable** (unable to support regrowth) (<100 µg C / L) (LeChevallier *et al*., 1996).
- ***What happens to the AOC concentration following the point of leaving the treatment works to reaching the consumers tap?***

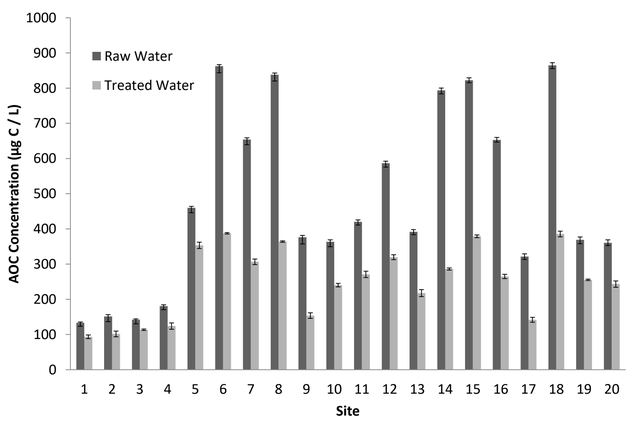


Figure 1: AOC in within 20 Scottish Water Systems

AOC concentrations found within treated drinking water at the works varied **from 88 to 377 µg acetate-C / L**

3 b. Application of Method: Distributed Water

- AOC was sampled within **raw water, treated water,** and **service reservoir inlet** and **outlets** within four drinking water distribution systems.
- To determine the relationship between AOC and other general water quality parameters, **total and intact cell counts (used to calculate % of intact cells), adenosine triphosphate (ATP)** and **total chlorine** samples were also collected from the same systems.

Self Organising Map (SOM)

1. A self organising map (SOM) approach was applied to the collected data
2. A **SOM** is a **data visualisation technique** that can be used to understand **complex relationships** between the input variables by visualising the grid's reference vectors as a series of component planes, rendered as shaded hexagonal cells (see Figure 2)

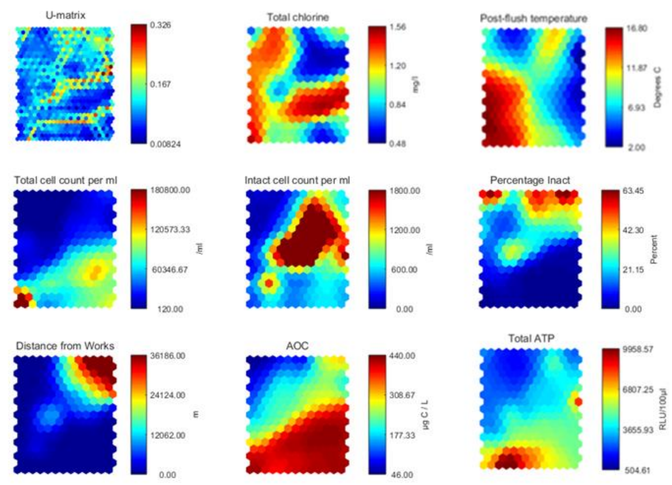


Figure 2: SOM Analysis of Drinking Water Quality Data. Blue denotes low and red denotes high values

- A negative correlation was found between AOC concentration and the % of intact cells; when the % of intact cells was low, the AOC concentration was elevated
- This suggests that non viable cells act as a source of AOC

4. Conclusions and Future Work

- Here we propose an **AOC bioassay** which utilises known bacterial strains ***Pseudomonas fluorescens* strain P-17** and ***Spirillum* strain NOX**, enumerated **using flow cytometry**.
- Application of the AOC method has demonstrated AOC to be a valuable drinking water parameter that can ultimately be used to inform and manage changes in the **microbiology of drinking water.**
- Future research is required to determine if AOC is added or removed by **biofilms** existing on pipe walls within water distribution systems.

5. References

- LeChevallier, M. W., Welch, N. J. & Smith, D. B. (1996), `Full-scale studies of factors related to coliform regrowth in drinking water.', Applied and Environmental Microbiology 62(7), pp.2201{2211.

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