Chlorine-free drinking water

how might that be done?

Water New Zealand's Principal Advisor Water Quality, **Jim Graham**, travelled to the Netherlands and Denmark to find out about chlorine-free drinking water supplies.

UV disinfection is sometimes used as an alternative to chlorine disinfection. Photo: Queenstown Lakes District Council.

It must be possible to operate safe drinking water supplies without the use of chlorine because they do this in other countries including the Netherlands and Denmark. But how do they do it and would it be possible in New Zealand?

The Havelock North Inquiry recommended that all water supplies are treated, including with a residual disinfectant, except in exceptional circumstances. The Government is likely to adopt this recommendation, but what might those exceptional circumstances be?

In June I travelled to Europe to speak with Marco Dignam, researcher at Waternet in Amsterdam, Netherlands, Lars Holmegaard, director of Lemvig water supply, Denmark and Henrik Bjorn, associate professor at VIA University College in Arhuss, Denmark.

The Netherlands

First up, the Netherlands doesn't provide a good comparison for our country. The geology, and hence water quality, is different, as are their motivations for not using chlorine. There are 10 water supply organisations in the Netherlands, They are publicly owned and structured on a corporate model. All connections are metered and all consumers pay volumetric charges.

The Netherlands is built on sand, clay and peat and it is small and flat. They stopped using chlorine to disinfect their water supplies due to concern in the 1970s about research which linked chlorine disinfection by-products to increased cancer risk. But while chlorine is not used, drinking water is comprehensively treated, including with disinfection, before being distributed.

Waternet operates the Amsterdam supply. They are a large organisation responsible for drinking water, sewerage, storm water, groundwater and nautical waterway control. Another part of Waternet is responsible for flood protection, water level management, surface water quality control and wastewater treatment.

They have 1.2 million customers and cover 20 municipalities, employ 1770 people and have an annual budget of €383 million ($660 million).

They operate two water treatment plants, providing 90 million m^3/yr via 3100 kilometres of pipes. Every property in their area is connected to their supply and they have a leakage rate of 2-3 percent in their network. All properties are also connected to their wastewater system and they operate 12 wastewater plants with 4200 kilometres of wastewater reticulation. Consumers pay €1.55/cubic metre for drinking water, about $2.70/$m^3$.

The Amsterdam supply highlights the differences to our drinking water supplies. Water is abstracted from two sources, river water from a branch of the Rhine and seepage water from a polder.

QMRA (Quantitative microbial risk assessment) is used to identify the risk of pathogens in source waters and multi-barrier approaches are used to eliminate them. The river water is abstracted and treated with coagulation and sand filtration processes before being conveyed a significant distance to sand dunes on the coast near to Amsterdam.

The water is run into ditches in the sand dunes so that it infiltrates through the sand, a natural filtration process. It is collected from underneath the sand dunes and undergoes further rapid sand filtration, ozonation, softening and carbon filtration before it is passed through slow sand filters. It is then distributed to the consumers of Amsterdam.

A polder is a low point, enclosed by embankments into which water seeps from the surrounding country and nearby lakes. Polder water has a coagulant added to it before it is stored in a lake. It then undergoes sand filtration, ozonation, softening, carbon filtration and slow sand filtration before being distributed.

Similar processes are used in other cities like Rotterdam but in the east, water suppliers use groundwater and treat it with aeration and filtration to remove oxidised iron and manganese. Groundwater is not usually disinfected but surface waters are, generally with ozone, UV, peroxide or chlorine dioxide.

Considerable research is funded by the water suppliers. A research group called KWR undertakes water research on behalf of the water utilities and is funded by them. They collaborate with the universities and water suppliers in this research. Both the Amsterdam water treatment plants divert 1/200th of their flow to pilot plants that are used to test new ideas and equipment, including challenge testing with viable microbes.

Management of distribution systems is more comprehensive than here. Without a chlorine residual, it needs to be. One of the key ideas used in the Netherlands is to maintain biological stability of the water through use of carbon filtration and sand filtration.

That's not to say the water supplied to consumers does not contain bacteria, monitoring by flow cytometry shows typical cell concentrations of 10,000,000/100ml.

The pipe network in Amsterdam consists mainly of cast iron, PE and PVC. Only small amounts of AC have been used (61 kilometres, two percent of total). They have a comprehensive pipe renewal programme. Pressure differentials are monitored across the network, all connections have backflow devices including RPZs at industries.

The water is monitored at 200 routine sites and a number of random sites for *E. coli*, Enterocci, HPC and Aeromonas. A lot of effort is put into ensuring water storage and distribution is secured against contamination. But the key thing that Waternet relies on is the knowledge and hygienic awareness of people working on the system. It is considered a mistake not to report anything considered unusual. The principle of staff taking ownership. Of course chlorine is used to disinfect new pipes and when repairs are undertaken.

Denmark

Denmark provides a much better comparison to New Zealand. The geology, outwash gravels from advancing and retreating glaciers with three significant aquifers under the country, is similar to areas of New Zealand where ground water is used.

Denmark is also small and flat. Every drinking water supply in Denmark uses groundwater and the Danes have 160 years of experience in the sustainable use of ground water for that purpose. They have never used chlorine because they do not consider it necessary.

But that is not to say the water is not treated. Aeration and sand filtration is used to remove iron, manganese and ammonia. UV disinfection is used temporarily in some places if the bacterial quality of water is compromised, but this rarely occurs.

Denmark is also similar to us in having a relatively large number of small water and wastewater utilities. They are owned by the municipalities, but have corporate governance structures and are operated as though they were private companies.

The Lemvig supply for example has a board appointed by the municipality which can include up to two consumer representatives. There are about 100 municipal owned water utilities like Lemvig in Denmark and a further 2400 community supplies, some quite large that are owned and run by the community.

There has been some voluntary aggregation of smaller water supplies in recent years. In 2010 a law was passed that removed direct operation and control of water and wastewater utilities from local authorities.

All water supply costs are recovered from consumers with mandatory water metering and volumetric charging. Domestic consumers pay the equivalent of NZ$ 3.20/m^3.

Some commercial businesses pay less as water suppliers seek to provide incentives to locate in their region. Half of the fee is a tax which the water suppliers collect on behalf of the Government. It is used to fund national initiatives considered necessary to understand and protect the groundwater source.

The universities, research groups and water suppliers work collaboratively to undertake the research they see as necessary to support the way they do things.

There are two key approaches which make chlorine-free water supplies possible in Denmark. The first is source water research and protection.

They have a national database of all groundwater bores with data back to 1818. Three hundred thousand bores are registered into the database and instant access to all information is available, including to the public. Bores are sampled and tested either

annually or biannually for a range of parameters. Additionally the Danes have comprehensively mapped and modelled all of their groundwater and designated groundwater protection areas. They have comprehensive action plans for groundwater protection which allows them to undertake comprehensive groundwater management and informs decisions about where bores can be placed and how much water can be abstracted. These programmes are funded by the national water tax collected by the water suppliers.

The second key approach is careful management of the distribution networks. Every connection has a backflow device, double check valves at domestic premises and RPZs at commercial premises. Testable devices are tested at least annually. Water losses are around 5-6 percent and if losses exceed 10 percent water suppliers are fined by the regulator.

In addition to the usual water quality monitoring, water suppliers undertake considerable flow, pressure and temperature monitoring. In Lemvig, all dead ends have been removed and the network is configured with ring mains, an arrangement called looping.

The network is divided into relatively small zones or district metered areas (DMA), which have a single supply point with flow and pressure monitoring. They constantly monitor usage and leakage by comparing DMA supply point volumes against aggregated household volumes. All data is databased and analysed so that a clear picture of network performance is provided.

But probably the biggest difference in both the Netherlands and Denmark is attitude. The Dutch don't want to use chlorine because they perceive it to be associated with health risks. But they know that means operating their systems in a particular way to minimise microbial contamination.

The Danes have high quality groundwater and don't use chlorine because they don't consider it to be needed. They take the approach of *find it clean, keep it clean, distribute it clean*. It seems to work for them.

And these approaches are supported by the public. The public values chlorine-free water and are prepared to pay for it. They understand that it costs a lot and requires comprehensive national programmes and approaches. It was explained to me that the Dutch and Danes have a high level of trust in their Governments, local and central.

They accept the ideas of metering, charging and paying because they place a high value on their drinking water quality. They see the importance of research because they realise it is necessary to maintain and improve the systems they prefer.

New Zealand

So what might those exceptions to treatment and residual disinfected water supplies look like in a newly drinking water regulated New Zealand? I think Denmark provides us with the best model.

Generally our groundwaters are of high quality, if not without risk and we have a good understanding of our groundwater resources based on the research undertaken by Regional Councils, ESR and NIWA. Maybe we need better funding models for that work and a more nationally coordinated approach.

We would need to do a lot more work on source protection, probably along the lines of what Tonkin & Taylor has done with Hastings District Council for the Heretaunga aquifer, but it would need to be nationally consistent. It seems certain that a new regulator will require comprehensive source water assessments along the lines of GARP (groundwater assessment of risk of pathogens) as done in British Columbia. QMRA would be another option, but I'm not sure that lumping these new requirements onto the many water suppliers is the best way to go about this.

It's probably time for us to be thinking about a national water research unit, along the lines of what is done in the Netherlands and Denmark.

Our approach to distribution networks would need considerable change if we are to have non-chlorinated supplies. There is an AWWA (American Water Works Association) standard for the protection of water quality in distribution systems (G200) which doesn't assume that a chlorine residual is required.

Compliance with that standard would be a good starting point.

Following the Dutch and Danish models would require the installation of backflow devices at every connection and a comprehensive, at least annual testing programme. Considerably more monitoring of pressure and flow and the reconfiguring of networks so that calculations can easily be made of water use and water loss. Networks would need to be modelled and big data would be required to continually monitor network performance.

Network water loss would need to be reduced to five percent or less, requiring considerable, expensive upgrading. These things are just the beginning.

But the major change required would be attitudinal, both amongst water suppliers and consumers. Because the costs of providing water supplies like this is high. Consumers would need to place a very high value on non-chlorinated water supplies and they would probably need to fund the necessary research.

The Dutch and Danes charge $\$3/m^3$ because they have been operating supplies in this way for some time. Retro-fitting is expensive and my guess is that consumers could be expected to pay more than that. It goes without saying that universal metering and volumetric charging would be essential.

Both the Dutch and Danes said that corporatised water entities, large or small, were essential because decision making needs to be independent of other municipal activities. Decision makers need specific water supply knowledge and water funding should not be competing with other projects.

One of the keys to achieving any of the above would be undertaking research to develop a greater understanding of water and wastewater systems, the people who use them and the environments in which they are placed.

Chlorinated supplies or not, future decisions about our water and wastewater need to be informed by coordinated New Zealand-centred research. A uniquely New Zealand water and wastewater research centre would be a great outcome of the current three waters review.

And then there is the question of fluoride. The Dutch and Danes don't fluoridate their water supplies. But that's another story. **WNZ**

• *Water New Zealand would like to thank Koen Overkamp and Sarah Lund for organising meetings in The Netherlands and Denmark.*