Water distribution WSP	**Microbial regrowth and disinfection in the network** *Management/technical guidance*	BON NETWORK …A global network of water suppliers committed to providing good safe drinking water…

Information derived from:
- Feedback from water suppliers

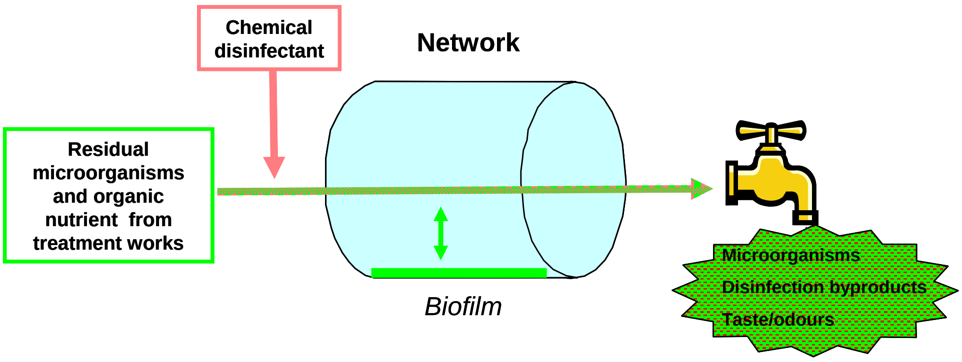
Related tools:
- Asset management
- Network design & modelling
- Treated water storage
- Corrosion and sediments
- Invertebrates within the network

Important Notes to users:
This document provides information to support improved management of piped drinking water quality by water utilities and other stakeholders. It cannot however be definitive and users must ensure that they assess local factors and particularly take account of any national or regional legislative requirements before use. Where necessary this may also need close collaboration with others. The priority to be given to implementing controls to manage identified water quality risks will depend on a proper prioritisation process by each water supplier.

Summary
Water leaving the waterworks should be completely free of harmful microorganisms and should also fully meet all relevant microbial standards including those for indicator organisms such as E.coli, and coliforms. Nevertheless, however well treated, the final water will always contain some residual heterotrophic organisms as well as organic nutrient. Particularly in surface derived systems these organisms will therefore regrow as water passes through the network and will also colonise the internal surfaces of water mains and other structures. Although not necessarily a health risk this can lead to other water quality risks and is thus often controlled by the use of residual disinfectants. However this in turn can result in the formation of disinfection byproducts which are themselves usually covered by regulatory standards, and unacceptable taste/odours to consumers. This document summarises how these complex interactions can be managed in order to ensure satisfactory water delivered to consumers.

Detailed information

Background
The interaction between microorganisms, nutrient and chemical disinfectants is complex and also affected by a range of other factors including temperature and time of travel though the network. The situation is amplified by the formation of biofilms on pipe and other surfaces. Typically even in a "biologically clean" network there can be 10^4 bacteria/cm^2 of pipe wall and this can increase by 2-3 logs in "biologically dirty" systems. It is thus common to use disinfectant residuals to manage regrowth within the network as well as provide some limited protection against ingress of microbial contamination.



Water quality risks

It is neither practicable nor necessary to have networks free of all microorganisms. Whilst it is essential to avoid any risk from pathogenic microorganisms, WHO advises that there is no evidence, either from epidemiological studies or from correlation with occurrence of waterborne pathogens, that heterotrophic organisms (HPC) alone directly relate to health risk. However sudden increases in HPC levels might sometimes be associated with faecal contamination though ingress or other means and therefore need further investigation.

However, as well as numerous free-living heterotrophic bacteria biofilms can also contain many other undesirable microorganisms. These include fungi, protozoa, nematodes and crustaceans and may be particularly an issue in older systems which contain deposits and sediments formed by the internal corrosion of metal pipes and/or insufficient treatment. This can give rise to a number of water quality risks which can increase in relation to the level of biofilm. Problems can include:

- Adverse taste and odour of water delivered to consumers
- Growth of aquatic organisms such as Asellus which are highly unacceptable to consumers
- Discoloured water associated with disturbance of iron stained biofilm
- Potential masking of opportunistic pathogens or other undesirable bacteria

Whilst it is very common to maintain disinfectant residuals within the network for microbiological control, this can at the same time also increase other water quality risks especially:

- Disinfection byproducts (DBPs)
- Unacceptable tastes/odours for consumers

The levels of both DBPs and unacceptable tastes/odours are linked to the extent of causative factors such as natural organic matter precursors, scale of biofilm, water age and temperature. However, it should be noted that consumer acceptability of tastes is often influenced as much by the variation in chlorine levels as the absolute value.

The standards which apply to DBPs vary between countries as does the relative degree to which consumers will find chlorinous taste/odours acceptable. Thus the level of control necessary can only be determined locally. It is though important to stress that the advice from WHO is that microbial safety should never be compromised in an attempt to reduce DBP levels**.**

Risk mitigation measures

Risk mitigation strategies for controlling microbial growths in the network whilst at the same time meeting locally determined requirements for DBPs and consumer taste/odours can be complex since they can be affected by a wide range of local factors. Risk mitigation should be part of an overall asset management strategy. Which combination of measures need to be introduced will depend on local resources, priorities and decisions but could include:

- Upgrading and/or improved operation at the waterworks. This can reduce seeding of microorganisms into the network (which can also be protected in particulate matter) and reduce organic matter in the final water that can act as nutrient for microbial growth and precursors for DBPs
- Improved management of the network to reduce water age and areas of stagnation (including treated water storage facilities) and avoid velocity surges which can disrupt biofilms. In some case network models can help to target such improvements
- Careful management of disinfection residuals within the network to keep them as low and stable as possible consistent with good microbial quality. Depending on the network this can achieved through management of the residual levels leaving the waterworks. However, in some cases the use of supplementary booster disinfection at strategic locations within the network can reduce the need for high residuals leaving the works and allow much more careful overall control of residuals. Some network models can also help with design of booster disinfection strategies.
- Choice of residual disinfectant. This is very much a matter for local decision and may also be impacted by local laws which could stipulate which disinfectant can or cannot be used. Typically there are three main choices:
    - *Chlorine*: An effective network disinfectant commonly used in many countries but can

lead to a range of disinfection byproducts. The rate of DBP formation is influenced by pH, time, temperature and organic precursor levels.

- *Monochloramine*: Monochloramine is usually pre-formed at the water works. It persists longer in the network than chlorine and tends to form lower DBP levels although it is a less powerful disinfectant. Monochloramine formation at the waterworks must be carefully controlled to avoid formation of dichloramine and trichloramine in the network both of which have very strong tastes which consumers find unacceptable. Care must also be taken not to mix chlorinated and chloraminated water within the network since this can also lead to formation of adverse tastes.
- *Chlorine dioxide*: This is a powerful disinfectant which minimises formation of organic DBPs such as THMs but does break down to chlorate and chlorite both of which have been the subject of health advice from WHO and which may be subject to local regulatory requirements.

- Introduction or review of existing network cleaning strategies to improve removal of sediments and other material which can exacerbate biofilms and other nuisance organisms.
- Review of long term network rehabilitation strategy to increase rate of renewal of mains in poor condition.

Typical control points

The most effective control points will depend on an assessment of the most likely risks and the potential causative factors. This can be helped by mapping the extent and nature of potential problems within the network using GIS or network models.

Based on this assessment control points could include:

- Levels of key parameters leaving treatment works e.g. disinfectant residual, DBPs, turbidity, organic nutrient
- Levels of microbial indicators such as E.coli, coliforms and HPC either ex works or at strategic points within the network
- Levels of disinfectant residual and its variability in the network
- Levels of relevant DBPs within the network
- Numbers of consumer taste/odour complaints

Reference for further detailed information:

- Relevant WHO publications
  - 2003 “Heterotrophic plate counts and drinking-water safety: The significance of HPCs for water quality and the human health” (Click here)
  - 2004“Managing microbial water quality in piped distribution systems” (Click here)
- Relevant case studies

Typical resources needed:

Depending on the quality of raw water and the condition of the water works/ associated distribution network, management of network regrowth and disinfection can be a complex process. In some situations therefore it can be is a major activity with potentially significant long term resource requirements. Risk based prioritisation of work though a comprehensive asset management plan is most likely to be the best way forward.

Document creation:

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