Can drinking water be delivered without disinfectants like chlorine and still be safe?

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Chlorine needed? Credit: Wisconsin Department of Natural Resources, CC BY-SA

When we open the tap, we expect the water to be safe. That is, the water should be free of pathogens that could make us sick and any chemicals that could cause problems later in life.

For the most part, potable water systems in the developed world have done a great job providing safe water. However, there are still unfortunate situations that develop, resulting in issues with the safety of drinking water.

Most notably, in the past several months, the city of Flint, Michigan, has been dealing with a crisis regarding their delivery of potable water. A significant number of the citizens of Flint were exposed to dangerously high concentrations of lead in their drinking water. The episode was triggered by a switch in drinking water source undertaken by the city, without the proper evaluation of the consequences regarding the change in the chemistry of the water.

The episode has brought much attention to water treatment methods to ensure public safety. In many countries the use of a disinfectant, such as chlorine or chloramine, in the distribution system is required. These countries include the United States and the United Kingdom. A disinfectant is used as a final barrier to protect human health against potential contamination events during distribution.

However, there are a number of countries that do not carry a disinfectant that remains in the water once it's distributed. How can these countries deliver safe water without this disinfectant included?

In a recently published paper, we, together with other colleagues, set out to evaluate this question. Our main motivation was to take a close look at whether municipalities could avoid some of the potential negative effects of a disinfectant while still ensuring public health.

The pros and cons of disinfection

One of the great public health successes of the 20th century was the eradication of most waterborne epidemics in the developed world. In the year 1902, chlorine was first added to water as a disinfectant in Belgium.

Additional sites in the United States and the United Kingdom following suit by 1908. This resulted in a decrease in the incidence of waterborne diseases.

Fast forward to 1974, when Dutch researchers discovered the presence of chloroform, a probable human carcinogen, in potable water.

Ever since, scientists have identified hundreds of disinfection byproducts (DBPs), compounds that are formed by the reaction between chlorine and naturally present organic matter in the water. The concentrations of these compounds are regulated in the United States and Europe based on measurements of indicator groups of compounds, such as trihalomethanes, which are known to be carcinogenic.

The discovery of DBP, coupled with negative public perceptions regarding the taste of chlorine, has motivated several countries, including the Netherlands, Switzerland and Germany, to move toward potable water delivery systems without disinfectants that remain with the water – known as residual disinfectants – and thus, reach people's taps. This change started in the late 20th century.

All water treatment facilities include a disinfection step designed to inactivate pathogens. This process can include different disinfecting agents such as chlorine, ozone, chloramine and UV light.

After disinfection, the water is considered safe. In countries that do not carry a disinfectant that remains in the water beyond the treatment plant, engineers focus on producing water that does not contain high concentrations of biodegradable material that might encourage microbial growth in the pipes. Microbial growth in pipes in the form of biofilm can be undesirable because it contributes to corrosion and water quality degradation and could potentially harbor pathogens. Generally speaking, these countries also conduct a higher level of treatment of the water.

In the United States and United Kingdom, a residual disinfectant is required within the water distribution system as part of the final barrier. But the use of this disinfectant also means that concentrations of DBPs must be managed. The current best practice for managing DBPs includes reducing water age in the system through pumping and storage optimization, aeration for stripping of volatile compounds at storage facilities and dosing disinfectant at remote sites across the system.

In the Netherlands, Switzerland and Germany, by contrast, a residual disinfectant is not used as a barrier. In these countries water utilities rely instead on advanced treatment, improved physical integrity of the distribution system and careful management of distribution system operations.

Distribution system management in the Netherlands, for example, begins with network design. This includes trials of so-called self-cleaning networks using significantly smaller sized pipes than in North America to reduce water age. There are also proactive operational programs such as monitoring, flushing, break repair and precautionary boil water notices for customers.

It's worth noting that water is distributed without a disinfectant only as long as sufficient barriers against contamination are in place. The concept of multiple barriers ensures safety in the event of a failure of one of these barriers, which include protecting the source water, multiple treatment steps and proactive management of the distribution system.

This prompts the question: which approach is right?

To answer this question, we need to define the parameters under which the approaches will be evaluated. Said simply, we need to address whether the presence of a disinfectant results in lower incidences of waterborne outbreaks. Regarding DBPs, we can agree that limiting exposure to them is a good thing.

Is chlorine needed to protect human health?

As it turns out, there is very little data showing that a disinfectant residual in the distribution system has prevented waterborne outbreaks.

A comparison of waterborne outbreak data from different countries shows that the Netherlands, the one country we evaluated that does not use disinfectant residual, has very little risk of waterborne disease. So in terms of microbial indicators of risks, systems with a residual disinfectant are not necessarily safer than those without.

One key difference between these countries could be the condition and operation of the pipes that distribute the water. In general, countries that do not carry a residual have invested in upgrading their distribution systems to limit contamination events from leaks and breaks.

For example, in the Netherlands, at least half of pipes have been replaced from cast iron to plastic since the 1970s, resulting in fairly young distribution systems. In the United States, there is a serious need to upgrade infrastructure and this will require a significant investment over the next decades. However, the investment is worth it to avoid another public health crisis like in Flint, Michigan.

One of the conclusions from our research is that potable water systems should consider moving beyond carrying a disinfectant and focus instead on maintaining and replacing their aging delivery systems and upgrading their water treatment steps. This will have the benefit of limiting exposure to DBP while also continuing to deliver safe water to consumers.

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