COSIMA

KlarCap

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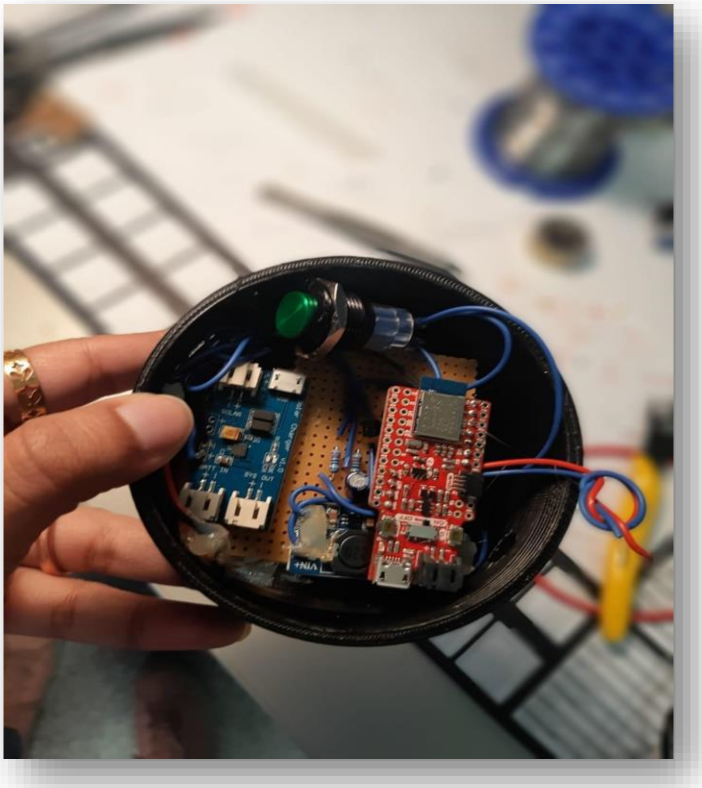
Abstract

When visiting a new place, be it for trekking, camping or some remote location - the first priority always is to have a clean source of water. It becomes necessary to disinfect the water before consuming it.

The contaminated water may look clean visually, but it may contain water borne germs and viruses. Drinking contaminated water may lead to several diseases such as cholera, diarrhoea, dysentery, etc. Treating these could be challenging especially when away from our comfort zones and without access to proper healthcare facilities. The best solution to this would be carrying a portable water filter which can disinfect water instantly and make it drinkable.



Innovation

The prototype shows a portable water filter cap that can instantly filter polluted water. This is composed of two parts. The first is a physically activated charcoal filter that eliminates solid particulates from the water, while the second is in charge of killing the microorganisms that may be present. The objective is to stand out in all aspects of purification (physical, chemical and micro-organisms).

The purpose of a physical charcoal filter is to remove suspended dust particles, chemicals such as chlorine, heavy metals, and other undesirable suspended particles. UV filters are used to destroy the DNA of biological agents such as E.Coli / Bacillus Subtilis and fully eradicate these dangerous microorganisms. UV-C light with a wavelength of **275 nm** is used in our prototype.

3-D Design

A 3d model for the enclosure of electronics was done using Autodesk Fusion 360. Then the model was printed with the help of OpenLab, Helmut Schmidt Universität Hamburg.

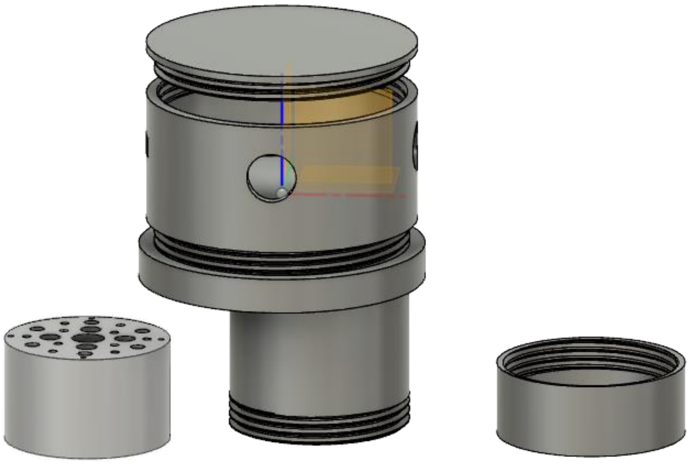


Fig. 1 *3D representation of the cap (front view)*

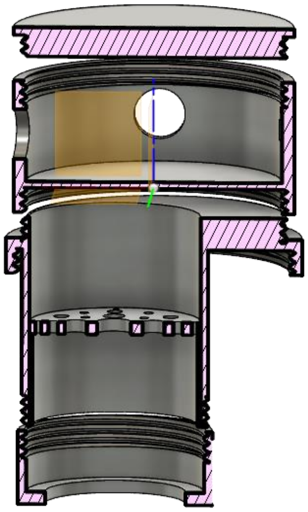


Fig. 2 *Cross-sectional view of the cap*

Electrical Circuit

The circuit enables the filtration process when the button is pressed. The circuit constituents are as follows:

- Microcontroller (nrf52840)
- Solar Charger
- Li Po Battery
- Boost Converter
- Cables and mechanical switches
- UV-C LED (275 nm)

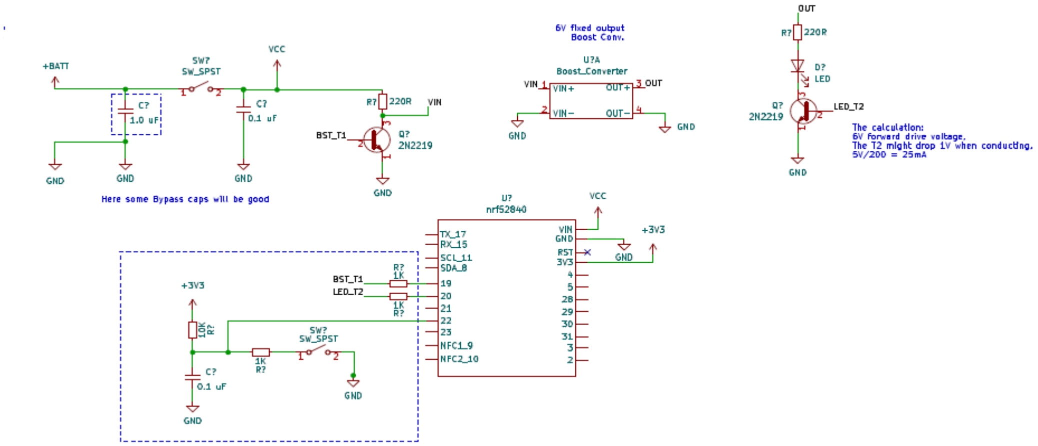


Fig. 3 *Schematic*

The layout of the schematic of the electronic circuit was completed using KiCad (open-source software for Electrical schematics and PCB design). In our circuit, we use nRF52840 as the brain microcontroller programmed to control the functionality of the UV light and the user input switch. This also includes a solar module to the circuit to support the environment ecologically instead of using LiPo batteries. The battery is recharged using this solar module and can also be recharged via a USB port. It is a two-switch circuit. The battery supplies 3.7V to the boost converter which boosts the voltage to 6.1V that is given to the UV LED. This voltage is maintained to have an effective forward biased voltage. The microcontroller governs this whole function.

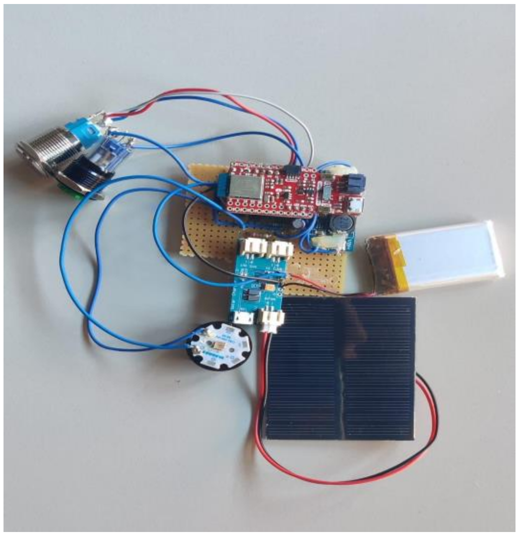


Fig. 4 *Components*

Software

The microcontroller is programmed using the Arduino IDE. The flowchart of how the code works is shown below. The system powers up the entire circuit when the power button is pressed. When the momentary switch (switch B) is pressed, the UV-C LED powers on for 60 seconds to destroy the germs in the water. The LED automatically goes off after 60 seconds. With this interrupt, the filtration process may be repeated numerous times (switch B).

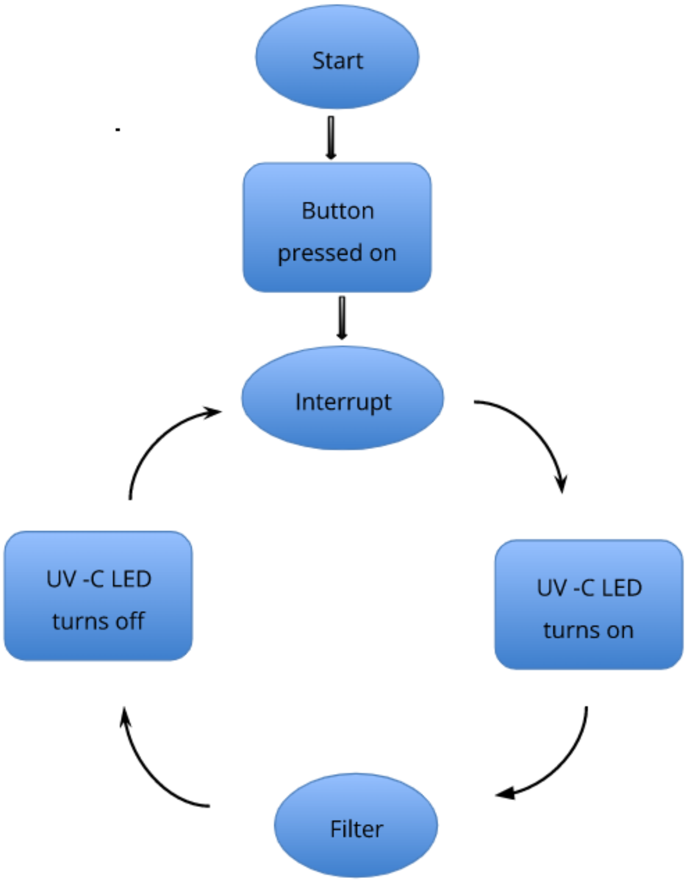


Fig. 5 *Filtration process flow chart*

Testing

Water Quality Standards

The following table depicts the safe drinking water level of each component.

Chemicals	Safe drinking level
Chlorine (Cl)	<250 mg/L
Iron (Fe)	0.3 mg/L
Copper (Cu)	1 mg/L
Lead (Pb)	0.01 mg/L
Nitrate (NO_3^-)	50 mg/L
Nitrite (NO_2^-)	0.1 mg/L
Alkalinity	80-160 ppm
pH	6.5 - 9.5 pH
Ca	>30 mg/L
Mg	10-30 mg/L
E. coli / B. subtilis	0 colonies

Table 1 *Safe drinking level concentration of each substance*

Physical filter

Charcoal is nothing but carbon. Charcoal is treated with oxygen to open up millions of tiny pores between the carbon atoms. The more porous the carbon, the better, as this will increase the surface area available to trap the contaminants. The activated charcoals are used to adsorb odorous or coloured substances from gases or liquids. -Activated charcoal is good at filtering several impurities such as chlorine. However, not all kinds of chemicals are filtrable, like sodium, nitrate etc. and hence they pass right through it. Also once all the bonding sites of the charcoal are occupied, it is time to replace the filter as it would no longer be able to purify.

Chemical analysis

Tests Performed

Element determination

ICP-MS	
analytes	Silver, arsenic, gold, boron, beryllium, bismuth, cerium, cadmium, cobalt, chromium (total), copper, iron, manganese, molybdenum, nickel, lead, phosphorus, selenium, antimony, titanium, thallium, uranium, vanadium, zinc
instrument	ICP-MS, PE NexIon 300D or 350D

To determine the elements in aqueous samples, ICP-MS (inductively coupled plasma mass spectrometry) is used. After introducing the sample into an 8000K hot argon plasma as an aerosol, the resulting ions are transferred into the mass spectrometer via interface cones. When ions enter the mass spectrometer, they are separated by their mass-to-charge ratio, allowing for very precise identification of analytes. The concentration in samples is measured using an external calibration and the results are reported in µg/l.

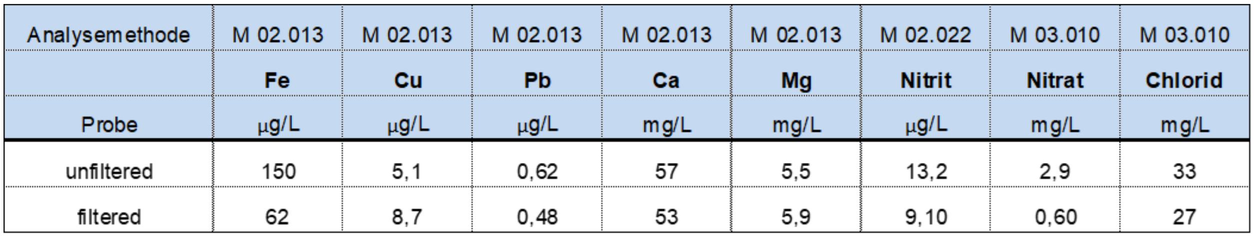
Quantitative determination of anions

Ion chromatography	
analytes	Fluoride, Chloride, Bromide, Nitrate, Phosphate, Sulfate, Iodide
instrument	IC system, Dionex ICS1100

In this method the sample is passed over the stationary phase (anion exchange resin) using an aqueous carbonate solution as eluent and separated there. The substances are then detected in the conductivity detector and quantified by comparing the peak areas with standard solutions. The result is given in mg/l or in mg/kg in solid samples.

Results

The table below depicts the results of the concentration found before and after the chemical analysis.



Analysemethode	M 02.013	M 02.013	M 02.013	M 02.013	M 02.013	M 02.022	M 03.010	M 03.010
	Fe	**Cu**	**Pb**	**Ca**	**Mg**	**Nitrit**	**Nitrat**	**Chlorid**
Probe	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	mg/L	mg/L
unfiltered	150	5,1	0,62	57	5,5	13,2	2,9	33
filtered	62	8,7	0,48	53	5,9	9,10	0,60	27

Table 2 *Results of chemical analysis*

Microbial analysis

The E. coli / B. subtilis was not added externally on purpose. The idea behind this is to collect water from random sources which are not suitable for drinking directly and then filter it with this device prototype. The substances mentioned in the table are to be measured before and after filtration.

Regarding E. coli / B. subtilis, the amount has to be zero to make the water drinkable (The Maximum Contaminant Level (MCL) for bacteria in drinking water is zero coliform colonies per 100 millilitres of water).

Results

Fig. 6 *a) Unfiltered sample (Sample A) b) UV filtered sample (Sample B)*

Each sample of filtered and non-filtered water from a lake in Hamburg was placed on an agar plate in the amount of 5 microliters. Microbial colonies were seen on both agar plates after 24 hours. However, the kind of microbe was not recognized. On the contrary, colonies on UV filtered agar plate were far less than colonies on a non-UV-filtered agar plate. The results so found are convincing and hence prove the concept of the prototype.

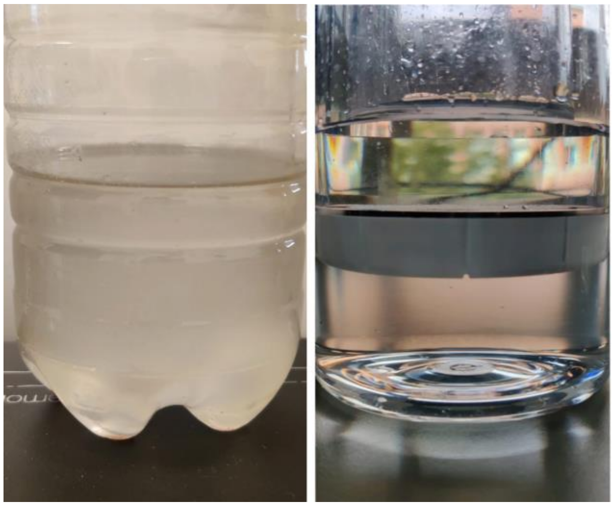


Fig. 7 *a) Unfiltered sample (Sample A) b) UV filtered sample (Sample B)*

Fig. 8 *a) Unfiltered sample with added E.Coli (Sample C) b) Filtered sample (Sample D)*

Sample C - E.Coli culture

Sample D - Filtered sample

The tests were repeated. This time E.coli was externally added to the water sample. The filtration effectiveness was limited by billions of E.Coli bacteria cells. So UV couldn't filter it properly. In a lake, there are only 350 cells/per 100ml.

Costing

Component	**Prototype Cost** (<5 units) (**€)**	**Production Cost** (>100 units) (**€)**
UV C led	4.91	3.0
Star Board	1.1	0.45
Heat Sink	8.7	2.5
Thermal Adhesive	0.75	0.5
nRF52840 / MCU	33.03	10

Li Po Battery	11.5	8
Boost Conv	0.79	0.4
Charcoal filter disc	5	3.5
3D-print	150	40
Production cost	10	5
Miscellaneous	15	10
Total	240.78	83.35

Table 3 *Market price of each component*

Scope

In a developed nation like Germany, we almost get pure drinkable water everywhere. But it is not true in all developing nations. And this prototype will be useful in those nations where access to pure drinking water is still a struggle. This product is developed taking into consideration the German legislation drinking water ordinance. Our motivation is to make drinking water accessible to people at an affordable price (developing nations).

Moreover, this is an easy-to-fit bottle cap which is carefully designed to ensure that it fits to locally standard bottle sizes. This product has a wide range of uses. Hiking, trekking, camping, visiting any remote locations, everywhere it is handy.

Limitations & Further Developments

The limitations so far include the source of water and the particle size up to which it can be filtered. This prototype works best when the source is running water. However, all the tests were carried out on the lake water.

To tackle the limitation of accessing remote water or increasing the input pressure, we planned to use a micro pump before the filtering step to better improve the ease of filling in water and also be able to use steep and remote water sources using an extended pipe fit to the micro pump.

Market analysis and Networking

This product is the resulting integration of various discrete components together with a custom-designed 3D printed, food-grade safe filter cap and proprietary hardware running embedded code. The manufacturing cost can be reduced in the mass production of the cap (possibly Injection moulding). In the process of designing and building the product, the team reached out to multiple suppliers in and outside Germany. We built networks and working relations with:

- Fabicity Openlabs
- Micro pump manufacturer - TCS Micropump (M200 series) they delivered us discounted components for micro pump testing (we plan to use this as a future upgrade, not currently implemented)
- 3rd party networks through startup events, who are interested in the idea and have spoken to the team regarding potential tie-ups in the future. We spoke to our mentors at OpenLabs and also connected with Fair Cap organisation and TUHH alumni, TU Berlin Alumni working on open-source hardware and water distillation projects in Deutschland as well as Greece.

Business Model

- **Paid Add-on services**
    - **Test strips or test containers:** Test strips or test containers could be ordered separately to check the quality of the water. Both of these would be a colour-based water test kit. These strips will be helpful to have a reliability check.
    - **Android app water quality meter:** Yearly subscription of an app-based feature which would generate a detailed report each time the water filtration happens. This would give the customers a sense of satisfaction as to whether or not more filtration is required. Implementations of this feature can be carried out using the Blynk IOT.

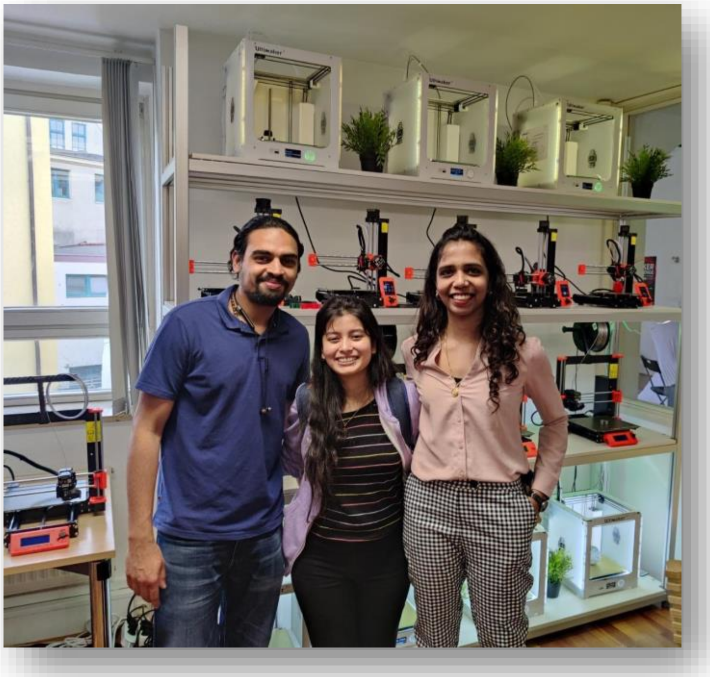
    - **Extended warranty/guarantee:** The warranty/guarantee period can be extended with an additional fee, but this fee would be closer to the original product selling price (say 40% of the original price). This will make the customers buy the newer product instead of extending the guarantee period. (Instead, should we provide a basic training video on how to charge the battery, check for damages, and change your physical filter discs.) The rest would not be a warranty but more like the assurance of the lifetime of the device. Warranty of such things should be limited to 6 months.

- **Patents:** Patent is an essential part of this concept. This model can be easily reverse-engineered and hence the patent of this product is important in this case. The prototype design is licensed under the CC BY-NC 3.0 DE License.
- **Customization of the bottle cap:** The bottle cap size can be customised on demand.

Acknowledgements

The idea has become a reality thanks to numerous collaborations. The prototype was developed with the collaboration of Fabcity OpenLabs and under the guidance of Prof. Dr.-Ing. High Khiem Trieu (Institute for Microsystems Technology, TUHH). In the FabCity Maker Challenge, the idea won 250 EUR to be used for purchasing hardware and parts, as well as 500 EUR to be used as resources (labs and 3D printing), for a total of 750 EUR raised from FabCity. In addition, mentor support and continued development were provided at OpenLabs Hamburg for a year. The project's 3D printing was handled entirely by OpenLabs. All chemical and microbial tests were carried out by Zentrallabor - TUHH and Microbiology lab. Thanks to Prof.Dr. Johannes Gescher and his colleagues Leonie Rominger and Edina Klein. Additionally, this project is also funded by TuTech.

Team



Team Supervisor

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Mikrosystemtechnik ,TUHH

KlarCap

We are students from Technische Universität Hamburg who have been working at the Institute of Microelectronics and Microsystems Technology (MEMS) since November 2020. Yes, from the pandemic year! Having diverse skills and expertise, ranging from software to electrical engineering, aided us in developing realistic solutions to real-world problem.

From Left to Right:

- **Varun Gonsalves**: Master's student at TUHH, currently working with Tesla motors.
- **Rijuta Bagchi**: Master's student at TUHH, currently having her experiences in semiconductor technology of discrete devices at Nexperia.
- **Suve Nisa Ramakrishnan**: Master's student at TUHH, currently working as wissenschaftliche mitarbeiterin at HAW.