Development of UV Portable Water Filter

Suhas Labade, Arun Dixit

VIGYAN ASHRAM

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1. Introduction

Introduction:

In Vigyan ashram around 100 students and staff members stay on campus and it's our need to get pure drinking water from available water sources. Major water source for drinking water is Well and Dam water which is contaminated and untreated.

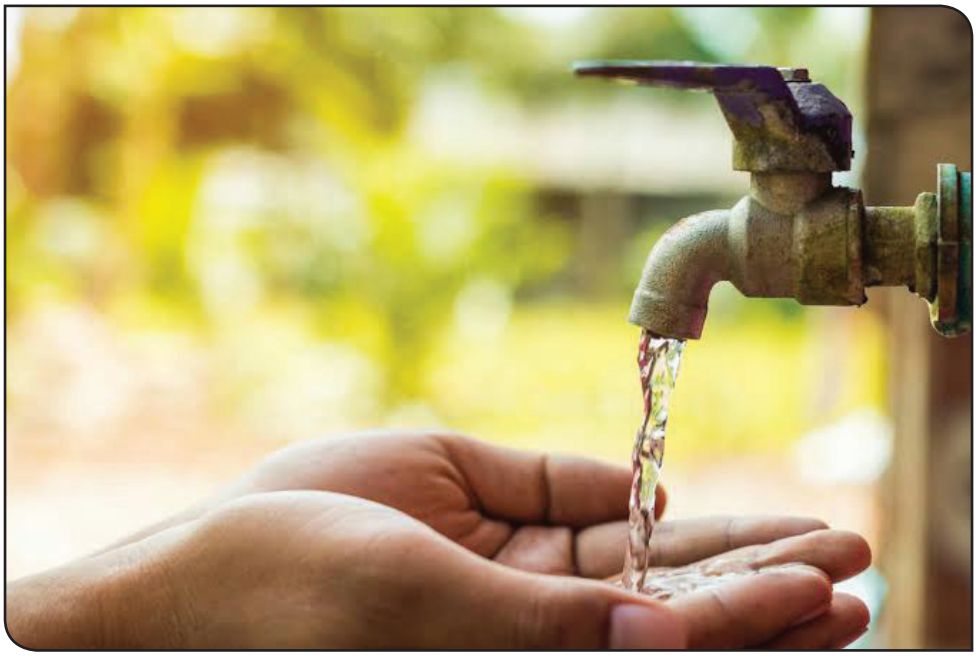
At Vigyan Ashram, we follow 'You can make almost anything' approach. For every problem we try to find out answer by learning science behind it, then experimenting and then designing our own solution based on our exact requirement.

This method has many advantages like it also leads to development of solution for people having similar problems. Further it trains our students in the process of development. This process also motivates some of them to start their own enterprises.

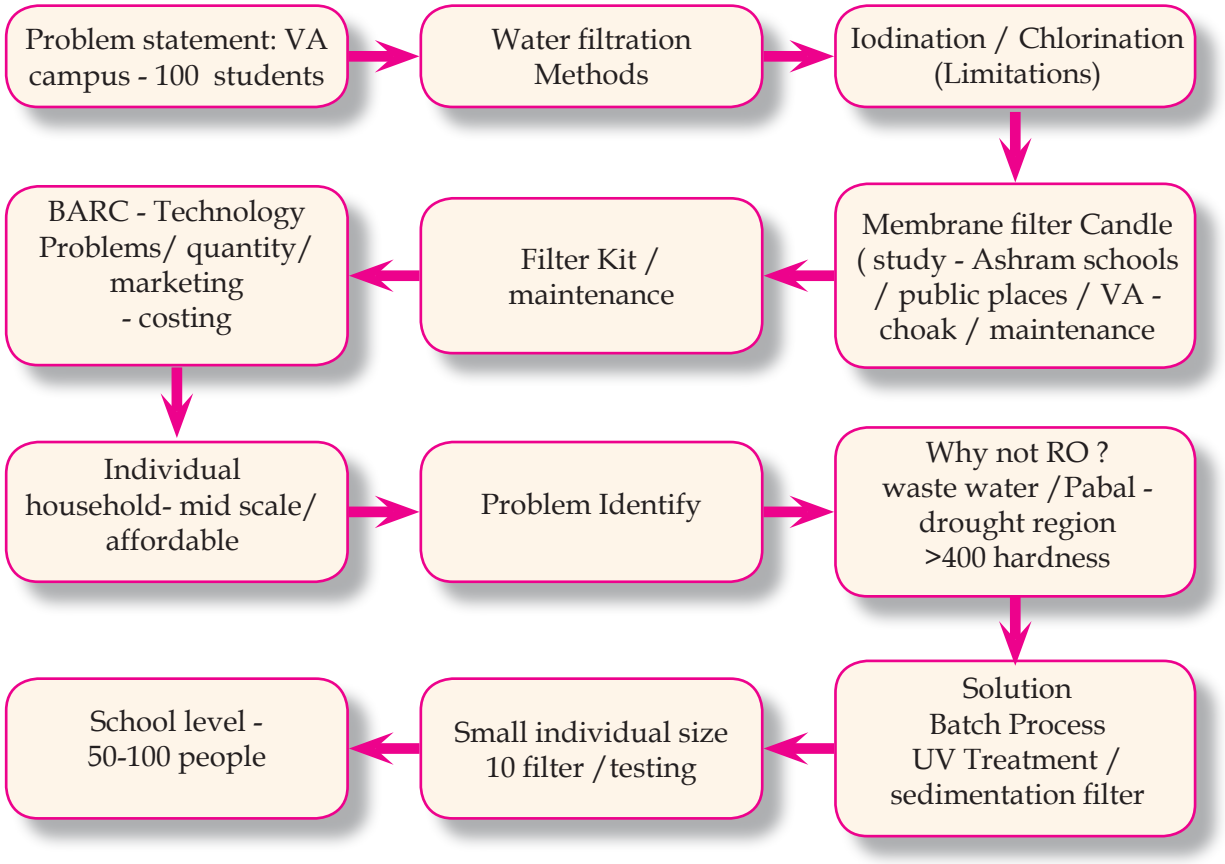
This document is above the journey to have a water filter systems that is affordable, effective and suitable to supplied water on campus.

This process of working on filters is going on for several years. Many students has contributed in this learning and experimentation.

During this development we tried different methods of water filtration and tested different available technologies in the market.



This document explaining overall development and future scope step by step in following flow –



Flow diagram 1.1 : Development stages of water filter at Vigyan ashram

There are several methods commonly available in market based on different working principles, each method has its own pros and cons, Initially we studied following methods to treat our water -

1. **Coagulation :** Adding alum /aluminum sulfate into untreated water. The resulting mixture causes the dirt particles in the water to coagulate or stick together. Then, the groups of dirt particles attach together, forming larger particles named flocks that can easily be removed via filtration or settling.
2. **Sedimentation :** Here heavy particles settle down at bottom called sludge and it can be removed through filtration and decantation.
3. **Filtration :** In filtration, water passes through a filter, which is made to take away particles from the water. It can be made up with sand or crushed anthracite (coal)
4. **Disinfection :** Its disinfected to get rid of disease-causing bacteria, parasites and viruses. Chlorine is also applied since it is very effective. Boiling, iodination and Distillation is another way to do that.

5. **pH correction :** To adjust pH levels, lime is combined with filtered water. This, also, stabilizes naturally soft water so corrosion can be minimized.

While designing water filter we initially considered to remove impurities in drinking water supply which has two forms -

1. Soluble impurities or invisible impurities like viruses, bacteria's, insecticide, pesticides and Calcium hydrogen carbonate, Magnesium hydrogen carbonate which increases water hardness.
2. Insoluble impurities that can be removed through filtration processes like candle / carbon filters or cotton cloth filters.

Till 2005, we were using chemical method to treat the water. We were pumping water from well near ashram to tank kept near kitchen. We used to keep iodine crystal in a bottle and filled it with water. We used put water in the bottle in the tank every day. There was a membrane filter in the kitchen, which was removing suspended particles and iodine was used to kill pathogens (virus, bacteria's).

In **Iodination** we need to add a measured amount of iodine to kill pathogens.

Afterwards, we started getting chlorine liquid bottles (Mediclore) from Gram Panchyat. We started using it for treatment for drinking water. It was effective but we understood the excess amount of chlorine affects on our health and also it gives bad odor and test to water. The main issue is meticulousness to put chlorine drops every day and in right amount, also it needs a minimum 4 hrs to process contaminants. Chlorine reacts with metallic pots and creates dark spots on it so it needs either plastic or earthen material.

We also tried another solution available in the market i.e. its gravity base filters that has iodine candles which can remove pathogens effectively and also filters water turbidity. Major challenge we faced in this type of filter is to get availability and durability of Iodine candles and there is no indication after the candle expires. Iodine candles can filter around 6000-9000 liters and after this it needs replacement. Most of the time people use it beyond limit or without iodine candle due to lack of knowledge or unavailability of candles. It's also not suitable for community places like schools, colleges where there is a continuous drinking water requirement.

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2. Problem Statement

Most of the water filter available in the market are for family size capacity. We have 100 students on campus and hence it doesn't work. Commercially available systems are costly and have many unnecessary features for us like water cooler, RO system etc.

We also visited many water filter system at public places. At many places the water filter systems was either nonfunctional or it doesn't give confidence that water is safe. Hence we have decided to study the water purification technology and build on for our campus.

Comparison of all these methods given below, each method has its advantages/ disadvantages -

Sr. No.	CANDLE FILTER	RO PURIFICATION	UV PURIFICATION	UF PURIFICATION	MF PURIFICATION
1	Can be with/ without electricity	Needs electricity for purification	Needs electricity for purification	Does not need electricity	Does not need electricity
2	Filters out most of Bacteria and Viruses from the Water	Filters out all the Bacteria and Viruses from the Water	Kills all bacteria and viruses but their dead bodies remain in the water	Filters out all the Bacteria and Viruses from the Water	Filters out only bacteria
3	Gravity or pump for pressure	Requires high water pressure. Therefore, an extra water pump is used in all RO purifiers	Works with Normal Tap Water Pressure	Works with Normal Tap Water Pressure	Works with Normal Tap Water Pressure
4	Cannot remove dissolved salts harmful metals	Removes dissolved salts and harmful metals	Cannot remove dissolved salts harmful metals	Cannot remove dissolved salts harmful metals	Cannot remove dissolved salts harmful metals

Sr. No.	CANDLE FILTER	RO PURIFICATION	UV PURIFICATION	UF PURIFICATION	MF PURIFICATION
5	Filters out all the suspended and visible impurities like mud, rust, dirt, sand etc.	Filters out all the suspended and visible impurities like mud, rust, dirt, sand etc.	No filtering	Filters out all the suspended and visible impurities like mud, rust, dirt, sand etc.	Filters out all the suspended and visible impurities like mud, rust, dirt, sand etc.
6	Size of candle of pores 0.3 to 50 microns	Size of membrane: 0.0001 Micron	No membrane	Size of membrane: 0.01 Micron	Size of membrane: 0.1 Micron
7	-	90% TDS reduction	0% TDS reduction	0% TDS reduction	0% TDS reduction
8	Low cost, Slow low filtration	Wastes a lot of water	No wastage of water	No wastage of water	No wastage of water

Following water treatment methods and techniques are available in market –

Micro-filtration	Comes in candle form with micro pores that removes particle greater in size and bacteria.
UF Treatment	UF (Ultra filtration) purification method uses membrane similar to RO membranes but with bigger pores. UF membranes essentially removes all colloidal particles including most pathogenic organisms and turbidity but fails to remove the dissolved solids and salts.
UV treatment	UV water purification is a method of water filtration which uses ultra-violet light to kill all germs, bacteria, microbes, cysts, etc. in water.
Reverse Osmosis	RO uses semipermeable membrane technology to remove dissolved salts, impurities and germs from water.

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3. Make your own filter!

Referring to all these technologies we have fabricated our own filter using materials available in the market. First filter we developed was a combination of UV and UF filter candles available in the market.

Following diagram describing its structure,here the overhead tank used to store supplied water from source and booster pump to boost water flow to pass from Sediment + carbon candles. Sedimentation and activated carbon candles were used to remove turbidity and organic chemicals. Solenoid valve controls water flow to pass it through UV candle to maintain retention time.

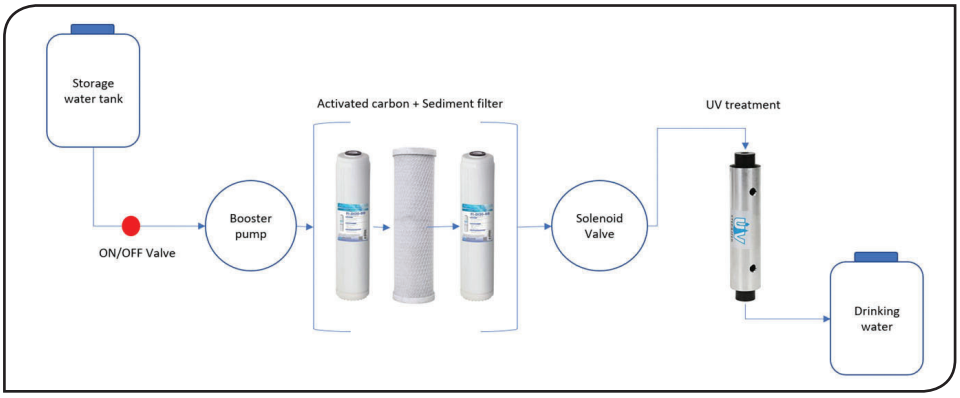

Fig. No. 3.1 : Filter kit flow diagram

We assembled all these components on campus and installed them at three places – Kitchen, Recreation area (Dream-house) and boys hostel.

Filter kit at Vigyan ashram kitchen

Filter kit at Student hostel

Required bill of material as below -

Sr. No.	Material Description	Quantity	Unit Price	Total
1	Spun pre-filter candle	02	80	160
2	UV Tube with case	01	300	300
3	Activated Carbon Candle	02	300	600
4	Booster Pump	01	1100	1100
5	Solenoid Valve	01	300	300
6	Pipe	3 meter	15	45
7	Elbow joints	15	10	150
9	Water Tab	01	100	100
			Total	**2755**

This filter kit worked effectively initially but given regular maintenance, leakages and part replacements due to moderately high-water hardness in this area.

Benefits of the system :

i) We used easily available stainless steel water container. This reduces the cost of the system.

ii) We learned assembly and removal of candles and hence it helped us doing regular maintenance of the system.

Following are limitations of this system –

i) Due to hardness of water. UV tube gets clogged. Since calcium carbonate coating gets formed on UV tube, they became opaque; which affected UV light exposure.

ii) Required retention time increases as coat increases that fails the system sometimes, it's also not measured.

iii) This system also needs an overhead tank, continuous electric supply and motor to drive water flow.

iv) It needs cleaning every 15 days and in rainy season sometime it clogs due to muddy water.

For recreation areas, is a public place and need bigger size container. Hence we have purchased SS water dispenser unit from fabricator in Pune. We have installed our own water purification system as above on it.

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4. Development of Sand filter

The supplied water on our campus is sometimes muddy and contains insoluble particles, which significantly affects the prefiltration stages of any normal filter. These particles primarily clog cotton filters and form coats on the UV candle. Consequently, it also reduces water flow, leading to variations in retention time for UV exposure and assumed flow rate. To address this issue, one of our DIC course student Miss Priyanka Gharat, developed a sand filter to be applied between the overhead tank and the booster pump, prior to the prefiltration stages. This sand filter consists of different layers of fine sand, gravels, charcoal, and stones, all stacked together in a PVC pipe with inlet and outlets for water to pass through all the layers. As a result, it effectively traps the insoluble particles and significantly reduces our maintenance needs.

We also installed this type of filter in Gurukul school in Pune.

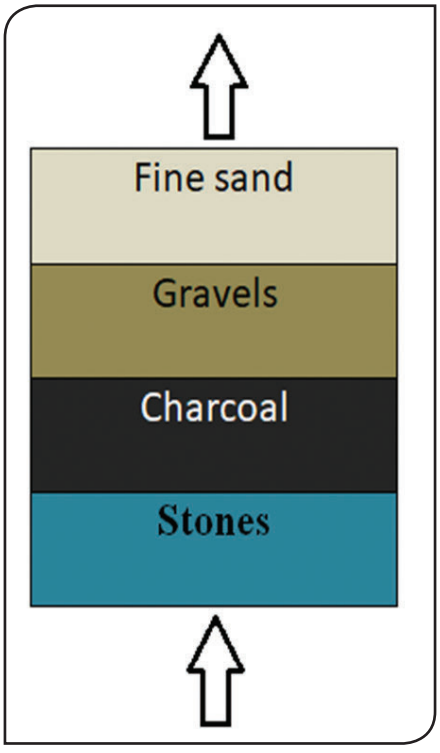

Fig. No. 4.1 : Sand filter kit diagram

Sand filter kit

UV filter installation at Gurukul, Pune

More information on sand filter is available here :

https://vadic.vigyanashram.blog/2020/06/19/solar-water-filter/

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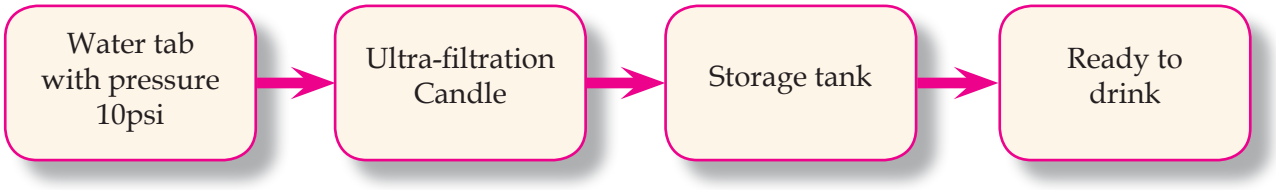
5. BARC Akruti Technology

BARC has developed a 'Akruti technology package', it includes water filter technology. We got access to these technology and we have decided to make filter using BARC design In this technology they used poly sulf one type of ultrafiltration membrane coated candles that removes bacteria to the extent of up to 99.99%. It also removes dead bacteria and completes turbidity. It doesn't require electricity and prevents loss of water during filtration.



Flow diagram 5.1 : BARC Akruti water filter flow diagram

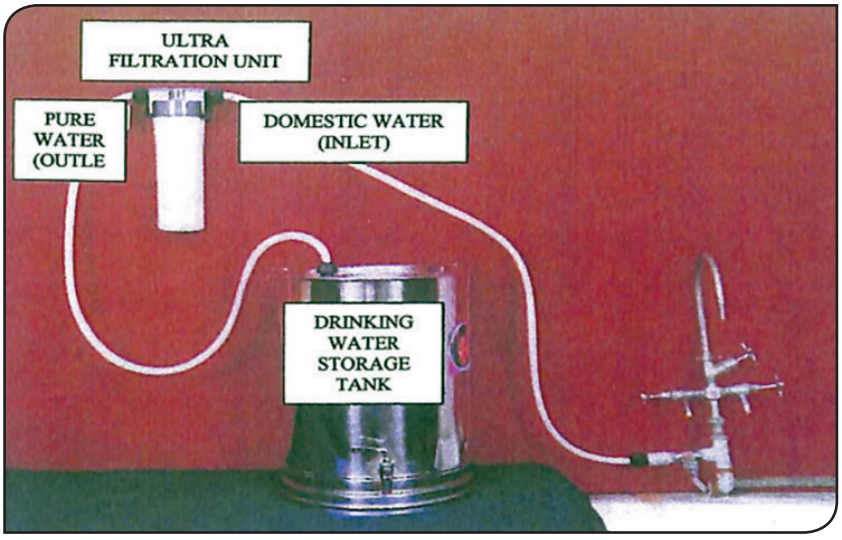


Fig. 5.2 : BARC Akruti water filter setup

Based on different pressures, various flow rates were considered in this design. Minimum required pressure needs to be 5psi that gives 1.5 to 2 lit water per hour.

Our DIC student, Mr. Amol Khamkar, initiated work on testing these candles and exploring the possibility of manufacturing them in large quantities. In 2018, when Kerala faced a flood, there was a high demand for portable filters of this type, prompting us to ramp up production to meet the needs. However, during this process, we encountered difficulties in sourcing Silver sulphonate in bulk quantities. Despite finding a limited quantity, we managed to deliver two filters to Kerala. Subsequently, we discovered additional limitations in mass production for this technology.

During the pilot testing phase, we encountered several limitations in this technology, which are listed below:

i) After 15 days of usage, the filter candles would stop water flow due to clogging. We faced challenges in accurately diagnosing the root cause of this issue. Subsequent testing of other candles also revealed the same problem.

ii) These candles require a hydrostatic head of 5 psi to 35 psi for proper functioning, which may not always be feasible on-site.

iii) Manufacturing these candles requires skilled expertise to achieve optimal quality.

iv) Additionally, the production process necessitates air-conditioned chambers with a relative humidity of less than 40%.

v) It's not a cost effective solution and difficult to get market value.

We have checked viability of mass production unit of these candles but found it to be difficult due to many big players in the market uses the same technology. More details on this technology available here : **https://www.barc.gov.in/akruti-tp/akrutitp.html**

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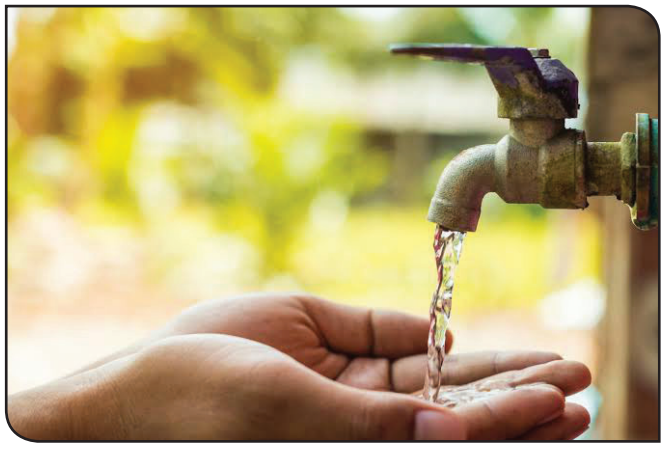
6. RO Everywhere !

Pabal is drought prone village. It has water scarcity. Still Gram Panchayat started RO plant, even there are private water purifiers, who are supplying water using RO method. One of the primary issues with RO technology is the substantial amount of water wastage it entails. In 2017, on the occasion of Independence Day, we organized a shramadan (voluntary work) at the Vegetable Market in Pabal village. During this event, we connected the nearby RO plant's wastewater, which was flowing on the streets, to the public toilets to utilize it for toilet flushing purposes. This solution proved effective for a certain period of time.

RO is useful when hardness of water is more than 400 TDS. It contains semipermeable membrane with pore size 0.0001 micron. It can be used to effectively remove many types of dissolved and suspended chemical particles as well as biological entities (like bacteria) from the water. If water TDS is less than 400ppm no need to use RO treated water.

Why not RO water?

Technologies available in markets like RO are not that effective and affordable in village like Pabal as water wastage is so often in this and it takes out most of the dissolved minerals. Also water hardness is less than 400 ppm of supplied water in Pabal so no need to maintain water TDS. Most of the time people over treat water and get rid of mineral deficiencies. So we decided to develop a new filter design that avoids gaps in previous methods.



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7. Nomadic people and water

Every year after monsoon, nomadic people came to stay on Vigyan Ashram, Pabal hills. They take water from our well and use it. They are not using any filtration. This leads to brainstorming among Vigyan Ashram, team and visit to filtration problem again. Through our experimentation, we have learned that to filter water we need two things :

I. To remove suspended particles, dust etc : Use of cloth, filter paper, membrane candle etc.

II. To kill pathogens : Use of UV lights.

Version 1.0 :

In the new design we focused on pathogens that majorly affect human health and spread water diseases. To kill pathogens, we tried to overcome difficulties in UV filter technologies available in the market. In the available water filter, usually UV candles come after pre-filtration and need another water source / tank to pass water continuously throughout in given retention time – it's a continuous type of filtering that needs continuous electric supply, overhead tank and motor to create water pressure. This increases electricity consumption and there are issues of clogging and water flow we identified in our previous designs.

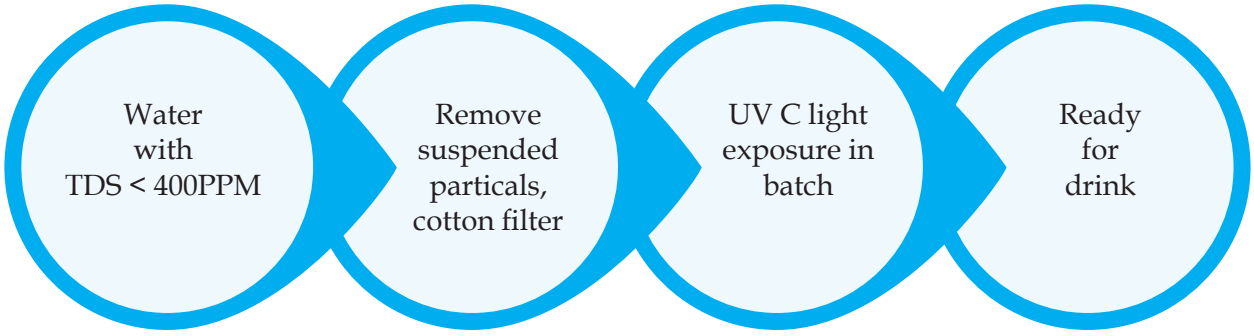


Fig. 7.1 : UV filter working flow diagram

To overcome these difficulties, we took trails of UV treatment in batch process i.e. provide UV C light exposure to water in bulk quantity in given retention time, which might kill pathogens in water in a short time and doesn't need motor, overhead tanks and continuous water flow like the market available system.

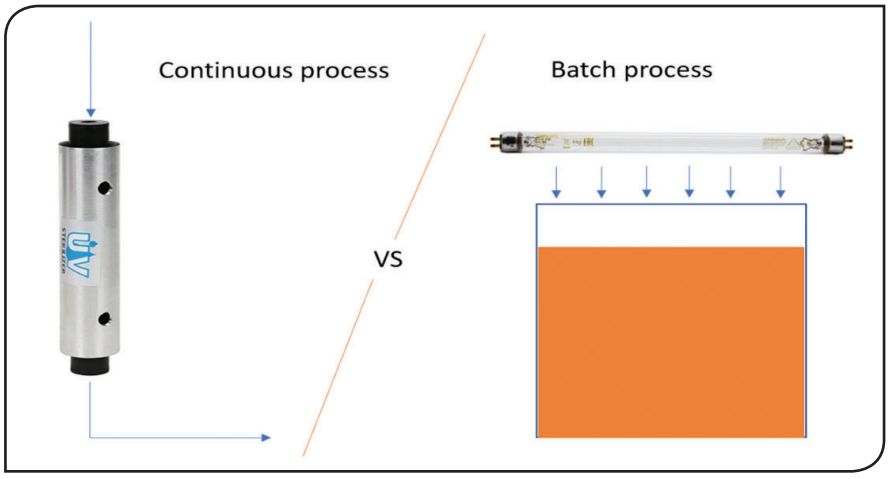
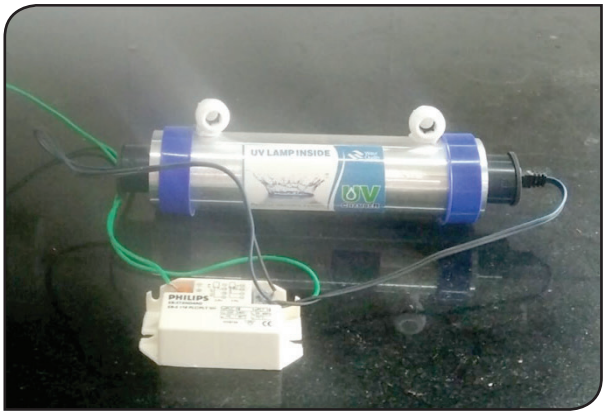


Fig. 7.2 : UV treatment : Continuous vs batch process

Trials on batch process



Retention time calculation in continuous process

Fig. 7.3 : UV treatment : Continuous vs batch process trials

We tested multiple samples with different quantity and retention time and we got successful results (H_2S test negative) for 20L water and 15 min retention time. In these experiments three parameters we identified –

1. UV light penetration to set up UV light and water surface distance. This varies if we stir water continuously. We took some trails with stirring water using submersible pumps with varied distances. It shifted from 6 cm to 30cm.

2. Retention time – If we stir water it reduces from 15 min to 8 min for 20L water capacity. It also reduces if we increase number of UV tubes.

3. Water capacity – if we increase number of tubes or retention time or add stirring it varies. We can treat more water in one batch.

Based on identified parameters we developed our first prototype with FRP mold to hold UV light tube and stirring motor. We tested this in one household with 20L water capacity and 8 min retention time with stirring. Its given positive results but after one month screws and metal frame of UV light holder started corrugating due to oxidation.

Testing Quality of water :

H_2S test

The H_2S test is a very common test used to assess water quality and determine the presence of pathogens in drinking water. The H_2S test essentially detects the presence of hydrogen sulfide in a water sample upon the formation of a black precipitate with iron; hydrogen sulfide is created by bacteria associated with mammal intestinal linings and thus act as an indicator of faucal bacterial activity.

In the beginning we were purchasing H_2S bottles. But afterwards, we started manufacturing H_2S bottles also. Now we are suppling H_2S bottles to our network schools.

https://vadic.vigyanashram.blog/2021/08/01/testing-of-diffrent-water-samples-with-h2s-test/

FRP mold to hold UV light tube and electronics

UV tube and Stirrer

Here we used a UV C light tube normally available in the market without a waterproof case due to electric components in the UV tube choke malfunctioned and stopped working. Details of all these trails and results documented here -**https://vadic.vigyanashram.blog/2020/10/06/solar-water-filter-2/**

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8. Version 1.1 : water filter

To make this weather proof, we browsed solutions available in the market and found a submersible UV C germicidal tube used in aquariums. Water test results with this tube came negative in the same setup and we found a new solution. With a submersible tube we made three new filters with 20L stainless steel tanks available in the market and tested them in different locations with 15 min retention time.

UV C light submersible tube

Testing units with submersible tube

Fig. 8.1 : Version 1.1 water filter

Here we removed the stirring part and increased retention time from our previous understanding. We tested them in Dr. Dixit sir's house in Pabal, Pune and Dapoli and still its working as per our expectations. Details of this version documented here –

https://github.com/SuhasLabade/UV-Portable-water-filter-

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9. Version 1.2 : water filter

Then in the next prototype we shifted to remove solid particulate matter based on the demand of one of our visitors. For this we again surveyed available solutions in the market and we found ceramic candle gravity type filters that can filter solid particulate matter and pathogens. Ceramic candle filters have micro pores that trap solid undissolved particles and even bacteria. We used these filters along with a submersible water tube fixed in a lower container and tested results again.

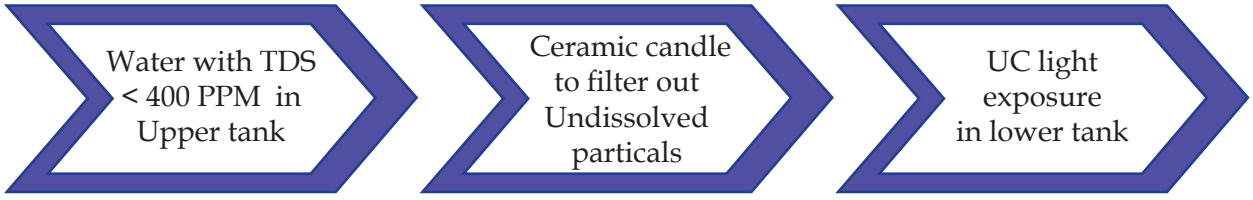

Fig. 9.1 : Flow chart for version 1.2 filter design

Ceramic candle filter with UV tube

Version 1.2 Complete filter unit

Fig. 9.2 : Version 1.2 water filter

We sold one unit of this to our visitor and took feedback from them. They found some limitations of this filter due micro pores of ceramic candles as water flow rate (filtration rate)from upper tank to lower tank is very less (around 1LPHr) which is not suitable for big families and public places.

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10. Version 1.3 : water filter

To get an option for a ceramic candle we found an Aquasure filter candle available in the market, which has cotton + activated carbon layers. Cotton layer removes turbidity and solid particles and activated carbon removes certain organic chemicals, pesticides, insecticides etc. We fixed this candle inside a 20L stainless steel container with UV protected PVC pipe attachments. This candle we can use to filter 6000L water and has a better flow rate (around 7 LPM). We also converted this unit in portable form by adding a solar inverter and solar panel to run UV light which consumes 9 Watt / hour.

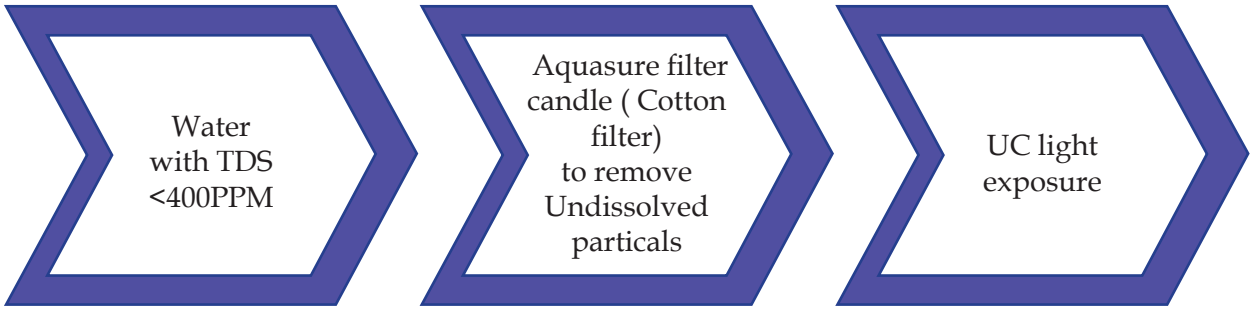

Fig. 10.1 : Flow chart for version 1.3 filter design

Aquasure (Cotton + carbon) candle attachment

Aquasure candle with UV tube

Fig. 10.2 : Version 1.3 water filter

Mukhai school workshop and Distribution

To manufacture and test 10 filters in different locations we received funds from Dassault system – DIY manual projects. We developed a DIY manual for this and manufactured 10 filters with help from Mukhai school students and distributed them in their house. We took feedback again and all of them are satisfied with performance and operation. They suggested a few changes to make them better handling and cleaning. We made these changes and now these units are available for sale under the brand name NEER filter. So now we have two systems –

i) NEER V.1.0 – It comes with a submersible UVC light tube, effective for water hardness below 400 ppm and less turbid water.

ii) NEER V.1.1 - This version has an Aquasure candle in addition with UVC tube to treat muddy water. It's also effective for water hardness below 400 ppm.

Both these versions come with solar inverter + panel setup if electricity is not available. :Electric consumption is very less – takes 9 watts /hour, 15 minutes ON time for one batch.

DIY manual of this filter with advantages over other systems available here – **http://vadic.vigyanashram.blog/2021/06/29/portable-solar-uv-water-filter/**

We also prepared a concept note for this to implement these filters in the tribal part for nomadic peoples, sugarcane labors etc. **https://docs.google.com/document/d/1VB4zR3EquJS_yAA6lzgcYAixboCVVVau/edit?usp=drive_web&ouid=108225846397181625907&rtpof=true**

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11. UV filter in medium scale

UV filter in medium scale (for school/ colleges) batch process

In Vigyan ashram campus we transferred our kitchen and student hostel filter on UV + UF batch system due to limitations we identified in the previous filter kit. Our DIC course student Sumedh Yewale worked on these modifications. Student hostel filter has a capacity of 200 liters, we installed two 9Watt UV tubes and previous pre-filtration – Sedimentation filter candle and carbon filter candle with motor and overhead tank. Here we replaced only continuous UV light treatment with a batch process which treats 200L batch in 40 min retention time.

The advantage of batch process over continuous process of UV treatment is that UV exposure needs to be given just for 40min for 200L water instead of entire day that drastically reduces cost on electricity. Also there is no chances of clogging and coating that affects on flow rate and retention time.

Student hostel filter with modifications

Vigyan ashram kitchen filter with UV tube fitment

Here we also added one float switch to control water overflow which happens usually. This system can be replicated in schools / colleges/ small kitchens and public locations as per requirements.

In the Vigyan ashram kitchen we used one 9-Watt UV tube for 50L water containers and 20 min retention time with previous pre-filtration. Documentation of both filter developments available here : **https://vadic.vigyanashram.blog/2023/01/23/uv-based-water-purification-system.**

Way forward ...

We are still working on a few modifications and adding more features/ controls in previous designs. Following are tasks that we are considering to complete in our next iterations –

1. Provide solution to reduce water hardness
2. Find another affordable option for Aquasure candles
3. Work on a control system that can reduce retention time of UV light and treat water effectively.
4. Convert medium scale system on solar energy
5. Marketing and sales.

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- **Save Your Life, Drink Pure Water.**

- **Conserve water, Conserve life.**

- **Pure water runs life.**

- **Water is a gift from the creator, Protect it ! Respect it.**

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