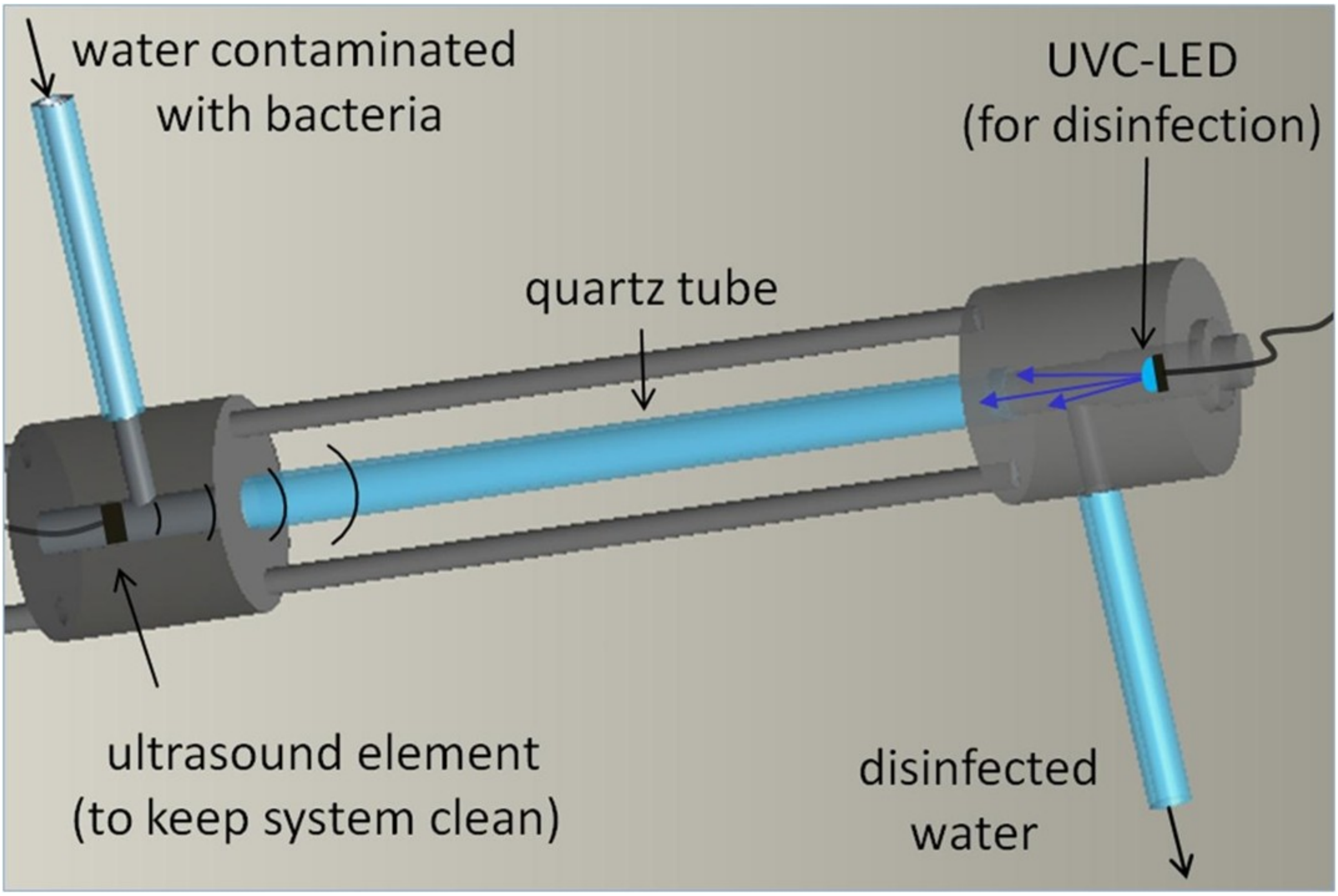
A DNA cracker from Ulm for making clean drinking water

Drinking water that is pathogen-free and safe for humans flows from German taps. There is no nutrient as vital to human beings as water and – at least in Germany – that is subjected to so many checks and controls. Nevertheless, access to clean drinking water is not to be taken as given. According to the latest WHO figures (2011), 768 million people do not have access to healthy drinking water, especially in some of the poorer African countries. The project "DNA-Crack" from Ulm aims to change this situation.

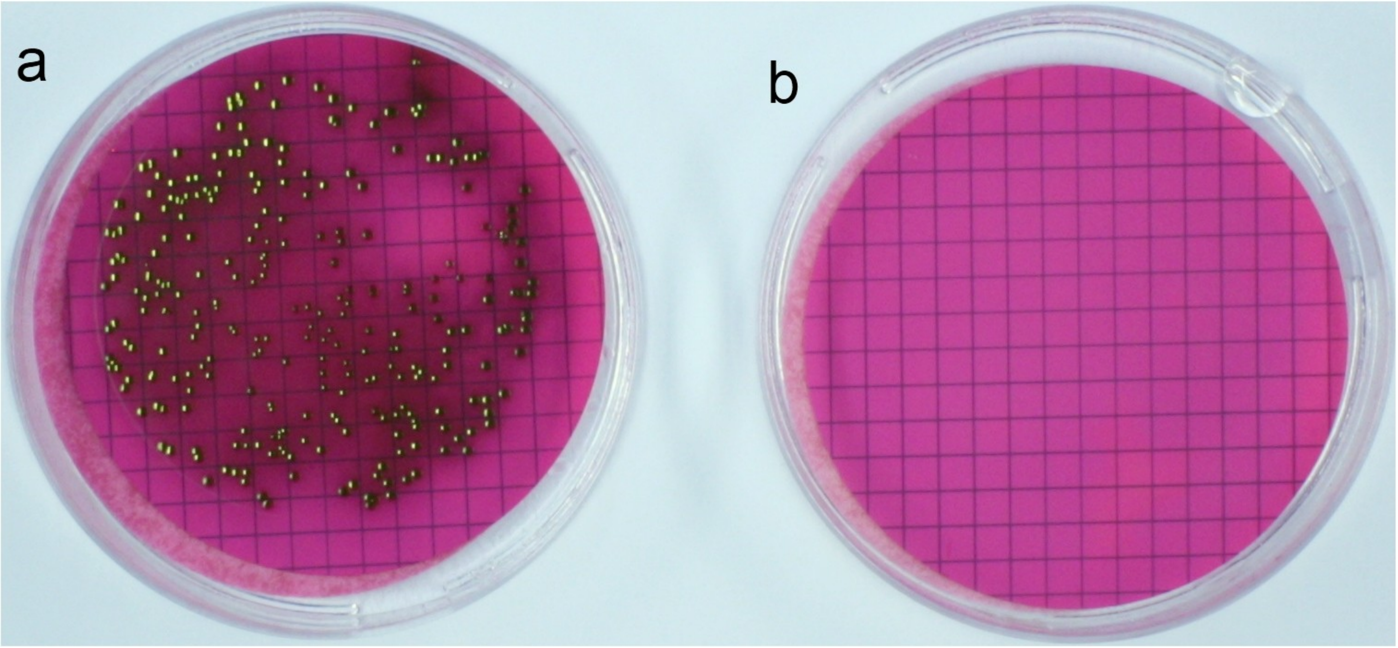


Schematic of the laboratory DNA cracker, shown here without integrated solar energy supply.

"DNA-Crack" is a cooperative project funded by the German Ministry for Economic Affairs and Energy under its ZIM (Central Innovation Programme for SMEs) programme, which is aimed at developing the "DNA cracker" laboratory prototype into a marketable commodity by 2015. The project is the continuation of work already carried out as part of the prize-winning projects of two medical engineering graduates from Ulm and is aimed at turning the scientists' ambitious goal into reality in cooperation with two companies called EPIGAP Optronic GmbH and fosera GmbH & Co. KG: the DNA cracker is specifically designed for small families living in remote areas with no access to water mains supplies and power grids. DNA cracker is intended to enable them to sterilize five litres of water per hour at any time of day or night. The DNA cracker is self-sustaining as it works on solar cells with no consumables and can run for many years without requiring maintenance. Prof. Dr. Martin Hessling from Ulm University of Applied Sciences is coordinating the project and is convinced that the DNA cracker is just what the developing world needs: worldwide, over 100 million people become ill every year after consuming contaminated drinking water; every day, over 3,000 children die from the consequences of consuming unsafe drinking water. In contrast to industrial countries where drinking water is disinfected in large systems with chlorine and other chemicals, rural areas in developmental countries either have no such systems or lack the infrastructure for distributing disinfected drinking water.

Need for alternatives

Bacteria can be killed by exposure to ultraviolet (UV) light. For many decades, around 50 countries have been using a method known as SODIS (solar water disinfection) for disinfecting drinking water. Contaminated surface water is poured into transparent PET bottles and exposed to the sun for at least six hours. During this time, the sun's UVA radiation kills disease-causing pathogens. This method helps prevent diarrhoea and thereby saves lives. However, the simple procedure has its limitations; it is unsuitable for disinfecting large amounts of water and storing it for later use. Investigations undertaken by Ulm University researchers have shown that if the water is not kept in cool conditions, pathogens that survive disinfection will start to multiply again.



UVC radiation kills E. coli: nutrient pads 24 hours after contact with water samples (left: contaminated water; right: UVC-treated water that is free of germs).

The Ulm researchers' DNA cracker is a small disinfection system, equipped with a novel UVC-LED, a small ultrasound generator, a solar cell and a battery. It is able to disinfect around five litres of water per hour. Germicidal UVC light (ultraviolet light with wavelengths between 200 and 280 nm) has been used for disinfecting water for many years. Energy-rich photons are absorbed and lead to the destruction of the genetic information in the DNA of microorganisms. Irreversible DNA damage renders harmful bacteria and viruses ineffective. Michael Sift, one of the researchers from Ulm, believes that inactivating human pathogens such as E. coli as well as those that cause life-threatening diseases such as cholera, typhus and amoebic dysentery is crucial.

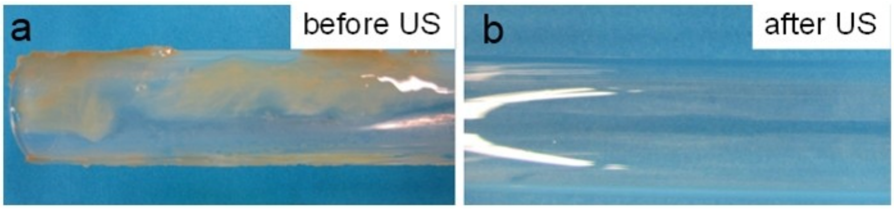
Hope for progress in LED development

Mercury vapour lamps have a strong emission peak at 254 nm, which is close to the DNA absorption maximum of around 260 nm. They are therefore suitable for killing bacteria using UV light. However, they are not very environmentally friendly, have a limited lifespan and require a high voltage supply.

UVC-LEDs have only recently become available as an alternative to mercury vapour lamps. UVC-LEDs have emission peaks between 240 and 280 nm. Current UVC-LEDs still have comparatively low power levels (one-digit milliwatt range) and a limited lifespan (around 1,000 hours). Based on information from his Berlin-based project partner, LED specialist EPIGAP Optronic, Prof. Dr. Martin Hessling hopes that major advances in LED technology will soon lead to high-power, long-life UVC-LEDs.

The most powerful UVC-LEDs to date have a maximum wavelength of 280 nm. Relative DNA absorption is, however, lower at 280 nm than at 254 nm, which, as mentioned above, is the radiation peak of mercury lamps. On the other hand, 280 nm wavelength UVC is absorbed less strongly by water, enabling UVC light to cover a greater distance in water. Hessling and Sift believe that LED systems are particularly suitable for use in technical devices due to their small size and low operating voltage and power requirements. They also believe that they will be suitable for compact UVC-LED systems with a solar energy supply.

Ultrasound for destroying biofilms



P. fluorescens prior to ultrasound treatment (left) and after 5-minute radiation (right).

Biofilms, groups of bacteria in which cells stick to one another, often form on the surface of flow systems (e.g. flow chambers, catheters) and are difficult to remove. The cooperation partners will therefore equip the DNA cracker with a small ultrasound generator in order to remove potential biofilm and other contaminations. Laboratory tests have shown that ultrasound increases the disinfecting power of UVC light in dirty water due to its ability to remove bacteria from dirt particles. This reduces the ability of dirt particles to protect bacteria against destruction by UV light. Experiments with a pre-prototype have already been successful. No pathogens survived the UVC-LED radiation of water containing a specific load of E. coli colonies (60,000 CFU/ml; CFU = colony forming units). With 160 million cases per year, E. coli bacteria are the most common cause of diarrhoea. An ultrasound treatment lasting just 5 minutes was able to successfully remove an E. coli and Pseudomonas fluorescens biofilm grown in a glass vial.

Miniaturization and endurance test

The biggest challenges are still to come. The DNA cracker needs to pass a practical endurance test, which means that it must be able to disinfect heavily contaminated water under extreme climatic conditions day and night. This requires a much stronger UVC-LED lamp (10 mW). In addition, the researchers will have to miniaturize the ultrasound generator and subsequently integrate it into the system. Moreover, the entire system, which combines UVC-LED and ultrasound with different voltages, must consume no more than 10 W in order to run on power generated by a pico-solar system. The DNA cracker's solar

A day’s walk away from the nearest town, these water storage facilities in Ethiopia are only accessible by foot or horse.
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system will be developed by fosera GmbH & Co. KG based in the city of Illerkirchberg, close to Ulm. The company run by an Ulm University of Applied Sciences graduate and experienced in Third World markets, sells 100,000 long-life solar battery LED systems per year and knows what application security is all about.

A functional DNA cracker, including a pre-filter for cleaning heavily contaminated water from puddles, waterholes or other types of surface water, will most likely be available by late 2015. However, current high LED costs prevent the system from being placed on the market, at least for the time being. Hessling and his team are well aware of this, but believe that LED technology development will make rapid progress, resulting in rapid commercialization and cost reductions. As originally planned, Hessling wants to optimize the DNA cracker for application in the field of medicine. He believes that the LED and ultrasound modules that are currently being developed are small enough for the point-of-use disinfection of surfaces in intensive care wards and dental clinics.

Sources:

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Sift, M.; Wagner, S.: Wasserdesinfektion: Untersuchungen zum Wirkprinzip der Solar Water Disinfection (SODIS), Master's Project Report, Ulm University of Applied Sciences, 2013 (in German only)