How can your smartphone make water safe to drink?

Authors:
Jianfeng Zhou, Wenbo Ding, Xing Xie, and others
Associate Editors:
Liesa Ziegler and Madeleine Corcoran

Abstract

Clean drinking water is essential for our health. Water containing bacteria or viruses can make us very sick. Unfortunately, not everybody has access to clean water from centralized water plants. However, nearly everybody nowadays has a smartphone! That's why we developed a small device and an app which can be used with a smartphone to kill harmful bacteria in water. It could mean that people without a clean water supply can easily disinfect their drinking water and avoid getting sick.

Introduction

Do you know how much water you need to drink each day? For children and teenagers aged 9-13 years old, it's about eight cups. Everything in our body needs water to work! But sadly, not everyone has access to clean drinking water.

In the U.S., for example, a lot of people living in rural areas do not get their water from *centralized water plants* . These plants are very expensive to build and maintain. This means they get their water from other sources, such as wells and springs – and it can have bacteria in it.

If you drink water with bacteria in it, you might get very sick – some people even die. That's why, people living in rural areas need to *disinfect* (clean) their water before they drink it. There are a few different ways to do this. For example, you can use *iodine tablets*, which are quite efficient at cleaning water. But they can also have negative side effects on your body if you use them for too long. So they are not ideal to use every day.

Other methods include using *ultraviolet lamps* and special *filtration systems*. But all of them have at least one disadvantage. Lamps use a lot of energy. Filtration systems are expensive and parts often need to be replaced when they get clogged. This makes them unsuitable for people who depend on such devices for everyday life.

Therefore, we wanted to use a simple energy source. One that nearly everyone nowadays carries with them constantly: a smartphone! What if we could clean water with such a common device? Wouldn't that save a lot of trouble?

Water found in nature may not be safe to drink.

Methods

We designed a downloadable app and a cheap device that can be plugged into a smartphone to disinfect water (Fig. 1).

The method our device uses is called *electrochemical disinfection*. It uses electric currents to generate substances that can kill bacteria. In our experiments, we used:

1. A smartphone to generate the electric current and
2. Copper wires as a source for the antibacterial substance.

Thanks to the electric current from the phone, copper *ions* are released from the copper wire. These copper ions kill bacteria.

Copper can also be dangerous for humans but only in much higher concentrations. We tried to find the perfect balance: where just enough copper ions are released to kill the bacteria, without reaching a harmful level for humans.
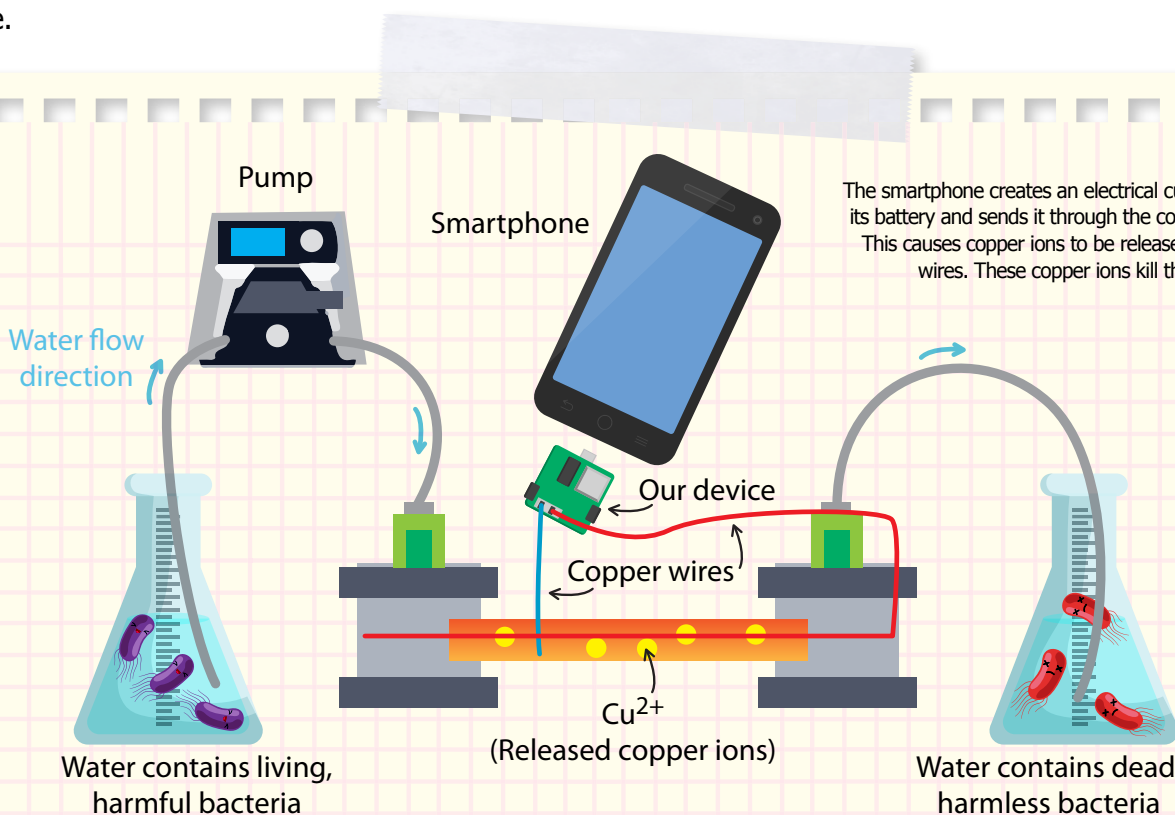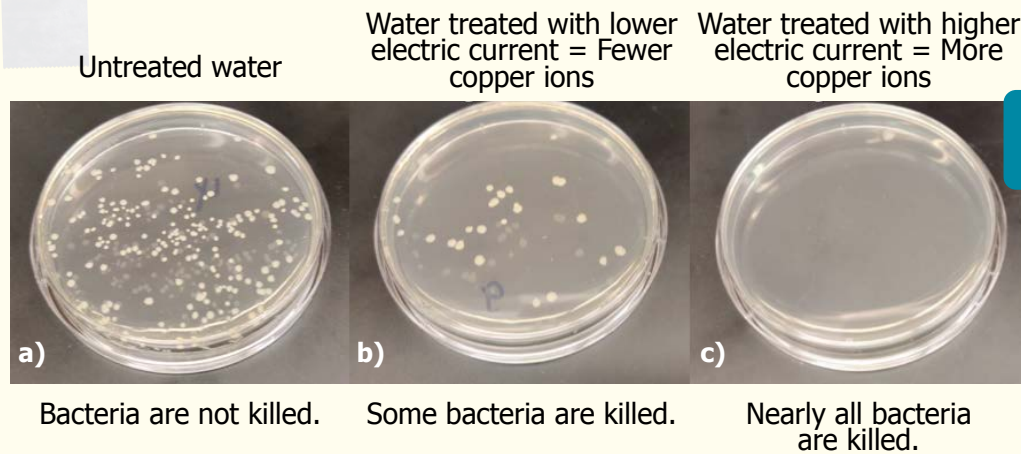

Pump

Smartphone

Water flow direction

Figure 1:
The smartphone creates an electrical current from its battery and sends it through the copper wires. This causes copper ions to be released from the wires. These copper ions kill the bacteria.

Our device

Copper wires

Cu^{2+}
(Released copper ions)

Water contains living, harmful bacteria

Water contains dead, harmless bacteria

Results

With our new device, we were able to kill almost all bacteria in the treated water. We tested how well this had worked by putting samples of our treated and untreated water onto *agar plates* (Fig. 2). If disinfection doesn't work, *bacterial colonies* grow on the plates.

We also found the perfect balance between killing all the bacteria but keeping copper levels low enough for humans. We worked out how strong the current needs to be and how fast the water has to flow past the copper wires to achieve this balance. With this *optimum* level, nearly all bacteria can be killed, while the released copper is still harmless to humans.

Untreated water | Water treated with lower electric current = Fewer copper ions | Water treated with higher electric current = More copper ions

Which treatment method worked the best? How can you tell?

a)

b)

c)

Bacteria are not killed.   Some bacteria are killed.   Nearly all bacteria are killed.

Figure 2:
We put samples of untreated and differently treated water on agar plates. Each white dot is a bacterial colony. By testing the water in this way, we were able to find the best way to run our device to make sure it killed almost all of the bacteria.

Discussion

Although our device worked really well we only tested it in a limited laboratory setting – so some things could be different in real life.

We were able to disinfect three liters (or 8 cups) of water by only using less than 1% of the phone's battery. The device was able to disinfect the water at phone battery levels as low as 5%. However, the disinfection of these three liters took about five hours – which is too long.

Still, all of our tests suggest that it is possible to improve the speed of our device quite easily. When this is done, anyone with a smartphone can use our device to disinfect their drinking water. Occasionally, the copper wire will need to be replaced. Luckily, these wires are very cheap. The whole device will cost only around $5 - $10.

We did not test if our device can kill other harmful microorganisms like viruses. Work by other scientists using copper ions suggests that they can destroy viruses too. Of course, this needs to be tested specifically before our device can be used by humans for their everyday drinking water.

Conclusion

Clean drinking water is a basic human need. Unfortunately, not everybody around the world can take it for granted. If you want to learn more about this problem, take a look at the UNICEF links in the reference section below.

Hopefully, our device will be ready for everyday use very soon! If you live in an area without access to water from a centralized plant, you can use it to keep yourself and your family safe from harmful bacteria in the water. Or, you could use it if you go on holiday to such areas.

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Glossary of Key Terms

Agar plates – small plastic dishes filled with agar. Agar is a substance on which a lot of bacteria really like to grow. It is a jelly-like substance that can be harvested from algae. We used nutrient agar plates: the agar provides the base for the bacteria to grow on, and the nutrients provide the food they need to grow.

Bacterial colonies – a big group of bacteria. A whole bacterial colony can grow from one single bacterium. Therefore one colony consists of completely identical bacteria. They can become so high in numbers that the colonies are visible without a microscope.

Centralized water plants – a building where water is cleaned to get rid of the harmful things, such as bacteria, viruses, particles and harmful chemicals, that can be in the water. The cleaned water is then distributed to the people living around the plant through pipes.

Contaminated water – water with harmful substances in it. These substances can be bacteria, viruses, or other microorganisms, or they can be particles or harmful chemicals – all of which can make humans sick when they are ingested.

Disinfection – the act of cleaning something so that it doesn't contain any bacteria or viruses. In this case, unclean water must be disinfected so that it's safe to drink.

Electric current – the movement of special so-called "charged" particles (= ions or electrons) through a specific space (for example, a wire).

Electrochemical disinfection – a method for cleaning water. An electric current is used to generate chemicals that are harmful to bacteria and viruses. The process of killing bacteria with these substances is called disinfection.

Filtration system – a system of filters. These filters have holes of specific sizes which only let through substances up to this specific size. So you can filter bacteria from water because bacteria are much larger in size than water molecules. Viruses are smaller than bacteria and therefore require filters with even smaller holes than for bacteria.

Iodine tablets – iodine is a chemical element that is harmful to bacteria. In the form of tablets, it can kill bacteria in your drinking water. If you drink water with too much iodine in it you can suffer from side effects like headache, stomach pain, and even fever.

Ions – tiny particles that have an electric charge: either positive or negative. This charge can be seen as chemically stored energy which can be converted into electricity.

Optimum – the best for our purposes.

Ultraviolet lamps – these lamps emit a very specific light that is harmful to most living creatures – it's also harmful to humans if you get a high dose of it! To operate these lamps you need a high amount of energy. Ultraviolet light is also emitted by the sun. That's why you get sunburn when you are out in direct sunlight for too long.

Check your understanding

1 Why is contaminated water dangerous?

2 What methods can be used to disinfect contaminated water?

3 How much time does it take our device to disinfect three liters of water and how much of your phone battery do you need for it?

4 Why is our device suitable for people to use all over the world? What are its advantages and what are its limitations?