Managing Water Safety and Quality in Distribution

Briefing Note

CIWEM Chartered Institution of Water and Environmental Management

Contents

CIWEM is the leading independent Chartered professional body for water and environmental professionals, promoting excellence within the sector.

May 2023

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CIWEM's position

CIWEM recognises that water companies actively take steps to maintain the safety and quality of drinking water as it leaves a water treatment works and passes through the network of pipes and storage reservoirs into customers' homes. It requires constant vigilance and effective responses, particularly in emergency situations, where immediate action is necessary to protect public health. The UK water industry reliably and consistently supplies drinking water of excellent quality: in 2018, the industry figure for public water supply compliance with the EU Drinking Water Directive was 99.95%[1] despite much of the infrastructure being old and inaccessible underground.

Clear and demonstrable benefits to public health have been provided by regulations governing the type of materials that are permitted to come into contact with drinking water needs to be maintained. Much of this work has been undertaken through development of effective standards and guidelines through collaborative working at national and the European level.

There are several advantages in water companies owning customers' supply pipes, including leakage reduction and lead pipe replacement. The supply pipes lead from the stop valve outside a property to the point where it enters the customer's home, and are currently the responsibility of the property owner. The plumbing inside customers' homes should remain the responsibility of the property owner. The costs and benefits of water companies adopting customers' supply pipes are described in more detail in the Water Supply Pipes PPS.

The UK has a good track of research into water quality in distribution and this work is essential for the long-term delivery of safe and sustainable drinking water. It is particularly important that the outcomes from research are of practical value to the operational and maintenance procedures undertaken by water companies.

[1] http://www.dwi.gov.uk/about/annual-report/2018/CIR-2018-England.pdf

Context

In England and Wales, the network of pipes is extensive: there are over 335,000 km of pipeline delivering drinking water. Pipes may be old and are made of a variety of materials. In addition, several thousand storage reservoirs help to maintain an adequate supply of water at a suitable pressure. There are approximately 24 million connections to homes and properties and managing this vast supply of water is complex. The condition of the pipes, including those owned by customers themselves, will impact the quality of the water and water companies have operational procedures in place and make recommendations to safeguard the quality of the water arriving at customers' taps.

It is important that the supply is properly maintained and operated to prevent any ingress of contaminants or to prevent any deterioration in water quality that may affect its chemical, microbiological and aesthetic quality. Regular checks on water quality are performed by water companies to assess for any deterioration. In the event of a water quality standard being infringed, immediate action is taken to identify and remedy the cause to minimise any risk to public health and/or supply drinking water that is unpalatable.

Operational practice and procedures

In the UK, a disinfectant residual is applied to drinking water leaving all treatment works. Guidelines from the World Health Organization advocate a maximum chlorine residual concentration of 5 mg/l for drinking water. Water companies apply a concentration based on knowledge and experience of the network that is often well below this concentration. Sometimes it is necessary to add additional disinfectant part way through the network to achieve a sufficient residual at the end of the network.

The residual serves two purposes. It provides some protection against ingress of any harmful microbiological contaminants. Also, a residual can act to preserve water quality by preventing the growth of microorganisms that may cause undesirable changes in its appearance or impart an unpleasant taste and odour to drinking water.

Chlorine (free available) and monochloramine are the two disinfectants commonly applied to treated drinking water. Chlorine is more effective as a disinfectant than monochloramine at an equivalent concentration, but the latter is more persistent and more likely to reach the end of a network in the absence of any additional disinfectant dosing

Both types of disinfectant residual, however, may be consumed during supply through the network. They can react with organic compounds in the bulk water and with different types of pipe material, particular iron mains.

Cleaning and flushing of water mains are very important operational procedures which are used extensively by water companies to maintain water quality in the networks by keeping the water fresh and removing any deposits which may settle in the pipes. Cleaning and flushing the pipes will also minimise the residence time of drinking water in supply and reduce the loss of a residual during distribution.

Water Quality Key Issues

Microbiological quality

Pathogen intrusion

A secure and well operated distribution system is essential to ensure a supply of safe drinking-water reaches consumers. One of the greatest risks to public health associated with consumption of drinking water arises from ingress into a network of faecal contamination that may contain harmful microorganisms. Ingress can occur through failure in the integrity of a network caused by deterioration in the condition of service reservoirs and water mains, including their fixtures and fittings, cross-connections and back-siphonage. Inadequate water treatment may also act as a source of contamination. Evidence has emerged that demonstrates, under fully representative but extreme physical conditions, there is a risk to water safety due to net ingress and transport of contamination, originating externally, during extreme short duration pressure transient events that can exist in a network[2]. The implications of these observations, however, remain to be established for public health.

Deterioration in biological quality

Drinking water is not free of bacteria. They will be present in the water as it leaves a treatment works or gain access through a failure in the integrity of the distribution system. Typically, most bacteria will grow as biofilms attached to surfaces of walls, pipes and particulate material accumulated in a network. The vast majority of these bacteria are harmless inhabitants of the natural environment and pose no risk to public health through consumption of drinking water.

In the absence of an effective residual and particularly for drinking water derived from a surface source, with its greater amount of nutrients compared to groundwater, conditions exist for excessive microbial activity, especially during the summer months when water temperatures are at their highest. It may cause deterioration in the aesthetic quality of drinking water through the production of undesirable tastes and odours and imparting discolouration. The growth of these bacteria can provide a source of food for higher organisms, such as free-living protozoa, nematode worms and crustaceans that are occasionally present in a network.

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[2] Fox, S., Shepherd, W.J., Collins, R.P. and Boxall J. B. (2015) 'Experimental quantification of contaminant ingress into a buried leaking pipe during transient events' ASCE Journal of Hydraulic Engineering. DOI: 10.1061/(ASCE)HY.1943-7900.0001040

Chemical quality

Chlorine

As mentioned above, chlorine is added to the water as it leaves the water treatment works to provide a protective residual as the water passes from the works to customers' homes. Levels of chlorine are very low, but some customers can detect chlorine levels in their water supply from their taps. Higher chlorine levels may be present if a customer is close to the water treatment works or if there have been changes in the network that require an increase in chlorine levels. Some water companies may need to boost the chlorine levels in their supplies if the networks are large and the water takes a long time to reach the customer. These levels of chlorine are not harmful. Customers should seek advice from their water companies if there is a sudden change in taste or there is a strong taste that makes the water undrinkable. More information can be found on the DWI website.

Trihalomethanes (THMs)

Linked with chlorination, Trihalomethanes (THMs) are formed at very low levels from the reaction between chlorine and naturally occurring organic compounds and bromide in the water; this is a slow reaction which continues in the networks after the water has left the treatment works. The THMs most commonly present in drinking-water are chloroform, bromodichloromethane, dibromochloromethane and bromoform. There is a limit in national regulations for a Prescribed Concentration or Value (PCV) for the total concentration of THMs of 100 µg/l. Although levels of THMs may comply with the PCV at the point at which the water leaves the works, levels increase in the network and may exceed the PCV by the time the water arrives at the customers' taps. Water companies have many strategies to minimise THMs at customers' taps including the use of chloramines rather than chlorine to provide a residual disinfectant, minimisation of the natural organic compounds by the processes in the treatment works before chlorine is added, speeding up the passage of the water by reducing dead zones in water distribution systems to minimise the potential for THM formation and removal of THMs after they have been formed during water treatment.

More information can be found here on the World Health Organisation website.

Iron and manganese

Iron occurs naturally in water and can be used with other chemicals to treat drinking water. Iron compounds, in both solid and dissolved forms, may have entered the distribution network over many years at very low levels and can build up in the

network. Iron may also enter the water from corrosion of the iron pipes frequently found in networks; harmless rust particles build up as sediment on the bottom of the pipe. The main issue with iron is aesthetic as it causes the water to become red/brown and cloudy.

Manganese too occurs naturally in the raw water source. Very low levels of manganese can pass through the drinking water treatment processes and enter the network. Even at very low levels, below its acceptable limit for drinking water, manganese compounds can build up over the years in pipes with low flows. Again, the main issue with manganese is aesthetic as it causes the water to become black/brown and cloudy.

Iron and manganese are most likely to be apparent in drinking water after a sudden change in the operation of the network, such as a valving change, or after an unplanned change in flow due to the use of hydrants for fire-fighting, or valving operations required to isolate a main to effect a repair. Water companies can minimise the risk of producing coloured water[3] by maintaining a flushing programme, making changes slowly to the flows in the network, chemically conditioning the water to reduce the potential for corrosion and replacing or relining old pipes with new pipes made from newer plastic materials. More details can be found here on the DWI website. Customers should seek advice from their water companies if their water is discoloured.

Taste and Odour

Customers may perceive that their water has a different or unacceptable taste and odour and this may be due to its passage through the networks to their taps or a change in where their water is coming from. Sometimes the taste and odour compounds are natural and arise because of the seasonal nature of the quality of the raw water sources. In some instances, it is the customers' own internal plumbing systems or domestic devices (copper or galvanised pipes, incorrectly fitted softeners and home treatment devices) which lead to the problem and it is not always straightforward to pinpoint where source of the taste and odour is coming from. New kettles, rubber washers or plastic fittings and tap inserts may all lead to changes in taste and odour.

[3] Husband, P. S. and Boxall, J. B. (2016) 'Understanding and Managing Discolouration Risk in Trunk Mains' Water Research. Vol. 107 pp. 127-140. DOI.10.1016/j.watres.2016.10.049

More details can be found here on the DWI website. Customers should seek advice from their water companies if their water has an unusual taste or odour.

Very occasionally the corrosion of internal copper pipes can lead to blue water or stains around fittings. More information can be found here on the DWI website.

Lead

The use of lead pipes for drinking water supplies was ended in the 1970s but there is a legacy of pipes and fittings supplying older houses which may result in lead in the drinking water from customers' taps. Lead is still used illegally in some solders or used by unqualified plumbers. Where the water is hard and well buffered, scale can form in the pipes and this may help prevent the leaching of lead into the water. Where water supplies are soft or where water companies have identified a risk of lead in the water, water companies add phosphate to the water as it leaves the treatment works to overcome the potential leaching of lead into the drinking water. Dosing with phosphate leads to the formation of an insoluble deposit of lead phosphate on the pipe wall that massively reduces solubilisation of lead. Water companies must maintain phosphate dosing at all times to keep lead levels low. Although these methods are very effective, dosing chemicals is costly, and the only way to completely remove the risk of lead in drinking water is to remove the lead pipes and ensure that lead is not used in any domestic fittings or solders. More details can be found here on the DWI website.

Pipes and pipe materials

The pipes are made from a range of materials including various forms of iron (including cast and ductile iron), asbestos cement, galvanised steel or iron and PVC. The materials used, and their construction and fittings, have changed over the years and it is mostly polyethylene pipes that are laid now because of their durability and the reduced impact on water quality.

As mentioned above, iron pipes can corrode which can lead to elevated iron levels in the water and to bursts in the distribution network. Walls of manufactured pipes have become thinner over the years as production of pipes has improved and so age alone is not a good predictor of the tendency of a pipe to burst. Also, the condition of pipes depends on the performance of anticorrosion coatings.

All pipe materials must be suitable for use in contact with drinking water and are regulated by the DWI through their approved product process to be safe for the supply of drinking water.

Conclusion

CIWEM commends the fact that compliance with water quality regulations in England and Wales in 2018 was very high (99.95%) despite the large distances that water has to travel to reach customers through ageing networks.

CIWEM recognises that water companies are pro-active in maintaining the safety and quality of drinking water as it passes through the network of pipes and storage reservoirs into customers' homes. Regular checks on water quality are performed by water companies to monitor for any change in quality to ensure that the water arriving at customers' taps is safe and pleasant to drink.

References / Further Reading

Drinking Water Inspectorate for England and Wales DWI, https://www.dwi.gov.uk/

Drinking Water Quality Regulator for Scotland DWQR, https://dwqr.scot/

Northern Ireland Environment Agency NIEA for guidance and links to the current regulations. https://www.daera-ni.gov.uk/topics/water/drinking-water

Scottish Executive (2006) Private Water Supplies: Technical Manual, ISBN: 0-7559-5151-4 Published by the Scottish Executive.

Camm, R., Ferrere, P., Hall, T., and G. Stanfield. (2008). UV Inactivation of Cryptosporidium. UK Water Industry Research (UKWIR) Report 08/DW/06/20. UKWIR, Queen's Gate, London.