ARSENIC WATER FILTER FOR DOMESTIC USAGE

INDUSTRIAL DESIGN PROJECT III
IDP 603

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INDUSTRIAL DESIGN CENTER
INDIAN INSTITUTE OF TECHNOLOGY
BOMBAY 2016

Approval

Industrial Design Project III
"Arsenic Water Filter for Domestic Usage"

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M Des Industrial Design 2014-16

Is approved as a partial fulfillment of requirements of a post graduate Degree in Industrial Design at IDC, IIT Bombay.

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Declaration

The content Produced in the project report is original work and takes due acknowledgement of referred content wherever applicable. The thoughts expressed herein remain the responsibility of the author undersigned and have no bearing on or does not represent those of IDC, IIT Bombay.

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Acknowledgement

I have collaborated, worked, taken help and been motivated by many people during this project. I would like to thank Development Alternatives, TARA, Dr. vijaylakshmi, Prof Sanjeev Chaudhary, Mr Santosh Maurya and his team at Ballia for immense support in initial studies and site visit.

Next I would like to thank my classmates, batch mates and other friends for the regular project discussions, valuable inputs and motivation.

Immense Thanks to Shokeen Kalyan from IIT BHU for his contribution in developing the new prototype and making sketches and drawings for final stage.

Last but not the least my sincere thanks to my guide Prof B K Chakravarty for immense support, guidance and help.

Contents

Abstract

- >435 blocks with Arsenic contamination
- 70 million at risk of Arsenic poisoning from groundwater

Figure 1: Indian map showing states with arsenic water contamination

Arsenic poisoning due to underground water is a big health concern in India, especially in the states of Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam and Manipur. These are the states with few of the Lowest Literacy rates, High Population, Considerably high water table and are Economically backward. Also these are the states with irregular to no electricity in many villages and remote areas. The main objective of this project is to develop an Arsenic water filter at Domestic level which filters water for a household. Since there is no electricity, Making a water filter without using Power supply is necessary. Also Arsenic contaminated water is not Visually contaminated and Most of the people don't know about it hence awareness of arsenic poisoning among people is necessary.

The main challenge in this project is to make a product which will filter water and will actually be used by the people of the region. Form Factor, Visual presentation, Handling, Usage, Cleaning, Economics and Durability are main considering factors for design.

Introduction

What is Arsenic?

Arsenic is a chemical element with the symbol "As." It is found naturally in rocks in the earth's crust. Arsenic is recognized as a poison and cancer causing substance (carcinogen). It occurs within organic compounds (combined with hydrogen and carbon), and within inorganic compounds (combined within sulphur, chlorine or oxygen). In water, arsenic has no smell or taste and can only be detected through a chemical test. Long term exposure to Arsenic can have adverse health effects such as melanosis (dark and light spots on skin) and Keratosis (hardening of skin on hands and feet); vascular diseases; birth defects; low IQ and lung, Kidney or skin cancers.

Groundwater Arsenic contamination

Groundwater sources are naturally contaminated with arsenic at some mineral rich areas through underground Aquifers. This contamination is usually at water sources between 20m-100m depth. Also human activities like mining and some natural calamities can result I underground water getting contaminated with Arsenic. In India arsenic contamination is most severe along the Ganga Brahmaputra Basin. The states mainly affected with groundwater Arsenic contamination are Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam and Manipur. The level of arsenic can vary from location to location. There is a possibility of few Wells to have Severe arsenic contamination and few to have none within the same village. The WHO requirement for safe arsenic level in drinking water is below 10ppb but as per Indian standards, 50ppb is accepted.

Arsenic Poisoning

Arsenic poisoning is a medical condition caused by elevated levels of arsenic in the body. The dominant basis of arsenic poisoning is from groundwater that naturally contains high concentrations of arsenic. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning from drinking water.

Symptoms and Effects:
diarrhea, vomiting, vomiting blood, blood in the urine, cramping muscles, hair loss, stomach pain, and more convulsions. (see fig. 2) The organs of the body that are usually affected by arsenic poisoning are the lungs, skin, kidneys, and liver. The final result of arsenic poisoning is coma and death

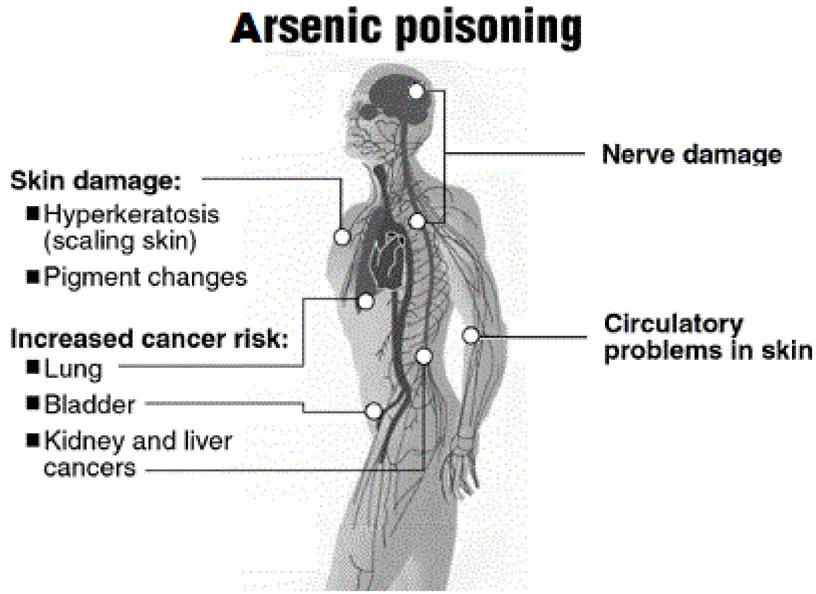


Figure 2: Arsenic poisoning effects

Figure 3: Skin darkening due to arsenic poisoning

Other Mineral Contamination

Other than Arsenic, the water in these areas are highly contaminated with Iron, Fluoride and in some places with Mercury. The filter developed could aim at removal of these minerals up to the safe limit if possible.

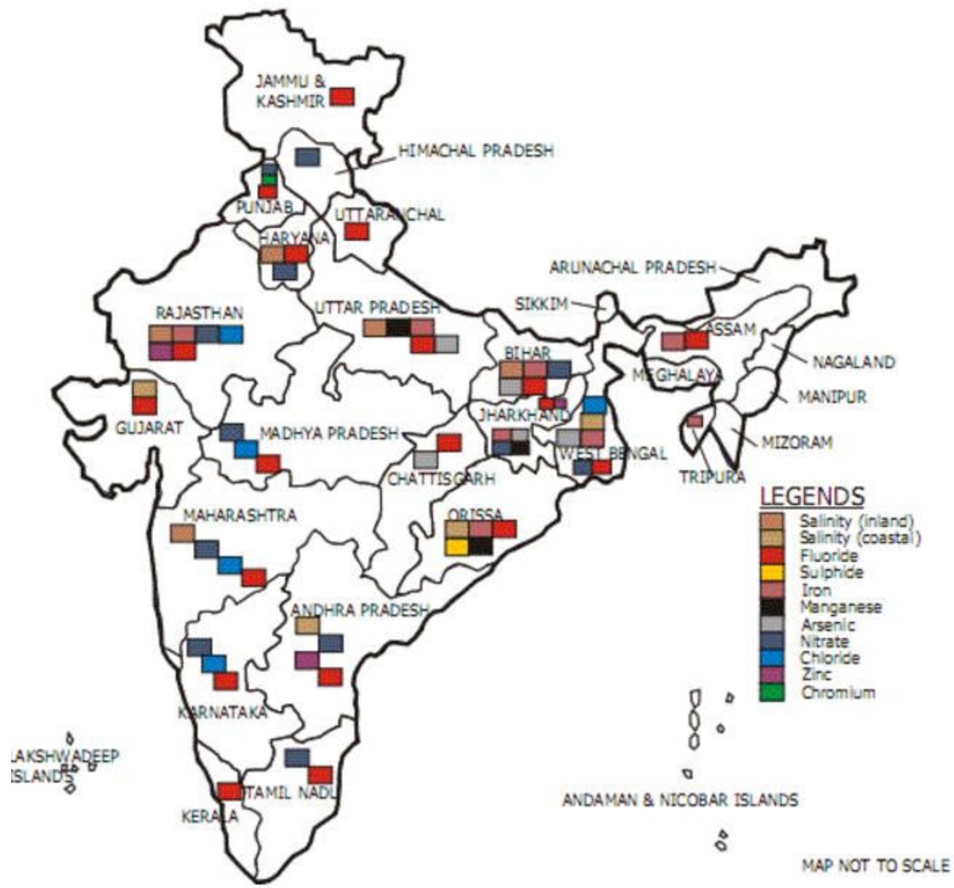


Figure 4: Indian map showing Minerals contamination

Learning from Heat pump lab and Prof Milind Rane

The project started with me exploring prof Milind Rane's lab. I Started with finding possibilities of using Solar steam for domestic usage other than cooking. From there many ideas sprung up but mostly it was becoming community based and the technology of generating steam is not really advanced hence there were limitations in the projects that I take up. Hence I shifted my attention to water filtration. But still the knowledge about solar steam generation and heating helped me in doing few ideations involving them.

Learning from Devalt and TARA

Devalt (Development Alternatives) is a NGO based in Delhi. They have been working intensively on Arsenic filteration. Devalt studied conditions of arsenic poisoning in Bihar and Uttar Pradesh and have developed a community level water filter to give arsenic free water. Also they ave been trying to develop domestic level water filter for home usage. There are two types of filteration units they have developed, one with single bucket with no filtered water storage and other with 2 buckets where the bottom bucket acts as storage. They proposed us to take up this project and develop a product based on the concept.

Figure 5a and 5b: Devalt headquarters building

TARA Works in the area of water filtration

Figure 6a: JalTARA Filter

Fig. 6b: Matka filter

Fig 6c: JalTARA Filter

Fig 6d: Community filter

Fig 6e: In line filter

Fig 6f: Compressed mud block

Discussion with Prof sanjeev Chaudhary

Prof. Sanjeev Choudhary from CESE, IIT Bombay has been intensively working on "removing Arsenic from Water" project. He has developed a low maintenance community level water purification system and it has been installed at several villages along the Ganges in the states of UP, Bihar and West Bengal. The purification technology is very simple and could be simplified to make the domestic level filter.

Fig 7a: IIT B Arsenic filter at Ballia

Fig 7b: Prof. Sanjeev Chaudhary

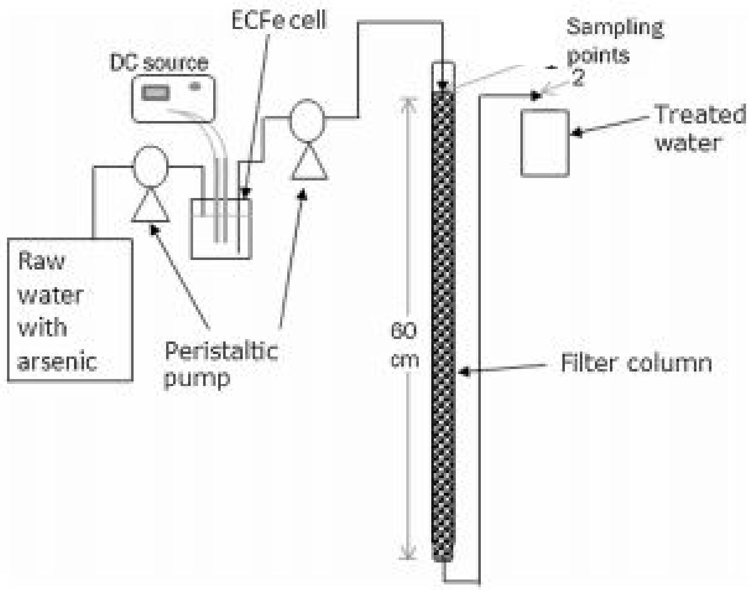


Fig 8a: Arsenic removal by electrocoagulation

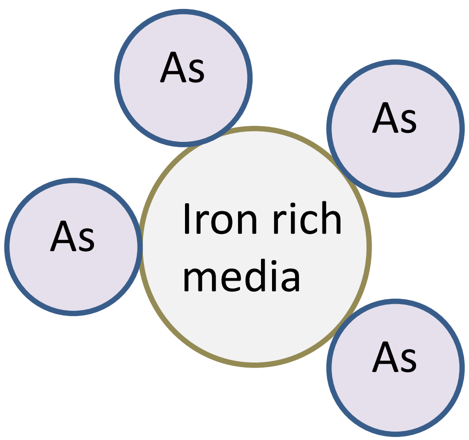


Fig 8b: Arsenic attached to Iron media

How is Arsenic Filtered?

Arsenic reacts with iron quickly and forms particles settled on Iron surface. Thus most of the Arsenic water filters wok on principal of facilitating maximum reaction with iron thus removal of more arsenic. There are two types of Filtration techniques mainly:

Arsenic removal by electrocoagulation.

In this method, Fe electrodes charge up the particles and attract and deposit the As particles on their surface. This method is very effective in arsenic removal but it requires electricity hence can be used only in the areas with available electricity.

Arsenic Removal by passing the raw water through Iron rich media:

In this method, the water is passed through iron rich media and the contact time of iron with water is really important here. Iron oxide reacts with arsenic particles and form a compound which could be easily segregated from water by passing water through vary fine medium. This method does not require electricity thus is possible to be used in many villages of india with less or no electricity.

Typical water Filtration techniques:

1. Carbon Filters
Pros:
Great for removing pesticides and chlorine
Inexpensive
Activated carbon filters are best suited for removing organic pollutants like insecticides, herbicides and PCB's. They can also remove many industrial chemicals and chlorine. Activated carbon will not remove most inorganic chemicals, dissolved heavy metals (like lead) or biological contaminants. To help overcome these weaknesses, many manufacturers use activated carbon in conjunction with other processes, such as ceramic filters or ultraviolet light.
Cons:
Does nothing against bacteria
Not long-lasting

2. Ceramic Filters
Pros:
Great against parasites and physical impurities
Easy to clean
Rust, dirt, parasites like Cryptosporidium and Giardia lamblia, and other impurities can be easily removed from drinking water by forcing the water through the very fine pores in ceramic material. Some breweries use ceramic filters as an alternative to pasteurization. They're also ideal for travel or backpacking, since they can be repeatedly cleaned by simply scrubbing the outside of the ceramic material.
Con:
Ineffective against organic pollutants and pesticides

3. Ozone
Pro:
Kills bacteria, viruses, algae and parasites
Ozone (O3) differs from normal oxygen in that it contains three atoms of oxygen instead of just two. This extra oxygen atom makes it highly unstable and reactive. When ozone gas bubbles through water, it quickly and very efficiently kills bacteria, viruses, algae, and parasites. Not only is it thousands of times more potent than chlorine, it doesn't produce any harmful by-products like chlorine does.
Cons:
Ineffective against heavy metals, minerals, and pesticides
Effectiveness dissipates quickly
Prohibitively expensive

4. Ultraviolet Light (UV) Light
Pro:
Kills bacteria and viruses
When microorganisms like bacteria and viruses absorb UV light, certain chemical reactions are triggered which kill the organism. This makes it a very efficient method of destroying pathogens like E. coli and salmonella without having to add chemicals like chlorine. UV light is one of the few purification methods that gets out viruses, which is particularly important if you live in a rural community or have well water.

Cons:
Not effective against all organisms
No effect on heavy metals, pesticides, or other physical contaminants

5. Ion Exchange Systems

Pro:
Prolongs water heater

Con:
Doesn't have any effect on water purity or your health

6. Copper-Zinc Systems

Pros:
Effectively removes chlorine, heavy metals

Another form of water filtration technology, being sold under the name KDF, uses granules of copper and zinc alloy to purify water. The copper and zinc molecules act like the different poles on a battery. As contaminated water passes through the granules, certain contaminants are drawn toward the zinc while others with a different charge migrate to the copper. Additional chemical reactions take place which release ozone and other compounds that kill bacteria and other organisms.

Con:
Ineffective against pesticides and organic contaminants

7. Reverse Osmosis

Pros:
Highly effective against metals, bacteria, viruses, organisms, and organic and inorganic chemicals

Reverse osmosis (RO) is a process whereby water is forced through a semipermeable synthetic membrane. It was originally used to transform saltwater into freshwater. Under the right conditions, RO systems can remove anywhere from 90% to 98% of heavy metals, viruses, bacteria and other organisms, and organic and inorganic chemicals.

Cons:
Wastes lots of water
Synthetic membrane degrades when exposed to chloride and physical contaminants
Systems can breed bacteria, requiring a carbon filter in between RO treatment and storage
Does not work well with hard water

8. Distillation

When used correctly, distillation provides the purest and safest water available. Distillation is a fairly simple process. Water is heated until it boils and turns to steam. The boiling action kills the various bacteria and other pathogens, and as the steam rises it leaves behind waste material, minerals, heavy metals and other heavier contaminants. The steam is then cooled and returns to water.

Arsenic Filtration Currently

Fig 9a: SONO Filter

Fig 9b: IITB Arsenic Filter

SONO Filters:
Popular in Bangladesh, Sono filters use Composite Iron matrix layer with other layers of fine and course sand, Brick chips and Charcoal. All the Media is arrged in layers in set of two buckets kept one on top of other. The unit gives 60-100 liters of water a day which is sufficient for a family of 20. The filters average age is approximately 8 years and it costs $38 approximately.

IITB Arsenic Filtration Unit
IITB arsenic filtration system is a community based water filtration system. The unit is attached to a tube well and when water from the tube well is filled in the filter, clean water comes out of the system. The filter works on slow passage of water through rusted iron nails. There are buckets filled with iron nails and water passes through these then goes through gravel and finally comes out of the outlet. The filtered water is having arsenic content below 10ppb which is WHO standard. The filtration unit is installed in several villages across UP, Bihar and West Bengal. Installation cost of one unit varies from 40k-75k depending on location. The system is low maintenance and effective.

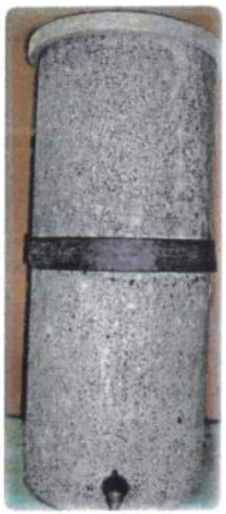
 

Fig 9c and 9d: RSM Filter and DRDO Filter

RSM Filters with Activated Alumina Technology

These are Ferro cement body filters with 2 parts one on top of other connected firmly with a circular rubber gasket. There is an iron removal candle and a sachet of activated alumina in the filter. The iron removal candle filters the iron from water and the the iron free water passes through activated alumina which removes arsenic from the water. It filters 23l of water a day. The iron candle needs to be replaces every two years and the activated alumina sachet ha to b regenerated every 6 months.

NMRL Filters, DRDO

Distributed by government in many villages of West Bengal and Bihar, the filter is in stainless steel and has 3 compartments one on top of other. The first chamber contains the filter media in a fine cloth bag and the second chamber contains fine sand for the water soluble particles to get filtered. The Filtration media here is activated alumina. The Filter is cheap and provides 15l of clean water a day. Many times the Stainless steel chamber vessels are used for storing edibles and grains hence not in use anymore.

Fig 9e: Kanchan Filte`

Fig 9f: Jal TARA Filter

Kanchan Filters
Mostly common in Nepal, These filters are designed and Developed by MIT in collaboration with ENPHO Nepal. Layers of Brick chips, Iron Nails, Fine sand and coarse sand are laid on a large bucket. Inlet is from top and after water passes through all the media, outlet is from bottom. The filter is effective in removing iron, Arsenic and bacteria/pathogens from water. It filters 15-20liters of water per hour. This filter uses locally available materials and is easy to manufacture and maintain. The unit is really heavy after installation hence cannot be very mobile.

Jal TARA Filters
Similar to other Home based Arsenic removal units, Jal TARA filters developed by Development Alternatives uses Alumina, Iron ore and sand to remove iron and sand. There are two designs, one in which a single bucket has all mediums arranged in layers and water is collected through the bottom outlet. In second design bottom bucket is for water collection, middle tubs contain filtration media and fine sand. The upper bucket where raw water is fed, contains sand. This filter produces approx.. 15l of water per hour.

Pureit Arsenic cum germ removal Filters

The filter has 2 stage pre filtration in top chamber where the sedimentation process removes particulate matter of upto 10 microns size. Then specially designed carbon compact trap filters particulate matter of 3-5microns size. A special attachment of activated alumina removes arsenic from water. This filter can work without electricity and inline water supply.

Fig 9g: Pureit arsenic filter

Market Gap

- Unavailability in **Indian market**
- Most products are jugaad and are distributed by organisations and not sold in market
- Technology uses where the **filtration media needs replacement**
- Extremely **heavy** to move
- Many products used as **storage vessel later**
- **Cheap looking** products
- **No mass production** makes product cost high
- Indian aesthetics missing from the product.
- Product not available to work without electricity or flowing water (live water connection)

Case Study_IITB Arsenic Water Filter

Water fed to filter through Hand pump

Clean water is collected in cans and vessels and taken home

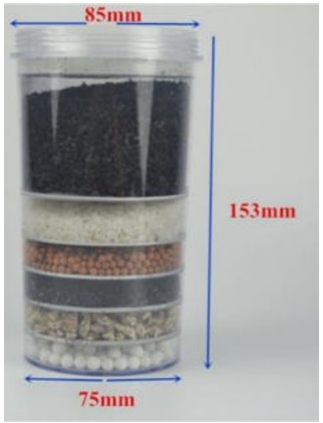
For areas with very high arsenic levels, the treated water from first filter is fed into the second filter for same processes to repeat.

Water now passes through a layer of gravel and sand which removes sedimentation

Water gets distributed to 4 Buckets filled with iron nails and slowly passes.

Diagram 1: IITB Water filtration process

Market Study



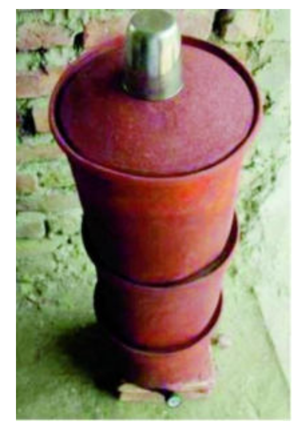


Fig 10a: Various filters in market

Fig 10b: Various filters in market

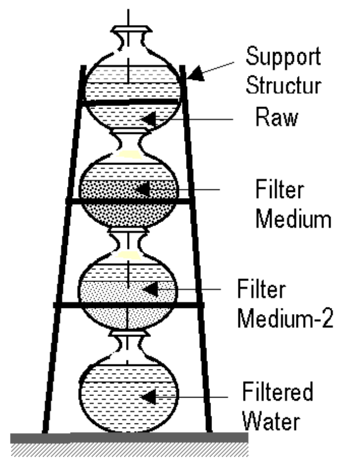


Figure 3.9 Pitcher (Kalshi) filter

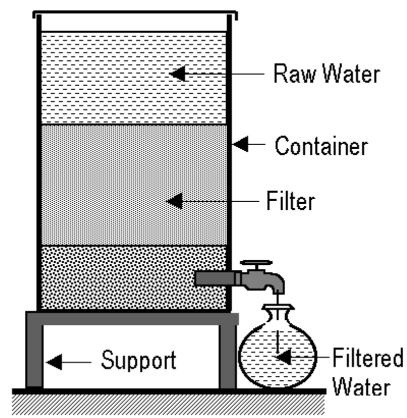


Figure 3.10 Small household filter

Fig 10c: Various filters in market

Field visit

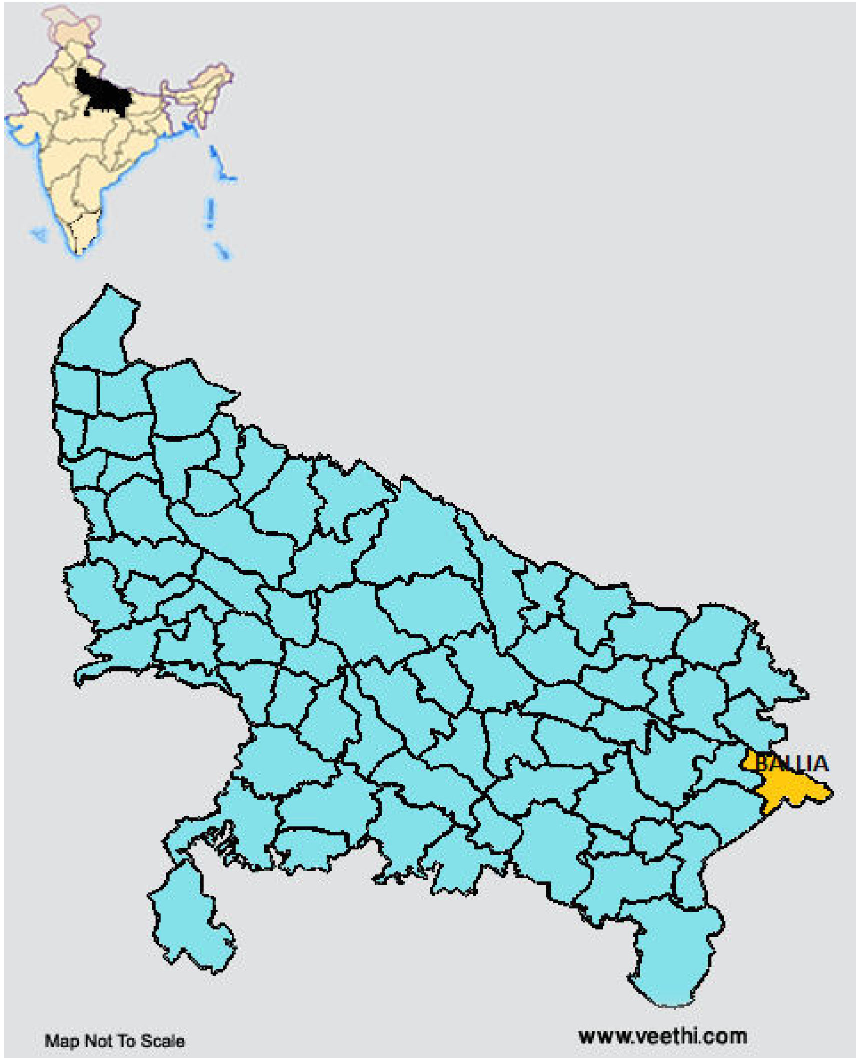


Fig 11a: Location of Ballia district

Arsenic contamination Areas

I planned on visiting an area from the arsenic contaminated belt where there is severe poisoning issue and people know effects of drinking poisoned water. Also I wanted to see the difference between an area with water filter available and another area without water filter nearby, to know the real difference filter and treated water brings in. Such arsenic contaminated areas are abundant in the Ganga and Brahmaputra basin all along the main river and its tributaries. There are some villages with arsenic levels as high as 1000ppb.

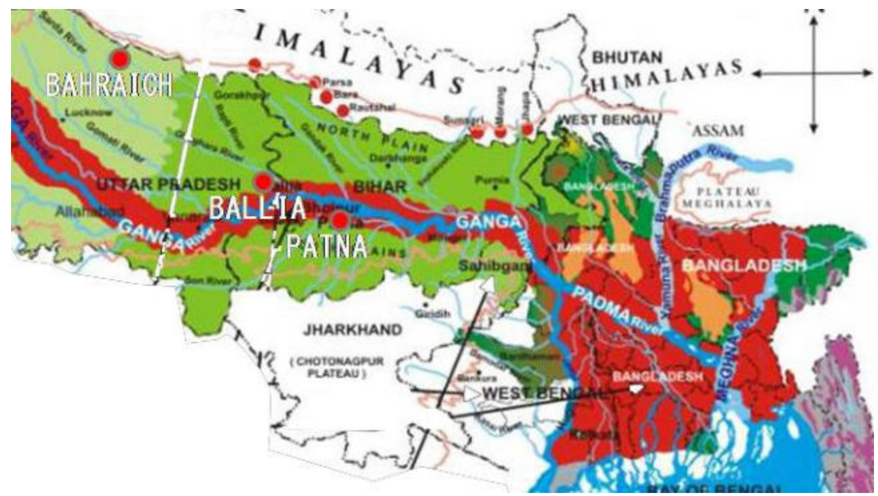


Fig 11b: Red shows arsenic affected area in ganga brahmaputra delta

Ballia

Major arsenic contamination in groundwater along Ganges starts with Ballia district and goes downstream till Bay of Bengal. Ballia Is a District which lies in border of Bihar and Uttar Pradesh. River Ganges flows along the eastern boundary of the district and river Ghaghra flows in northern part of the district. There are Contaminated areas along Ganges and Ghaghra both. I chose to visit Ballia city first and from the city I visited several affected villages in the duration of 2 days.
CESE, IIT Bombay has done intensive work in field of arsenic poisoning in Ballia. The community level arsenic removal unit by IITB is installed at around 90 locations along the district. There were several villages with people dying from skin and liver cancer caused by arsenic poisoning regularly and there is considerable redction in new poisoning cases in these villages after the filters have been installed.

Fig 12a: Ballia Station

Fig 12b: Ballia Town road

Fig 12c: Ballia Town

Places I visited:

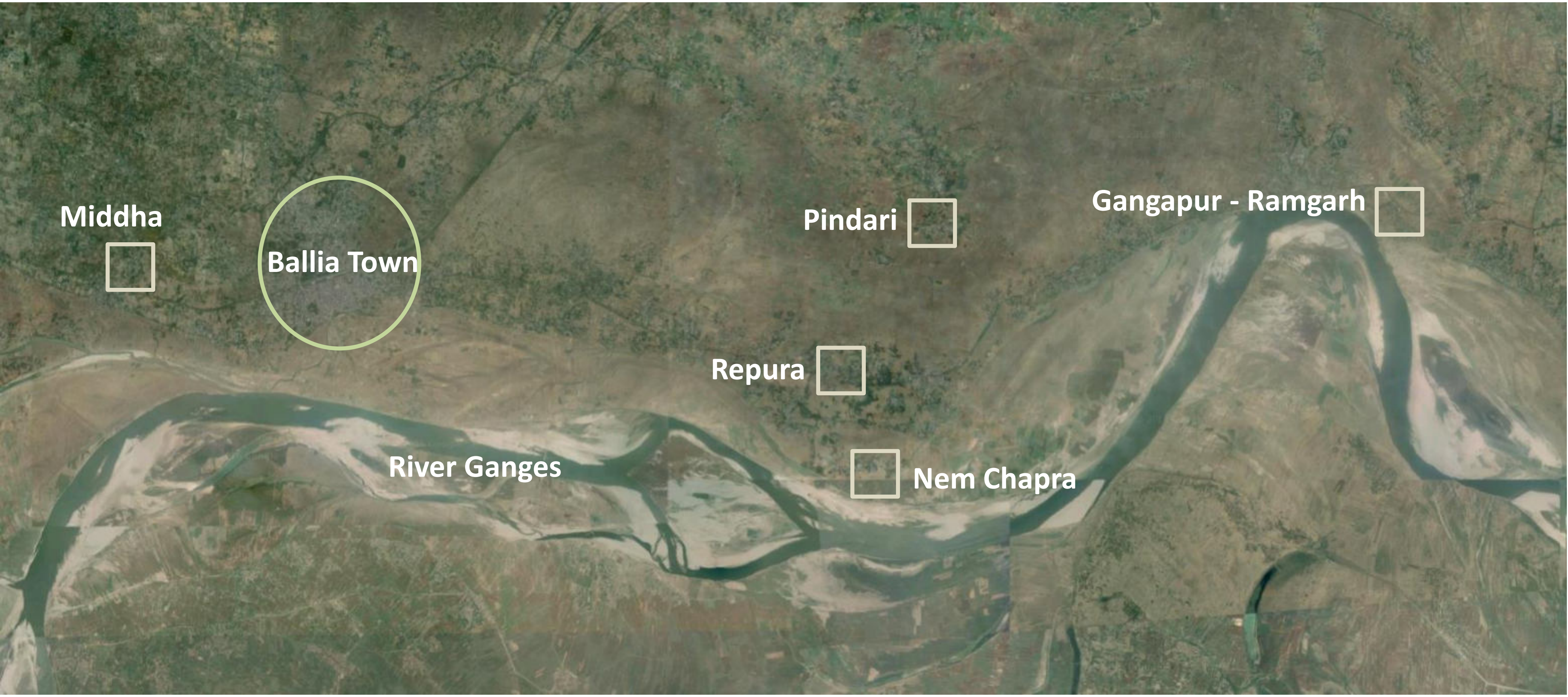


Fig 13: Location of villages along River Ganges

Fig 14a: Gangapur ramgarh village

Fig 14b: Chain Chapra

Village visit:

Gangapur – Ramgarh:

One of the worst affected village in the region. Almost everyone is dependent on Agriculture. The village comes in the erosion area of Ganges and is affected to frequent flooding. Almost all Tube wells are having high Arsenic levels. There have been several deaths in the village due to Arsenic poisoning. Almost 80% of population is Affected by Melanosis or Keratosis(Skin Diseases).

Chain Chapra

The Pilot village for installation of Community level Arsenic separation Unit, this village has many people who have healed from Melanosis and Keratosis as they have been Drinking treated water for almost 5 years now. The villagers are really aware of how to take care of the filtration unit and have been maintaining their units independently.

Fig 14c: Repura village

Fig 14d: Pindari village

Repura

A village close to Nem Chapra but without any single Arsenic Water Filtration Unit. The water sources in this Village are not yet intensively tested but there have been several Skin diseases and Cancer cases in this villages. People are compelled to Buy RO water cans as they know the water is poisonous. There is a campaign going in the village to install Water filtration units. People are ready to pay for filters.

Pindari

Another Village close to repura, This village too is not yet tested for arsenic Poisoning but the people there have clear signs of Arsenic poisoning. The people are ready to get a filtration unit which works without electricity if its available in the market and has low maintenance.

Survey Methodology:

The survey with people was in form of interview. Sixteen households from 4 villages were interviewed. There was no survey form with particular questions which had to be filled. Instead I broadly divided my questions into 3 categories"
Persona – About the family size, details, occupation and Background
Context – Water source, Storage, Usage, collection etc
Communication – Asking their views about safety, their Affordance capacity, Participatory design.

Questions Regarding the project:
What is the product?
What are the major requirements of the project?
What are the Micro requirements of the project?
Who is the user? / Who all are the users?
What is the time wise utilization of the water filter?
What is the water source?
What is the water fetching method?
What is the standard water storage method?
Where is the water stored?
Family water consumption (Men, Women and Children separately)?
What do they feel Polluted water looks like?
Is there water pollution in their water? Their opinion?
What Kind of water related diseases they know about?
Do they know their water is contaminated?
Family health history?
How to make people aware of arsenic poisoning?
Current water filtration method?
How much is ok to be spent?
How to make the filter easy to use?
How to do easily cleaning and maintenance?
How to make people know the worth of this filter?
How will the product sold?
How will the maintenance service be provided?
How much space we can take?
Where is the product placement in house?
What is the general Taste I Products?
What are the Material Possibilities?
How will the Waste be Disposed?
How will the refill be done?
What is the technology?
Who provides the technology?
How to make the product visually appealing?
How much visual appearance matters?
What do they want it to look like?
What are Previous works done in this area?
How are previous Domestic level Arsenic filter doing?
What are other Water filter types?
What are the Material Possiblities?
What are the preferable Material (Cost, Availability, Context)?
What are the analogies possibilities?


Fig 15: A soil eroded Ganga bank

Fig 16: Person with arsenic poisoning related sking diseases

Users

- the villages are densely populated with each house having a hand pump
- Severely affected villages have very high cases of skin diseases.
- No continuous electricity in the households
- Agricultural means for livelihood
- Young people in many house live in cities
- Economically diverse people. People are from both, rich and poor background.
- Caste system followed in village with lot of discrimination
- People aware of arsenic poisoning issues
- Ready to spend money on water filtration.
- People felt great health improvement after drinking treated water.

Fig 17a and 17b: A hut(above) and a Bunglow at Ballia

Fig 17c: Open drain

Users

- There is not much of awareness about sanitation in villages
- Water containers are kept near drains many times
- Houses are spacious and Big.
- Even small huts are spacious
- Almost equal distribution of men and women, though men are more visible.
- Almost 20% of population below 15 years of age

Other Government funded filters in villages

Fig 18a: DRDO Filter lying waste

Fig 18b: DRDO Filter not in use

Fig 18c: Government filter

Fig 18d: RO Water bought from water vendor

NMRL Filters by DRDO was distributed to the villagers in 2005. The filter works with activated alumina. It needs replacement every year but villagers couldn't find the replacement and hence the filter was waste later and is used to store grains now.

Government has installed filters in some villages but it is not maintained and outdated hence most of them are again giving high arsenic water. People are compelled to buy RO water 25l bottles. These cost rs 50/bottle which is very expensive for the villagers.

Fig 19: Home based Iron testing is done in villages. Guava leaves are used. The water with higher iron level instantly changes its colour to black when tender giava leaves are crushed and put in it.

Figure 20: (Clockwise from top left) A government installed water faucet bringing water from overhead tank, IITB Arsenic filter, Handpump & a RO water bottle bought from water vendor.

Water Source

Main source of water in the villages is Tube wells. There are various Dia cross section tube wells available. A few open wells are also present in each village but these are not used for drinking water. There are several Issues with the source of water:

- Source gets flooded in monsoon
- Underground water contamination
- Government pipelines have bad odour and high iron content
- Open wells are not arsenic contaminated but really dirty and rarely used now
- Ganga water too is heavily polluted due to industries upstream. The villagers know thi and don't use Ganga water for drinking.

Water Collection

Water collection for drinking happens twice a day. Usually the young adults of the house collect water after or before school. Water for all other usages is taken directly from the tube wells which are present in almost all households and at several public locations.
Since many kids come to collect water for their houses, The container size is usually small so that they can easily carry them.

Figure 21: A young girl collecting water in old soft drink bottles at evening

Figure 22: (clockwise from top left) water can uncovered kept on cowdung coated flooring in kitchen, various jerrycans and plastic buckets containing water kept on a small elevated platform, a RO water can with Metal buckets and one bucket of water for a family of four stored next to cowdung cakes.

Storage of Water

Drinking water is stored in plastic buckets or jerry cans. Almost each house stores at least 10liters of Drinking water with them. Water is filled twice a day. There is no particular platform in most houses and Water cans are kept on floor which is usually mud and cow dung plastered. When we asked about cleanliness of the containers, most of the households said they clean the containers every alternate day.

The kitchen where the water I stored usually is:

- Large with mud flooring
- Less or no shelves, everything happens on ground
- Traditional chulhas at ground level
- Bricks are used to make temporary platforms
- Cow dug cakes(gobar upla) also is stored in kitchen.

IIT Bombay Arsenic Filter in village

Figure 23: IIT Bombay arsenic water filter in use in various villages.

	Gangapur-Ramgarh				Repura		Pindari		Chain Chapra			
	House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10	House 11	House 12
Family size(No. of people)	4	3	9	5	8	6	3	5	12	6	3	4
Liters of Drinking water stored (Approx)	30L	65L	60L	40L	70L	40L	30L	40L	50L	50L	30L	30L
People suffering from any water related disease	No	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No
Collection of water source	Gov Pipeline	Tube well	RO water vendor	Government Filter	Tubewell	Tubewell	Tubewell	Tubewell	IITB Water Filter	IITB Water Filter	IITB Water Filter	IITB Water Filter
collection timimgs	Not Fixed	Morning	Morning	M and E	M and E	M and E	M and E	Not Fixed	M and E	M and E	M and E	M and E
Collecting member	Son	Housewife	Delivery	Son	Daughter	Son	Daughter	Daughter	Son	Daughter	Daughter	Son
Water storage location	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen
Water Storage container	Pl. Bucket	Pl Jerry can	RO Bottles	Pl. Bucket	Pl. Bucket	Pl. Bucket	Pl. Bucket	Pl Jerry can	Pl Jerry can	Pl. Bucket	Pl Bottle and Al Vessel	
Water storage position	Floor	Brk platform	Floor	Floor	Brk pltfrm	Floor	Floor	Floor	Brk pltfrm	Floor	Brk pltfrm	Floor

Table 1: Table showing survey data from four villages

Observations

- People are in general aware of arsenic contamination in water.
- Almost every one in some severely contaminated village suffers some skin disease
- People have money to buy RO water but no electricity to install their own filter
- Community based filters serve lot of people but don't have ownership hence maintenance becomes issue. Many times a breakdown goes for months as no one takes initiative to repair.
- Water is collected twice daily and is stored in plastic buckets or jerry cans.
- Kids usually collect water after or before school.
- There is caste system still followed in villages hence each community wants their own filtration units.
- River flood covers community filters occasionally
- Kitchens are usually big and have mud+cow dung flooring.
- Food is cooked in traditional chulhas
- Electricity not available for more than 6hrs a day on an average
- Arsenic contamination has become a business with many illegal water vending systems.
- People want less maintainance and no further expenditure on the filter they have got once. That's the main reason for failure of previous DRDO filter.

Design Brief

Design an **Arsenic water filter for Domestic Usage**. The water filter should be able to give water with **arsenic level lower than 50ppb**.

- The **assembly** of the filter should be **simple** and it has to **be easy to clean and maintain**.
- To prevent misuse, the filter components should be for sole **filtering purpose only**.
- It should use **components** which **don't require regular replacement**.
- Should be **compact and light** and can be moved in flood situation or cleaning.

Design Criteria

User ease in usage
- Filling of water
- Taking out water
- Repair and maintenance

Manufacturability
- Process of manufacturing
- Materials

Workability

Longevity

Self change of Media
- Easy replacement
- Availablity

Cleaning

Compactability

Modular

Stackability

Components

Trusted

Analogies

Easy transport

God

Attractive

Economical

Alternate materials

Contamination safe

Safe water

Strong

Low maintenance

Manufacturing from
available technology

Misuse Proof

Locally repairable

Easy cleaning

Movable

Compact

Filtration stage requirements

Water inlet chamber → **Iron medium** → **Permeable Medium** → **Clean Water Storage**

Water inlet chamber
- Good inlet capacity
- Covered
- Regular cleaning
- Water visibility

Iron medium
- Even water fall
- Cleanable
- Less gap for slow percolation
- Separable

Permeable Medium
- Upper layer cleaning
- Different levels of permeability
- Separable
- Readily available

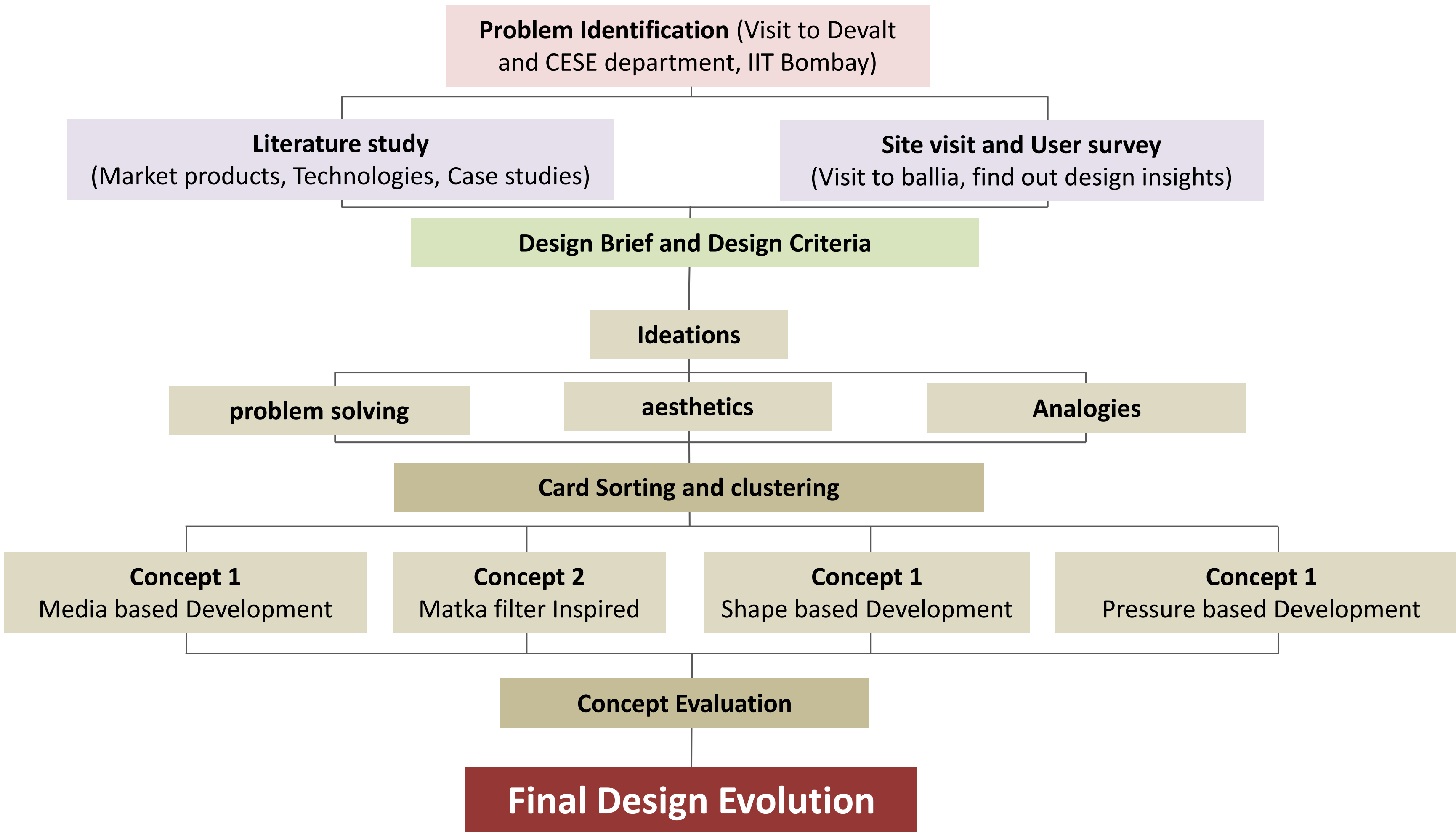
Clean Water Storage
- Light proof body
- Inside edges filleted for easy cleaning
- Tap fitting with minimal surface area

Quantitave Requirement

Based on interaction with the villages and observation of their usage pattern of water, **2 sizes are to be proposed**. **For 10 people Family**, total drinking water consumption per day will be approximately **60 Liters/day.**
For 6 people family: 36 Liters/day.

Filling of water happens twice a day.
Keeping the factor of safety, the capacity of **water inlet** should be **30L** and **storage water container** should be **35L.** For smaller filter, inlet should be of capacity **18L** and filtered water storage should be **22L**.

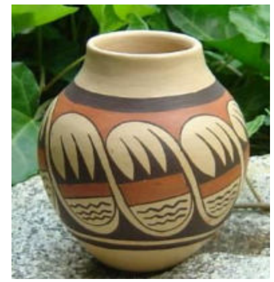
Design Methodology



Ideations

- Problems related to filter identified and several ideations done to solve each issue.
- Ideations for filtration unit done separately for its compactness
- Analogies taken to get varied spectrum of ideas in shorter duration.
- Direct analogies give direct design inputs and solutions hence taken to start with. Later indirect analogies taken to get vertical innovation.
- All ideations were individually cut and spread on a table. Then Cards were clustered into 4 groups of similar characters. These four clusters formed basis for concepts.
- Concepts were developed and detailed seeing the manufacturabily, assembly and ease of usage.

Mood Board



Mockup _ simple filter

Figure 24: Candle filter modifications to arsenic filter

A ceramic candle filter was modified to filter arsenic from water. This was the first step of designing process to understand the volume and workability of the filter.
The upper chamber of the filter was filled with gravel till the ceramic candle upper level. Then a pot containing iron nails were put on the filter. Water coming from a funnelled vessel will first get into the nails pot and then from bottom will seep in to the candle percolation area.

Filtration Unit

The first attempt was in making the filtration unit more compact and easily cleanable. Thus several ideations on this were done. Water should pass through iron rich media and then through a percolation media. For this several ideations were done. Few of them are:

- Making a brush of iron fibres using ceramic percolation plates as base. When 2 brushes get interlocked, the unit can act as filtration member.
- Keeping steel wool in a ceramic container. This makes cleaning and replacement easy.
- Using iron plates with pores instead of loose nails
- Making the fe media in layers and each layer separated by another through a barrier.

Filtration Unit

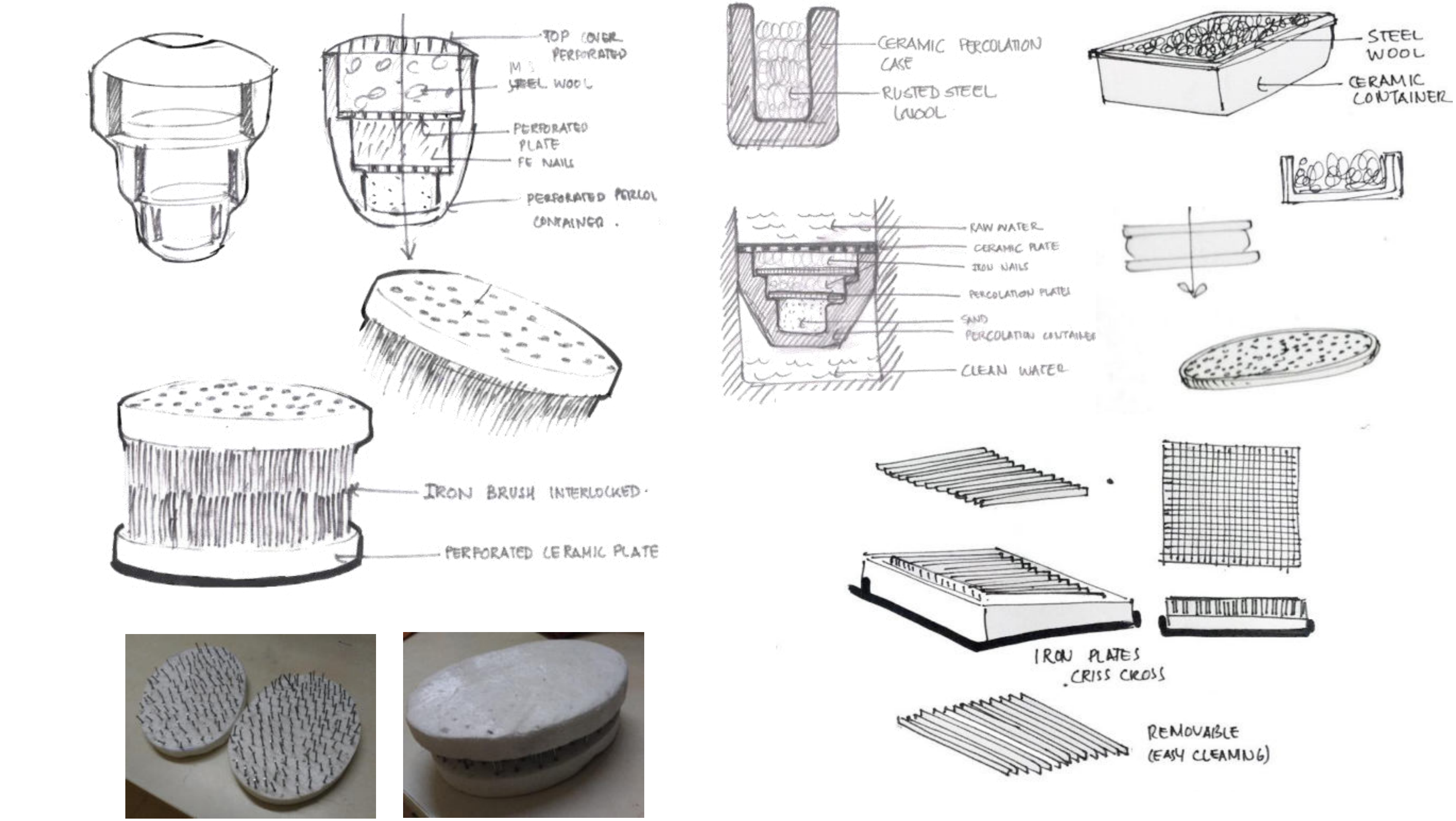
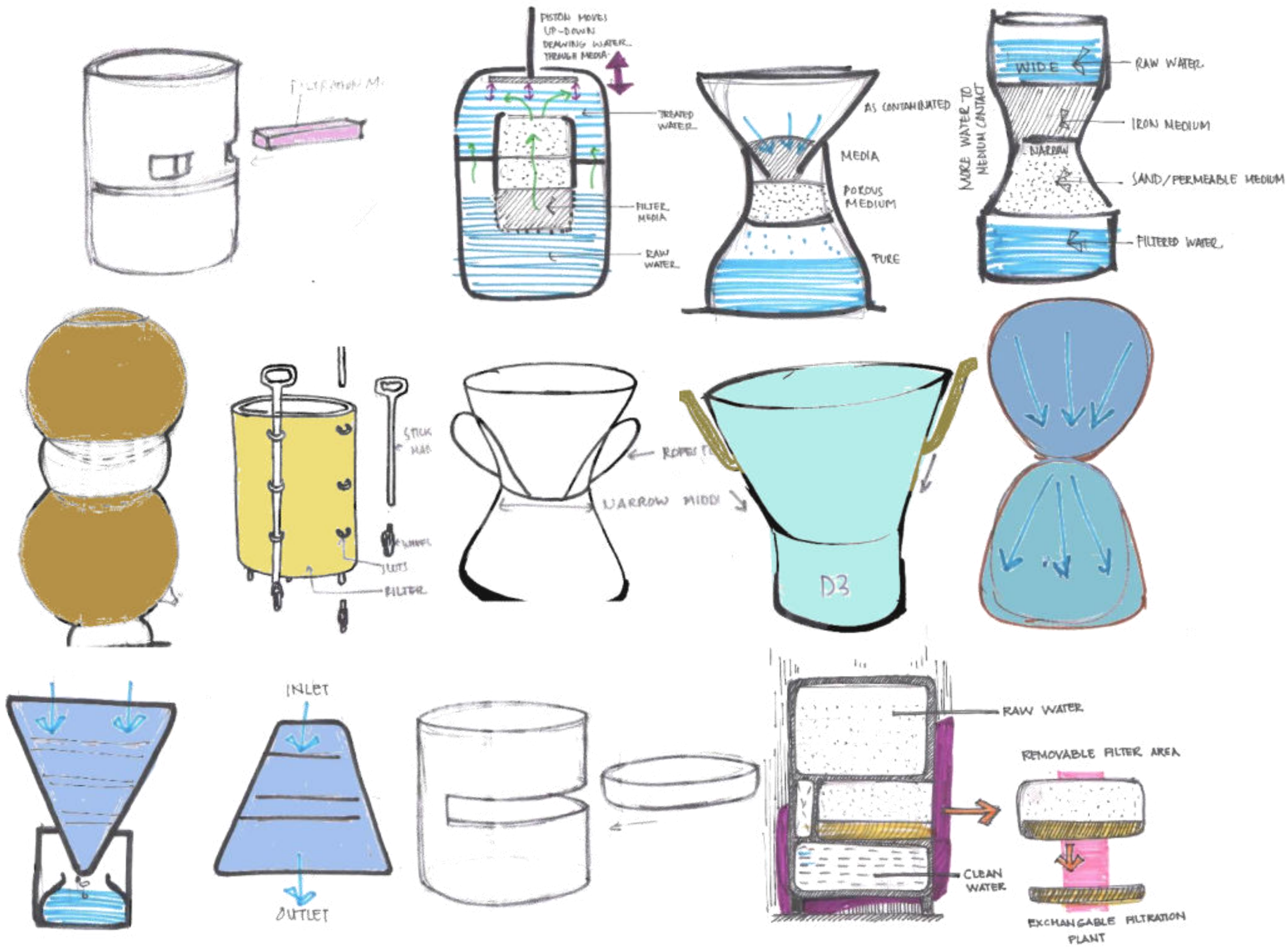


Figure 24: Ideations for Filtration unit.

Handling and portability



Various shapes were thought of for handling and portability aspect and few ideations were done.
It has been noticed that the concepts where the mid part was narrower got higher portability easiness.
Also if the structure can be disassembled into several smaller members its easier to handle and carry.

Figure 25: Ideations for Handling and portability

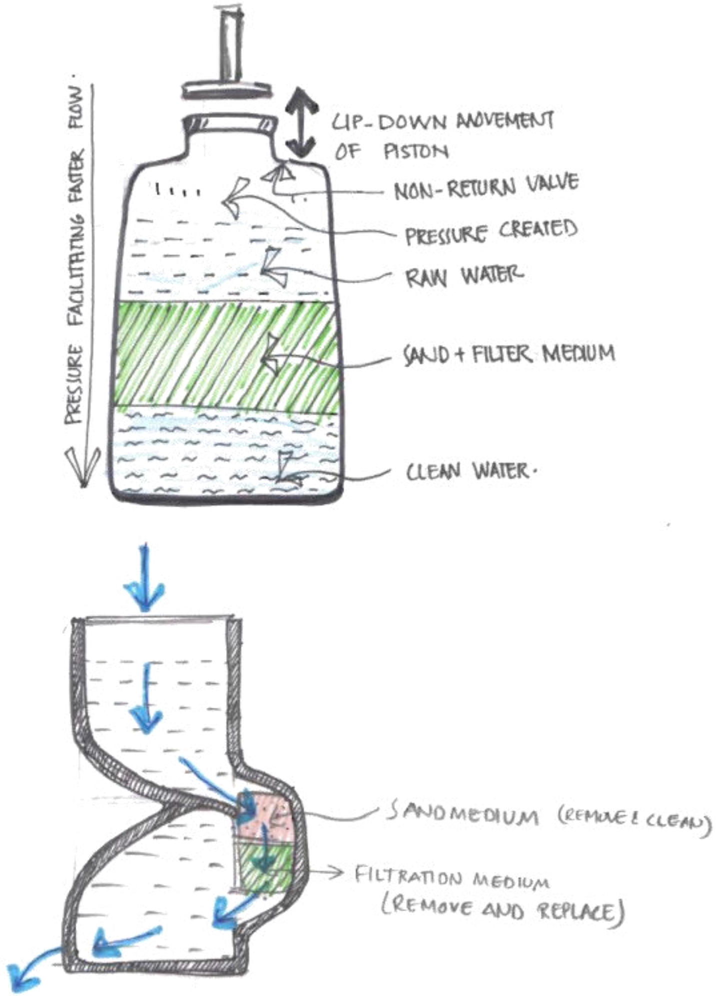


Figure 26a(top) and 26b(bottom): top: piston assisted filtration, Bottom: Water flow through narrow media region, reduces media volume

Pressure based Filtration

Ideations on pressure based filtrations were done where external pressure was implemented to the system either to make it travel anti gravity or to make filtration faster. One problem with this approach is, by fastening the water speed, its reaction time with media will reduce causing inadequate filtration.

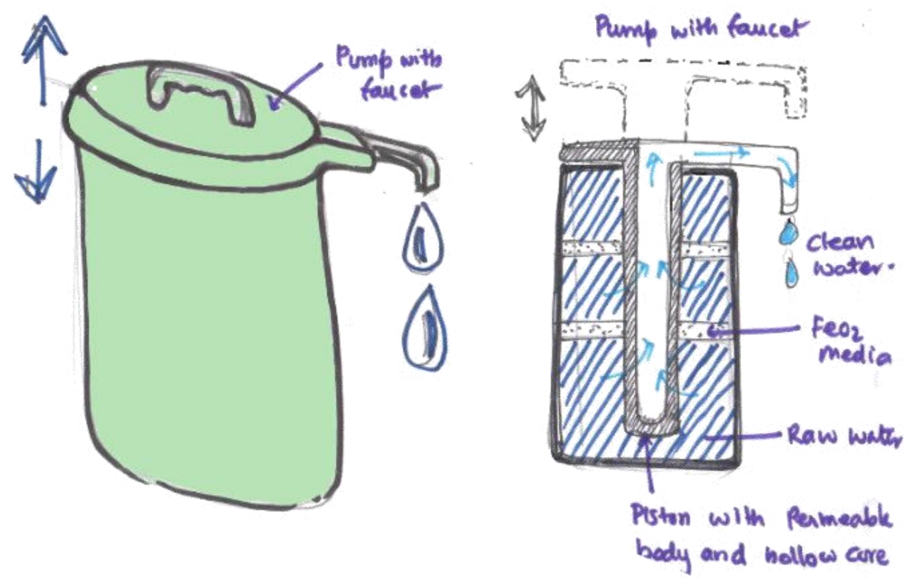


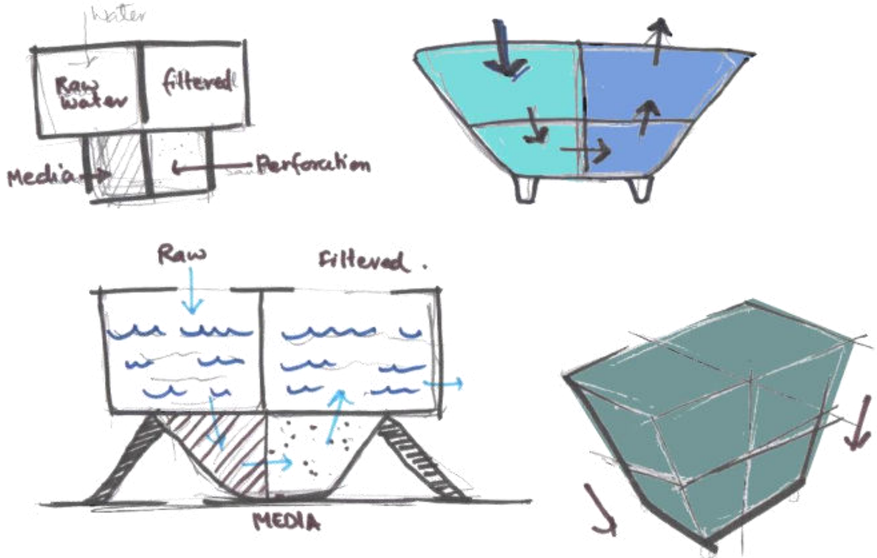
Figure 27: Water filtration using piston assisted pressure, Piston is percolation body with hollow core which carries filtered water out.

Working with Analogies

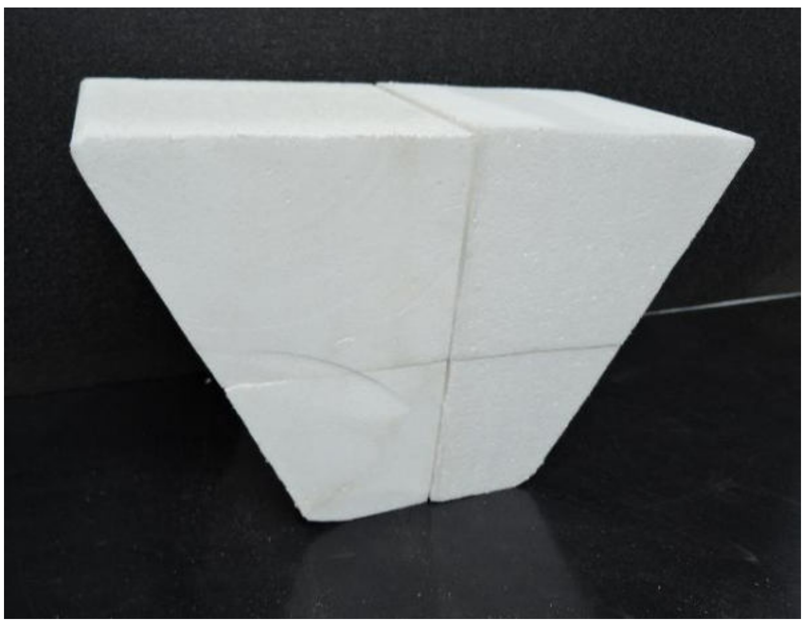
Analogies are external inspirations or references taken while designing or idea generation. Taking Analogies reduces the idea generation time drastically and several unique ideas could be developed. It also helps in pushing limits and coming up with craziest ideas.
There are various types of analogies. Most commonly used ones are Direct analogy and Indirect Analogy.

Direct Analogies:
Any object or process or external idea from where we are taking inspiration should somehow be related to the design problem. For example, in my project Direct analogy can be plants water filtration, Oil filters, Heart (pumping blood) etc.
Indirect Analogies:
Any random references taken to develop the idea for the project. The analogy should no way be related to the problem. In this process, the analogy has to be broken into process and components and from there Ideas are generated. In this process we take wildest possible ideas which are not usually thought in general circumstances. For example I took taxi ride, cyclone, pressure cookers, rooms etc. as indirect analogy in my project.

Analogies



Human Heart:
Human Heart pumps blood through four chambers; left atrium, left ventricle, right atrium and right ventricle. Similarly water passes through four chambers. The filtration media and percolation membrane chambers are below so water travels down and then up.
This form of tapering body gives immense possibilities in form exploration and high portability.



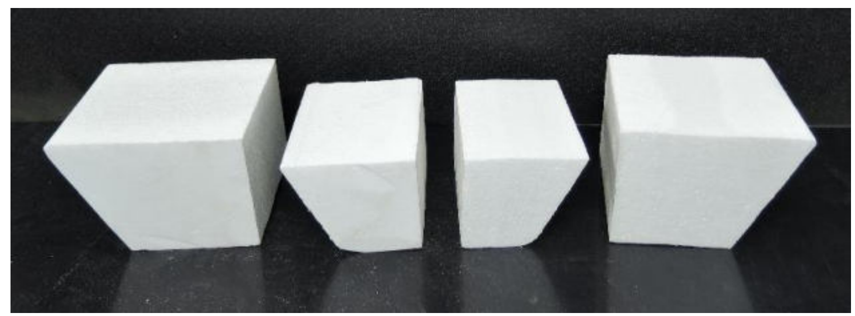


Figure 28: Filtration in a Tapering body 4 chamber filter.

Analogies

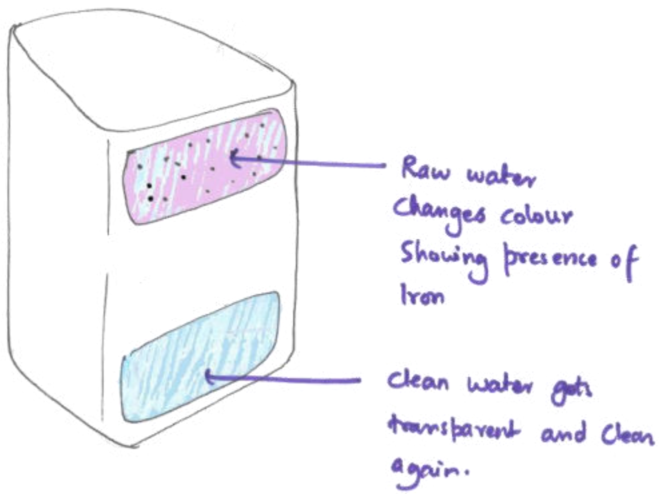


Figure 29: Idetion taking pressure cooker as analogy

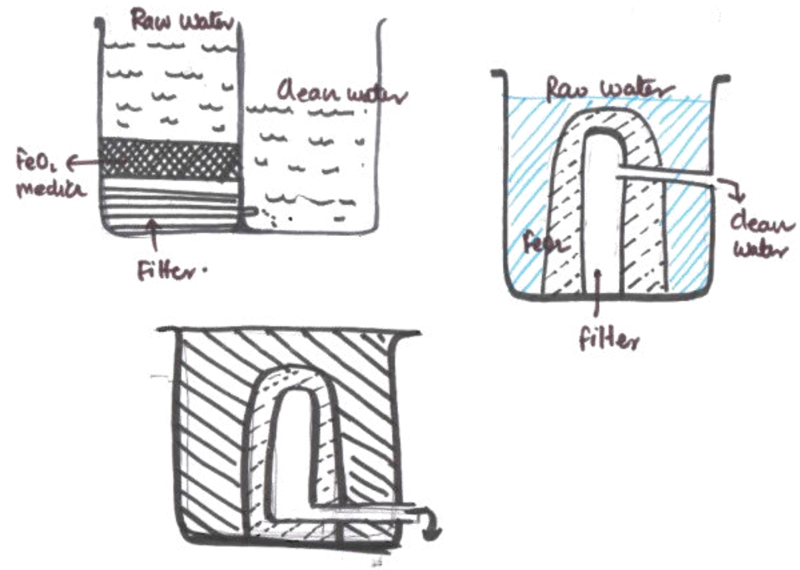


Figure 30: Idetion taking oil filter as analogy

Pressure cooker:
The charesteristic feature of cooking with pressure cooker is that it has a loud whistle. Whistle helps in giving signal to the user that the food is cooked. Similarly if the water colour in the inlet chamber and outlet chamber are different, the user gets trust and proof that the filter actually works.

Oil filter:
In an oil filter, water passes through layers of folded filter paper wrapped compactly around a tube. In this method the horizontal flow of water happens. This kind of filtration if implemented in the arsenic water filter reduces volume drastically.

Analogies

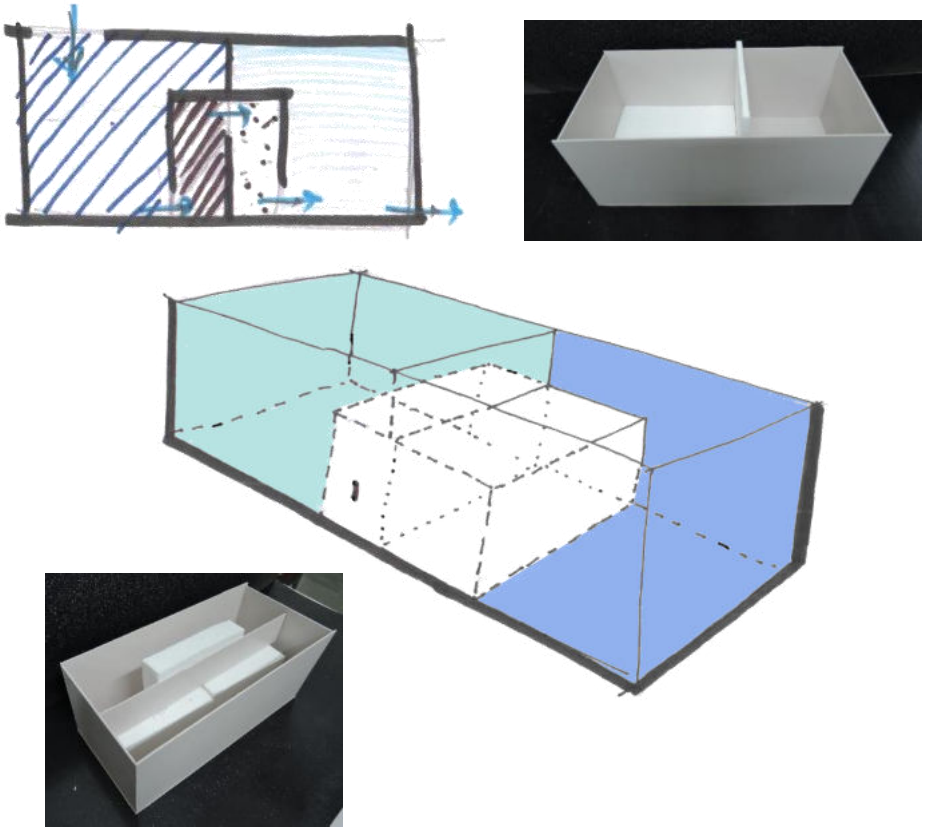


Figure 31: Idetion taking rooms as analogy

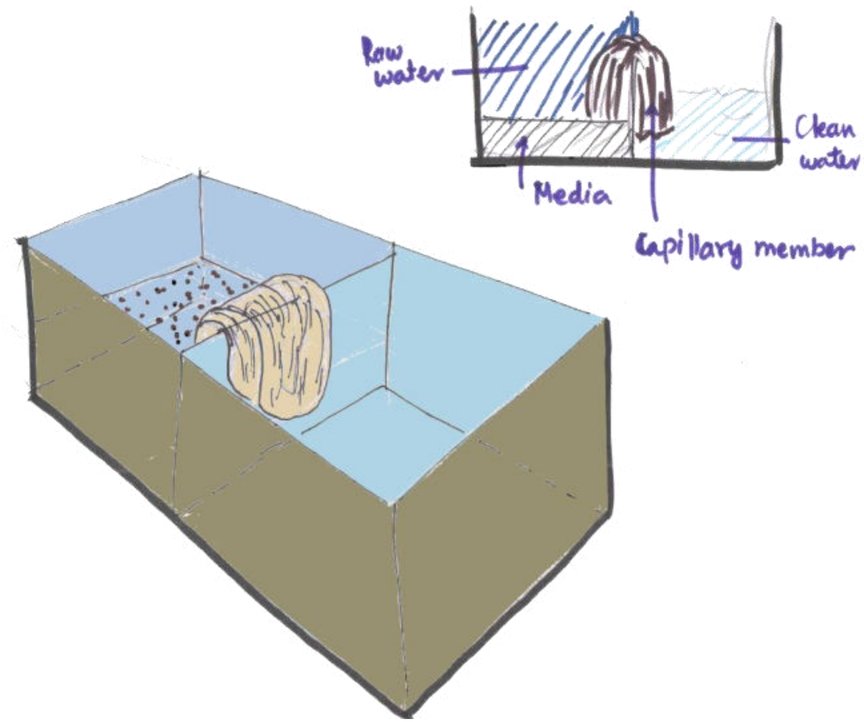


Figure 32: Idetion taking tree as analogy

Doors and rooms:
Like a room with entry on one side and exit on the opposite, water passes horizontally through chambers. Atmospheric pressure helps in water to pass. Speed slower

Tree:
Like water rises a tree through capillary action of natural fibres, after media reaction, water is carried through fibre to next chamber. Sediments and suspended particles cant travel through the capillary membranes.
Lighter and compact.

Analogies

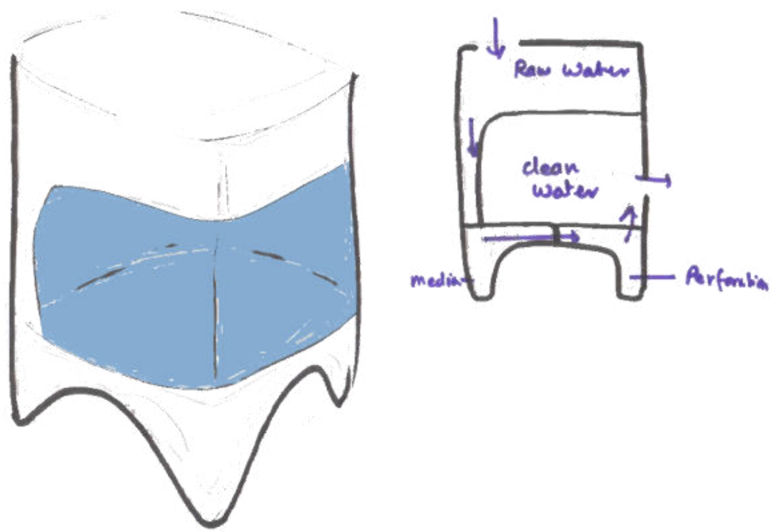


Figure 33: Idetion taking osmosis as analogy

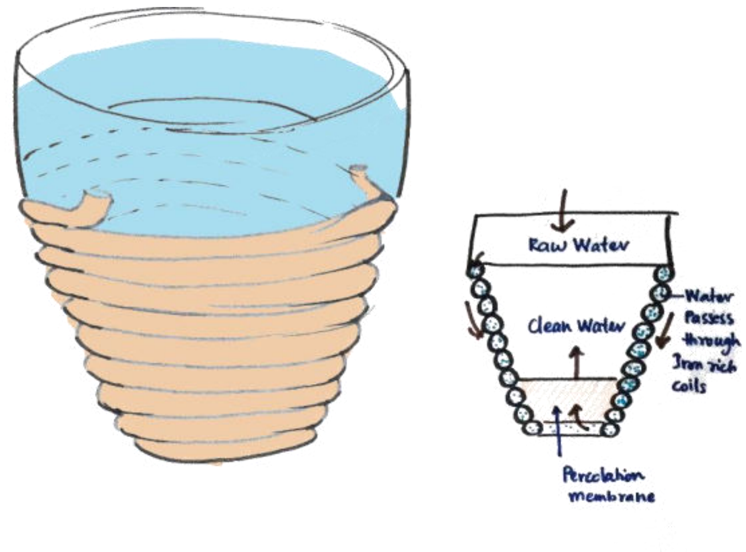


Figure 34: Idetion taking Taxi ride as analogy

Osmosis in tree:
Roots collect water from the tree and cleans it through mebrane and the wat`er then travels through the body. Similarly here media is at the bottom most level. The stand structure is not required in this. Water travels to the bottom where edia is, it reacts with media and percoation then travels up tp vollection chamber.

Taxi ride:
Filtration media is filled in pipes which coil up to make a frustum vessel. Raw water travels through the pipes and reaches base. There it a collection chamber and prcolation member at bottom. Water percolates through the percolation member and gets collected in the clean water chamber.

Analogies

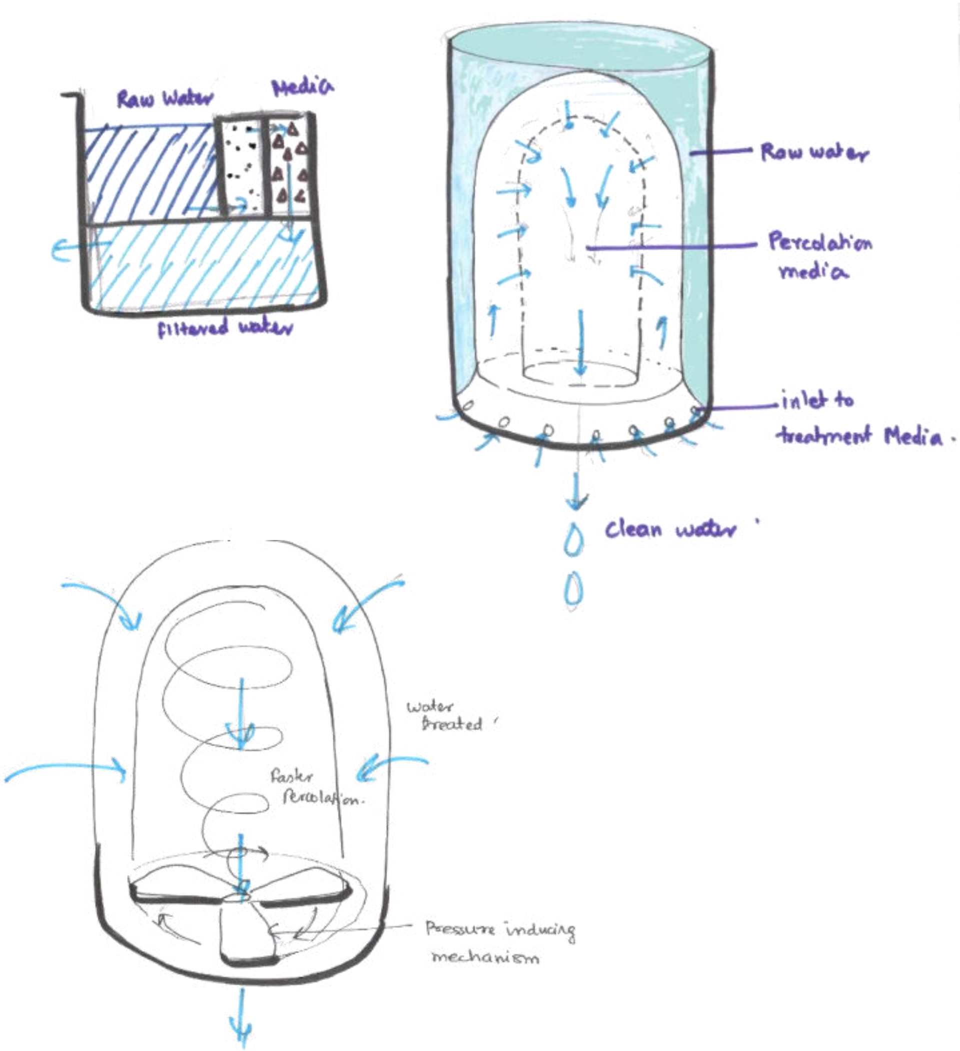


Figure 35: Idetion taking cyclone as analogy

Cyclone:
The water flows in circular motion like cyclone. Since water flow path is increased, circulation time increases too. This increases the reaction time but decreases the flow rate of water. Keeping a member to artificially increase the flow rate (eg. Fan or pump) can be advantageous. The setup becomes compact, easy to handle and clean.

Card Sorting and clustering

Figure 36a and 36b: Card sorting and clustering process

After generation of a number of ideas for solving the problem, the ideas are sorted into 4 clusters. The common features formed a cluster. The clusters were formed under the headings:
Gravitational Matka filter based
Pressure based
Shape based evolution
Media based evolution

The ideas were again reviewed under each cluster and a champion idea was decided. Characters of other ideas were implemented to the champion idea and 4 concepts were evolved from the 4 clusters. The concepts were later evaluated for final design evolution.

Card Sorting and clustering

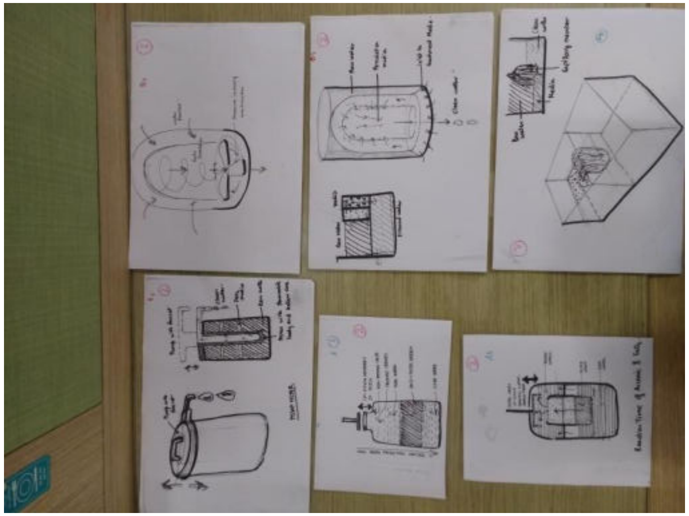


Fig 37a: Pressure based development

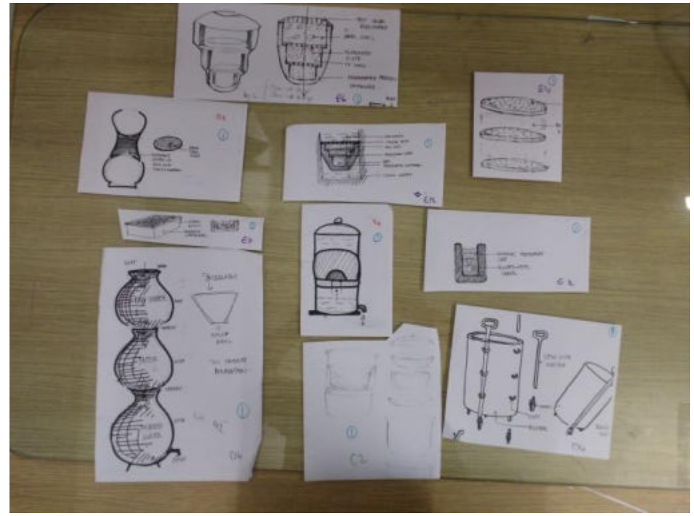


Fig 37b: Gravitational Matka filter based

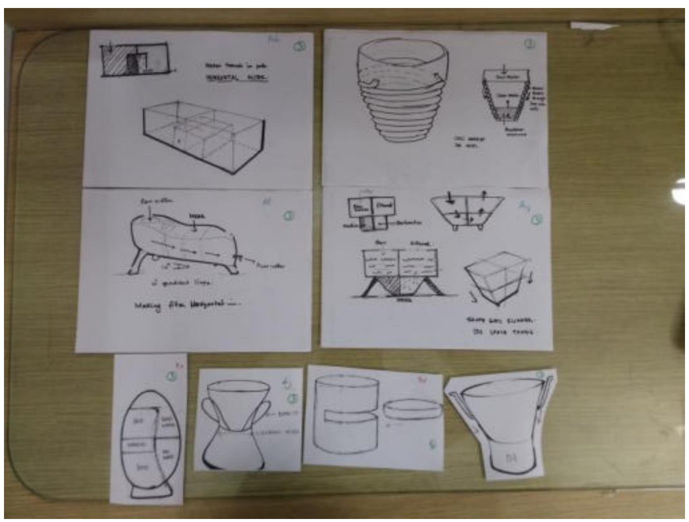


Fig 37c: Shape based evolution

Fig 37d: Media based evolution

Concept 1

Media based development

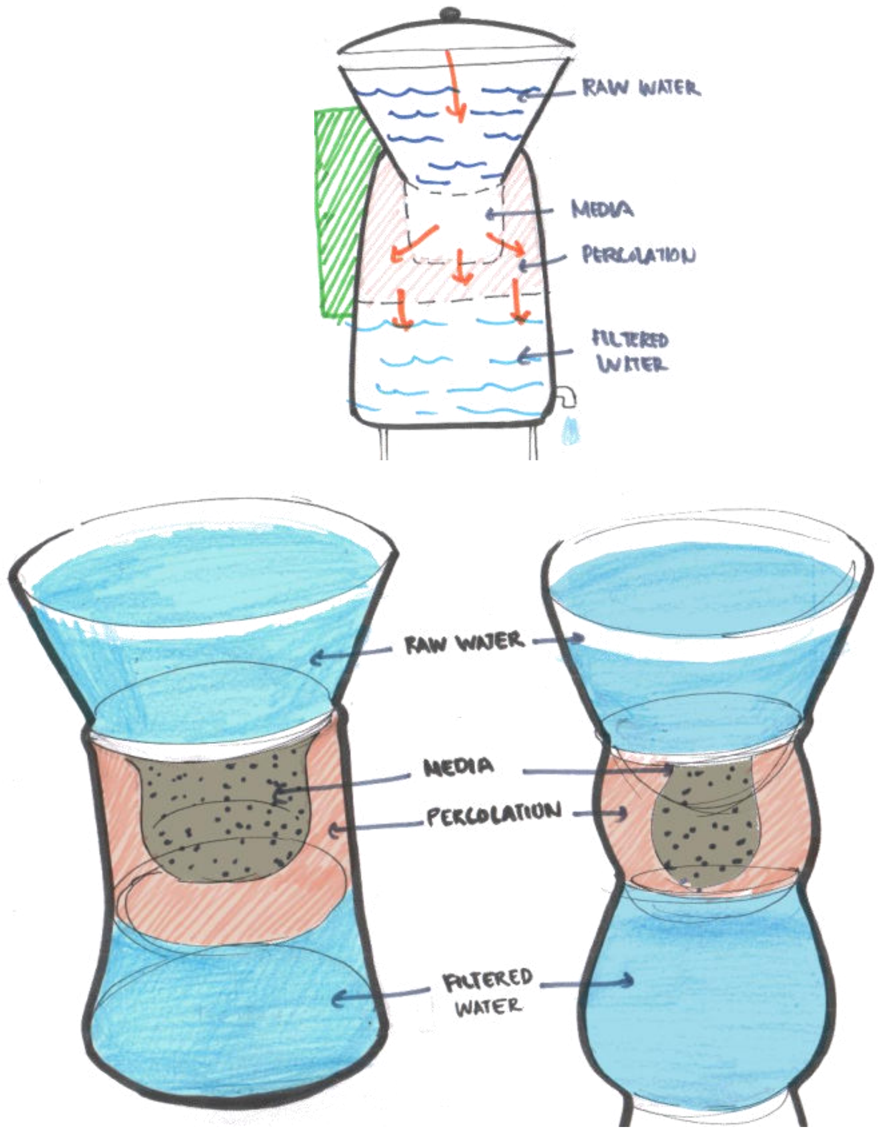


Fig 38: Concept 1 section and 2 shape varioations (one with round body and minimum edges)

Top inlet chamber is conical with wider feeding end and narrow exit to the media end. Hence the cross section of media reduces which in turn reduces volume. The media contained in a bag is surrounded with percolation member. Collection chamber is below collecting the filtered water, The top and bottom chambers could be made into transparent body. The central chamber can be easily removed and cleaned.

Pros
Simple manufacturing
Durable
Wide inlet narrow media contact area (volume reduced)

Cons
Needs stand to keep
Percolation member prone to breakage

Concept 2

Matka Filter Inspired

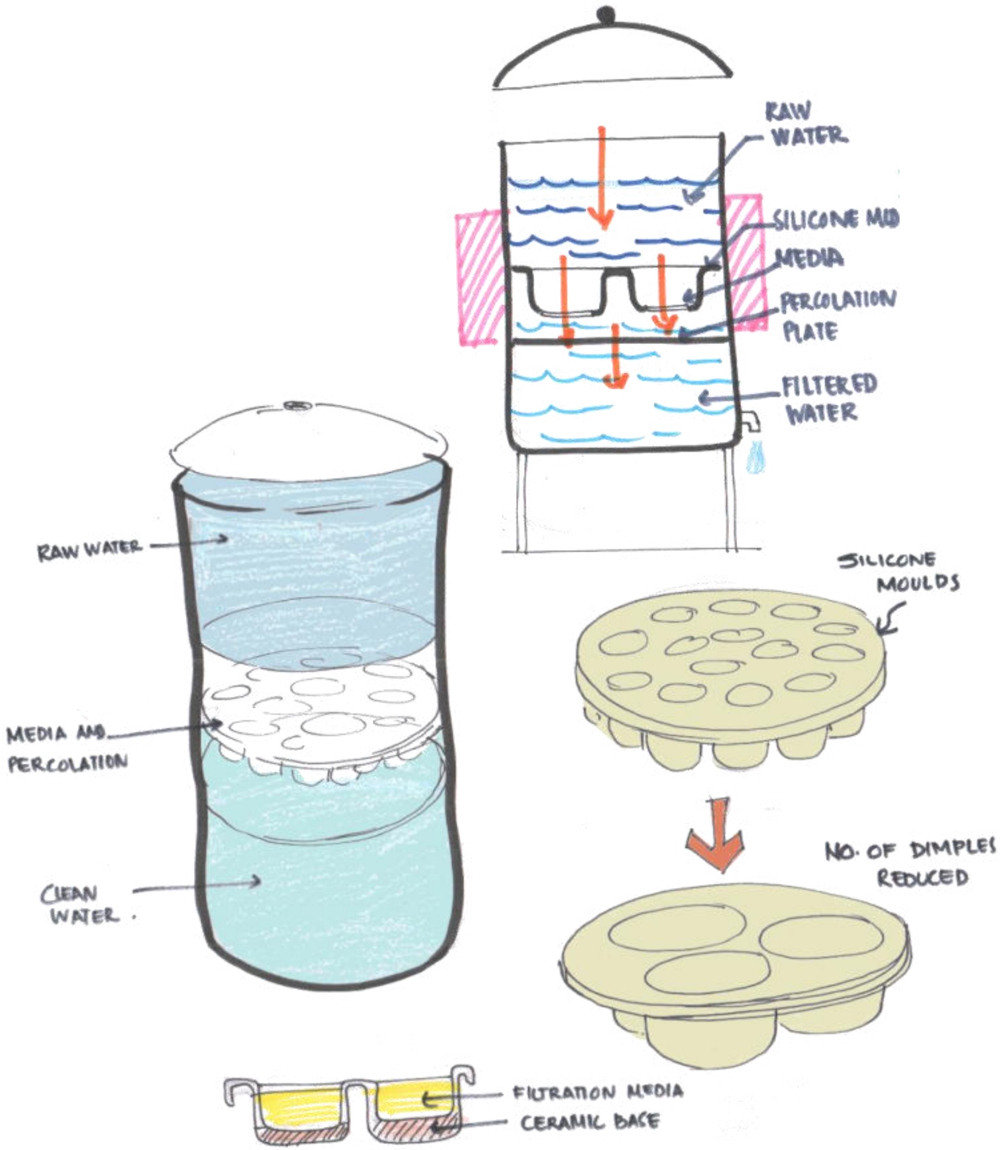


Fig 39: Concept 2 section and view with inner silicone plate detils

The filtration unit is not contained in a separate chamber but in silicone moulded container. The central part is a silicone plate with 3 cups. The base of the cup is cut and is fixed with ceramic percolation plates. The cup is filled with iron rich media and is put above the collection chamber. Then the raw water chamber with perforations at the bottom is kept above the whole setup.

Pros

Faster Flow of water due to gravity
Easy cleaning of the body
Simple manufacturing

Cons

Needs Stand
Regular cleaning required
Can be heavy
Possibility of misuse of the filter material.

Concept 3

Shape based development

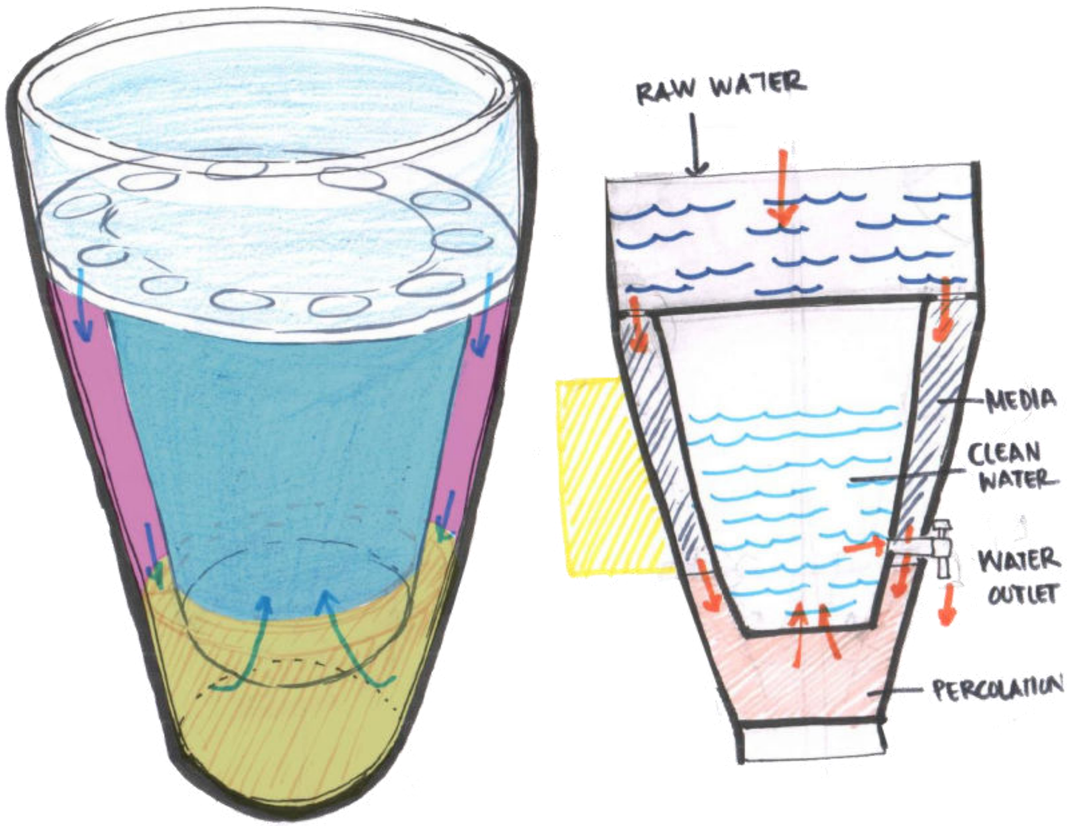


Fig 40: Concept 3 section and view showing the water filter with media in the jacketed body. Water passes through the media, reaches percolation member at bottom and travels up to get collected at central chamber

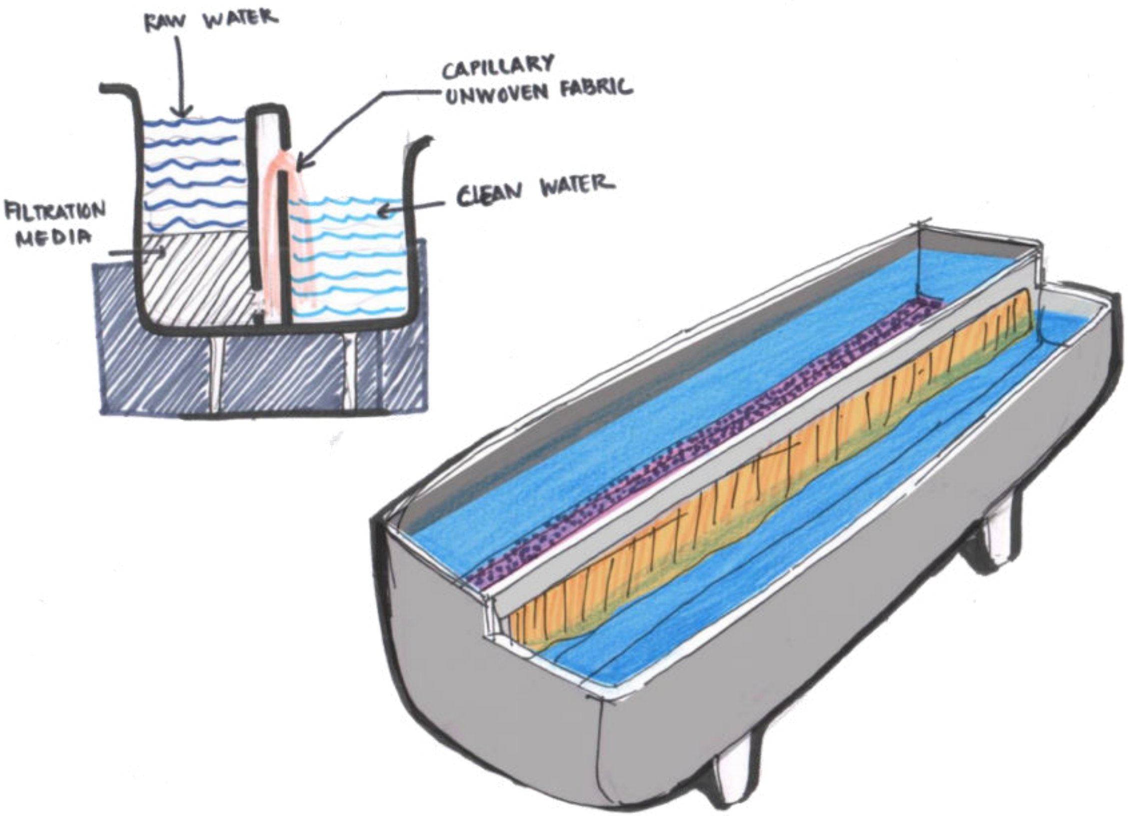
A Big container encases all the components. The ceramic moulded percolation member is kept in the bottom. Then inner chamber is kept on that. Inner chamber is concentric to the outer body. Then media is filled in the gap between inner and outer chamber and finally is covered by plate containing holes in the gap.

Pros
No need to keep the filter in stand.
Compact
High reaction time
Filtered water away from light and environment
Easy manufacturing

Cons
Not very easy to clean
Assembly slightly complex
Water level not visible
Chances of media getting messy while cleaning

Concept 4

Pressure based development



The raw water chamber has iron rich media at its bottom with a narrow chamber adjoining it. The narrow chamber divides the filter through and through making a separate filtered water chamber at the other side. A capillary member inside the narrow chamber passes water from there to the filtered water chamber. The capillary member carries only water and leaves behind sediments. In this process filtration rate depends on the length of capillary media. Hence length of the whole unit will increase in one axis and height and volume will drastically reduce.

Pros

Low weight

Horizontal, can be kept in shelf

Cons

Shape takes more carpet area

More possibility of recontamination with microbes

Fig 41: Concept 4 section and view showing the 2 long chambers. Water comes to the firsht chamber and reacts with iron media at the base. Then it travels through capillary media to the next chamber.

Concept Evaluation

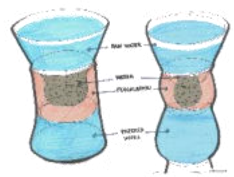
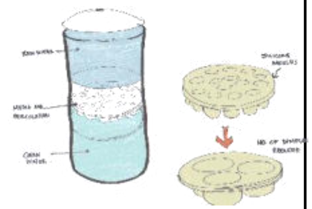
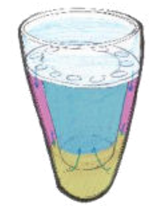
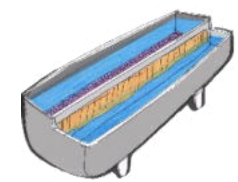
	Concept 1 	Concept 2 	Concept 3 	Concept 4 
User centric	7	9	9	8
Manufacturability	7	8	9	7
Longitivity	8	9	9	8
Self Change of Media/ Cleaning	8	8	7	7
Compactness	8	8	9	7
Total	38	42	43	37

Table 2: Concept evaluation

Design Development

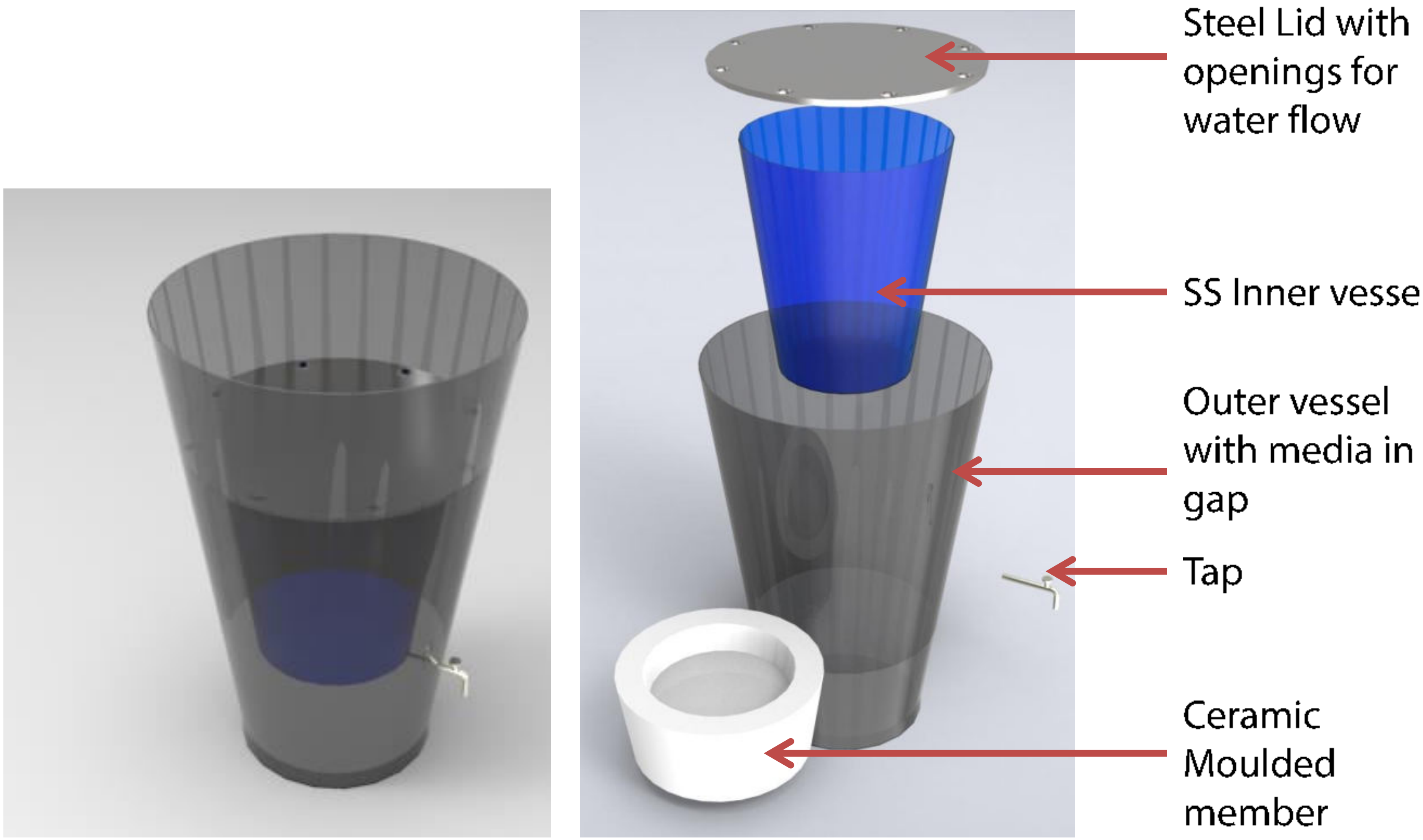


Figure 42a and 42b: final concept parts and exploded view.

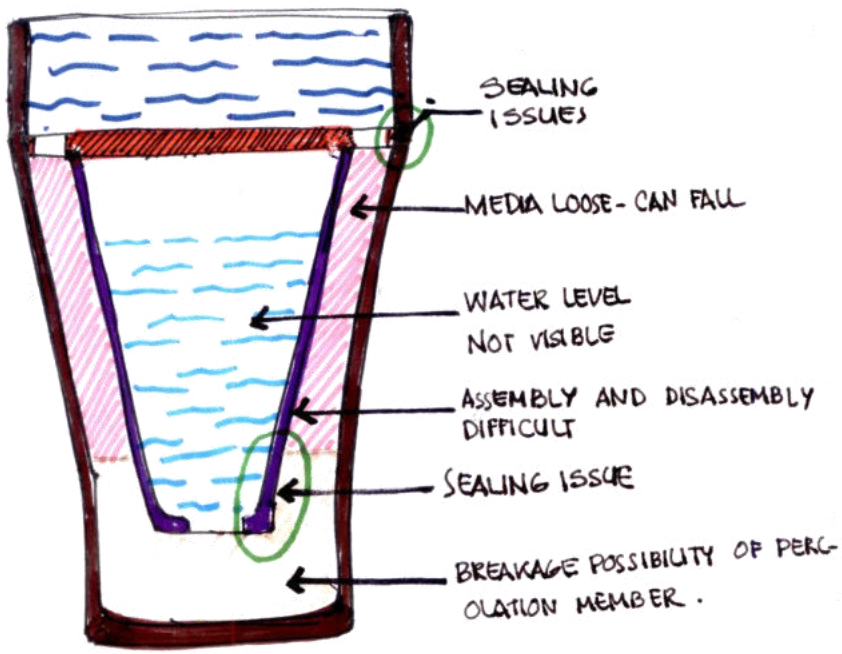


Figure 43: Section of the design showing issues and weakness of the concept that need to be resolved

Issues with the concept:

- Maintenance and clean ability of inner chamber.
- Assembly process tedious as the media is not contained in its own chamber but has to be filled once the assembly is done.
- Sealing and water seepage issues at the bottom where the inner container fits ceramic percolation member.
- Chances of breakage of percolation member while cleaning
- No support for inner container and is supported only by ceramic mould
- Media has to be limited to wider chips. Powder media cannot be used.

Design Modification

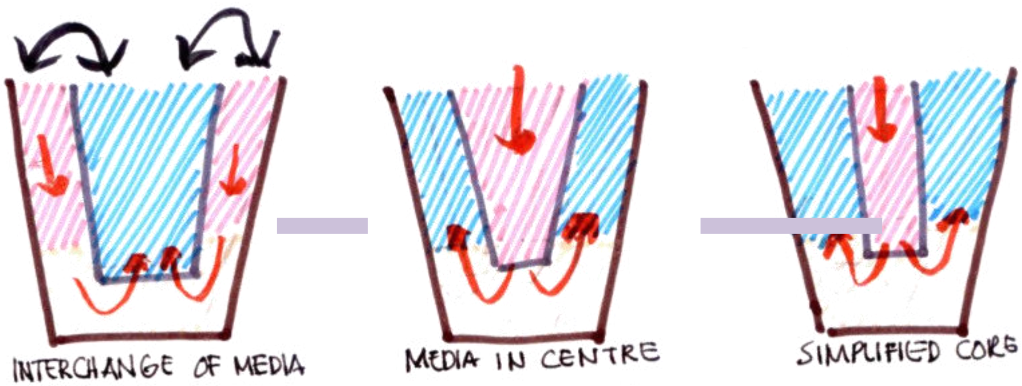


Figure 44 : Modification of the design by taking the media to the core and water to the shell. This core further cylinderified once any first.

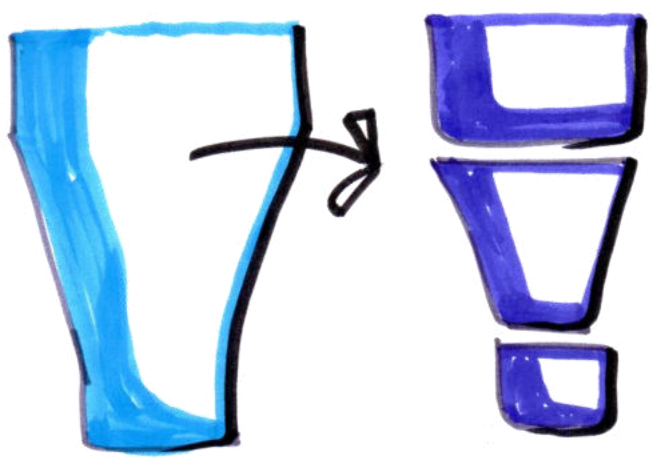


Figure 45a the single outer cover broken into 3 parts for easy handling and cleaning. :

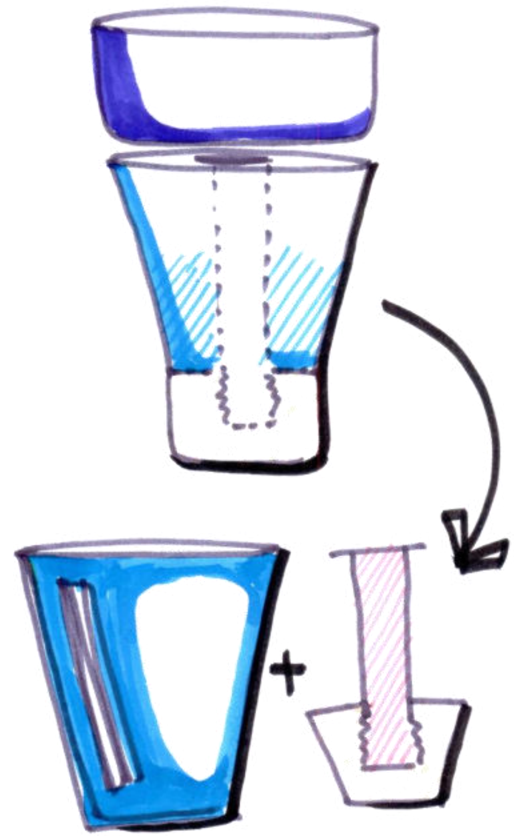


Figure 45b : candle is suggested to be made into an individual unit moulded with the slope of bucket.

Final Design

Fig 46a: Modified final design render view

Fig 46b: Modified final design exploded view

Drawings

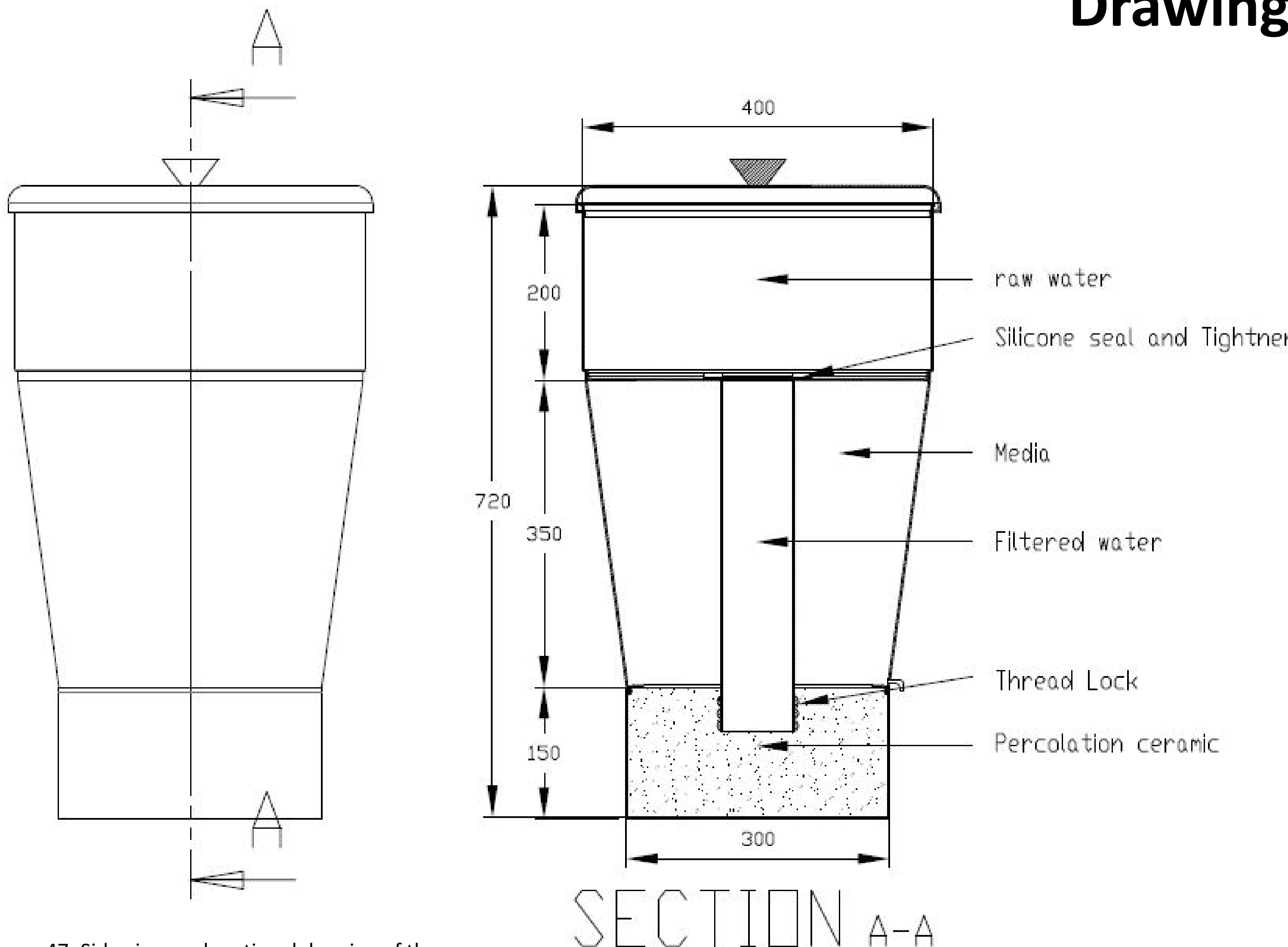


Figure 47: Side view and sectional drawing of the water filter. The dimensions shown here are for the small filter for family of 6

Details

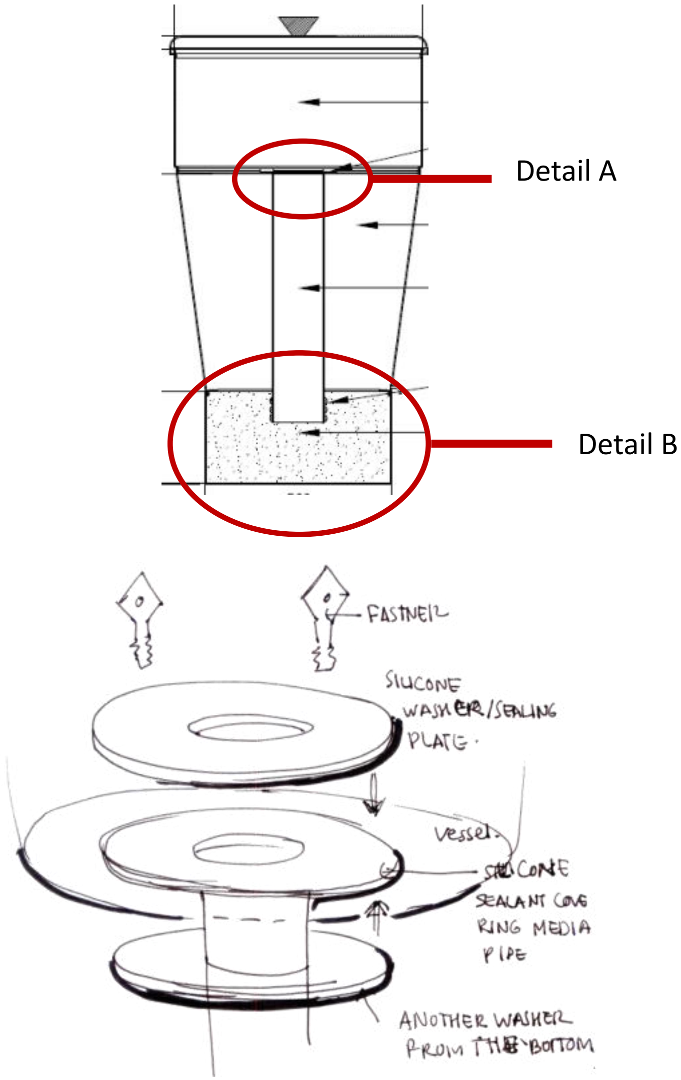


Figure 48a: Detail at A, the media chamber goes in top chamber hole from top. The top rim of the media container keeps it on place. Rubber sealant rings from up and down now used to make connection waterproof.

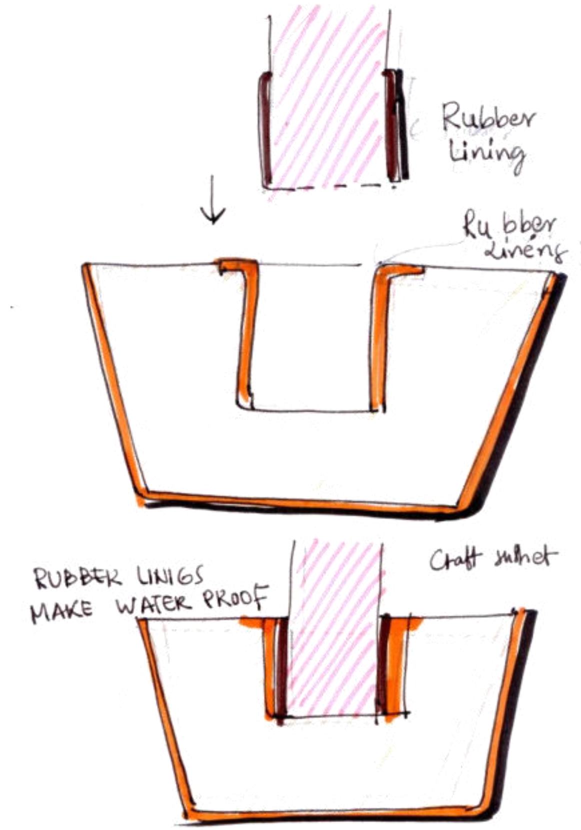
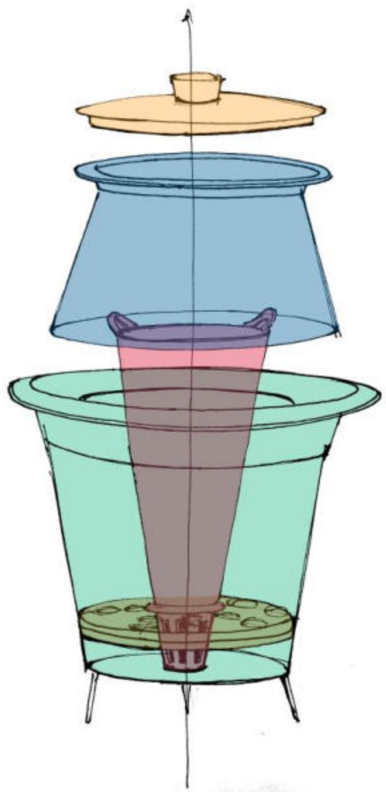
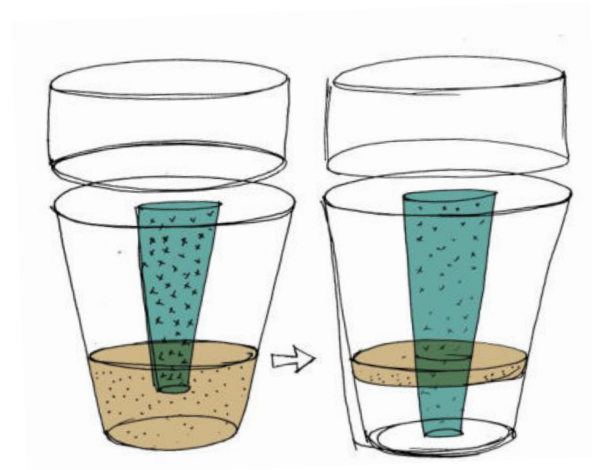


Figure 48b: Detail at B, media chamber has rubber layer below. The structure comes and fits in the ceramic structure which has a hole with rubber lining. The friction of rubber keep them if a class audience. .

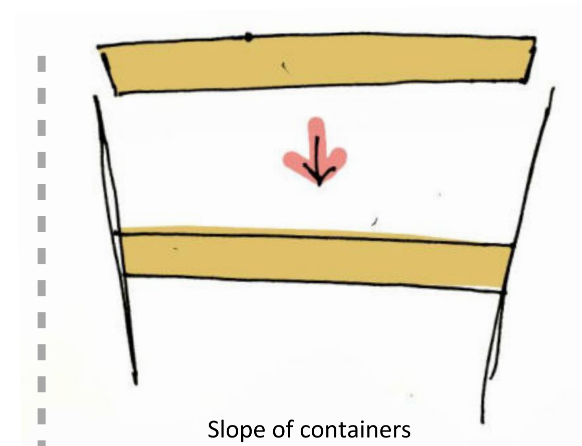
Design Decisions



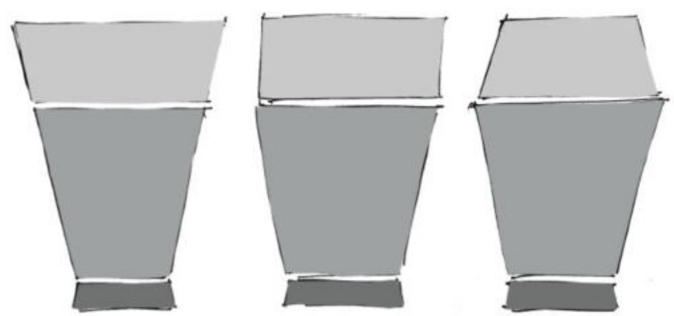
Inside view of the filter

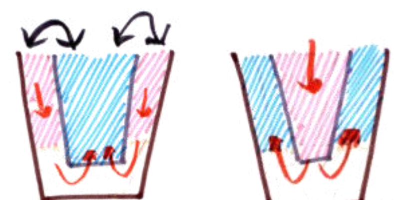


Full ceramic base converted to Disc so a gap space achieved for sedimentation.



Slope of containers helps in easy fitting





Bringing media inside and water outside in the jacketed container helps in easy assembly and cleaning

Assembly

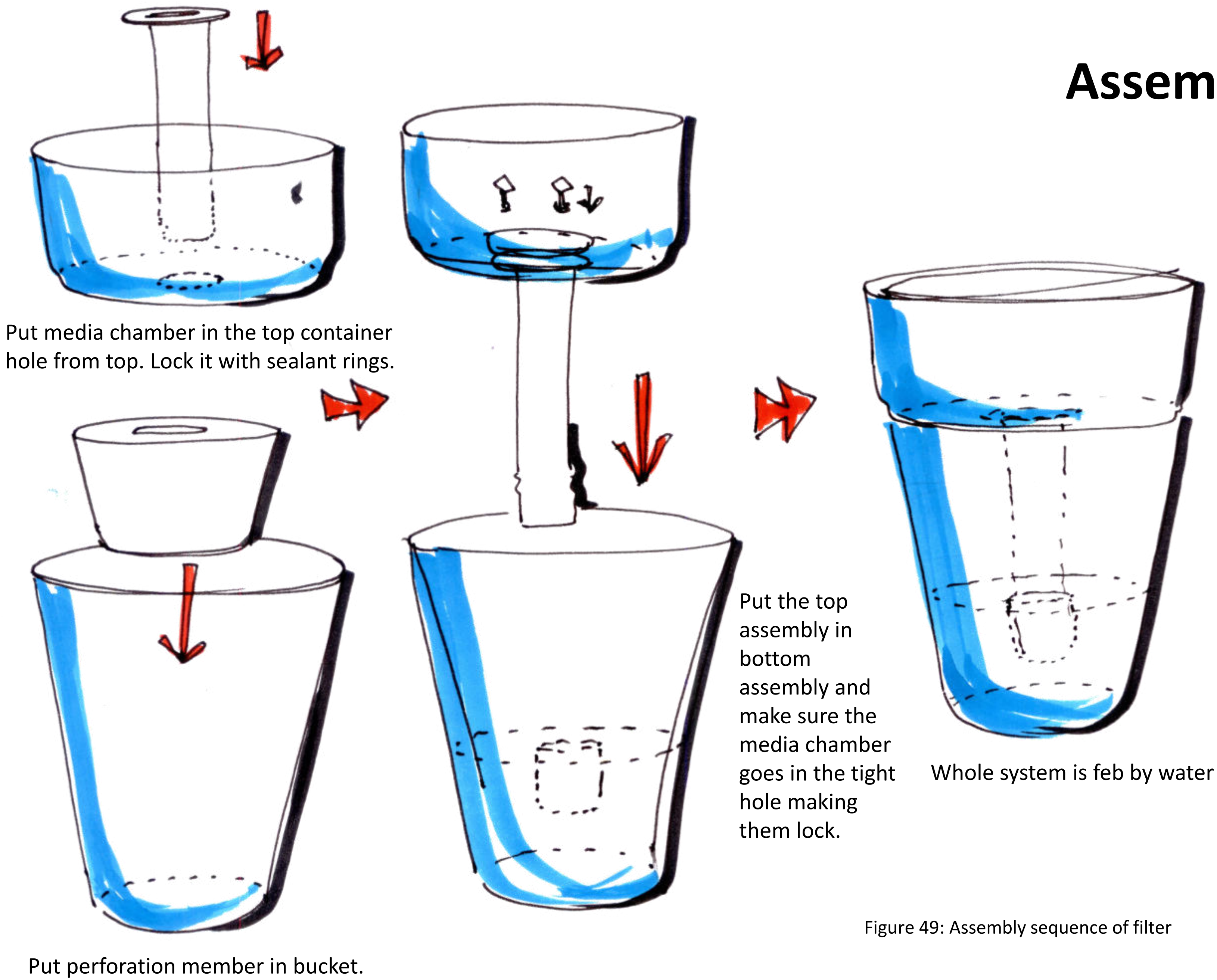


Figure 49: Assembly sequence of filter

Drawings

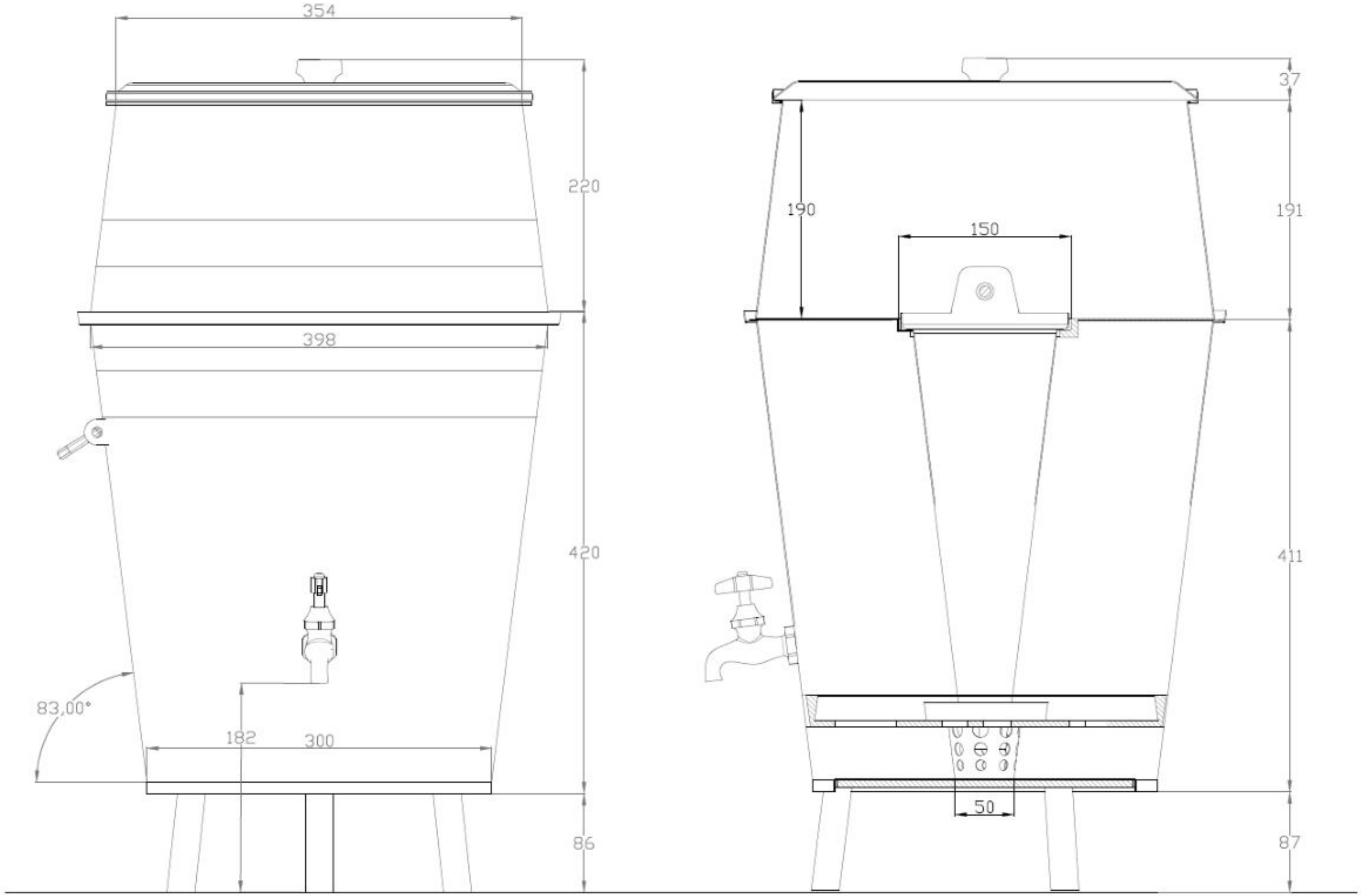


Figure 50: drawings

Materials and colour

Figure 50a: Various material and colour possibilities in this design. The central collection chamber can better utilised to make the overall product interesting. Copper, Grass, Iron ore, Plastic and ceramics are the possible options.

Working of filter

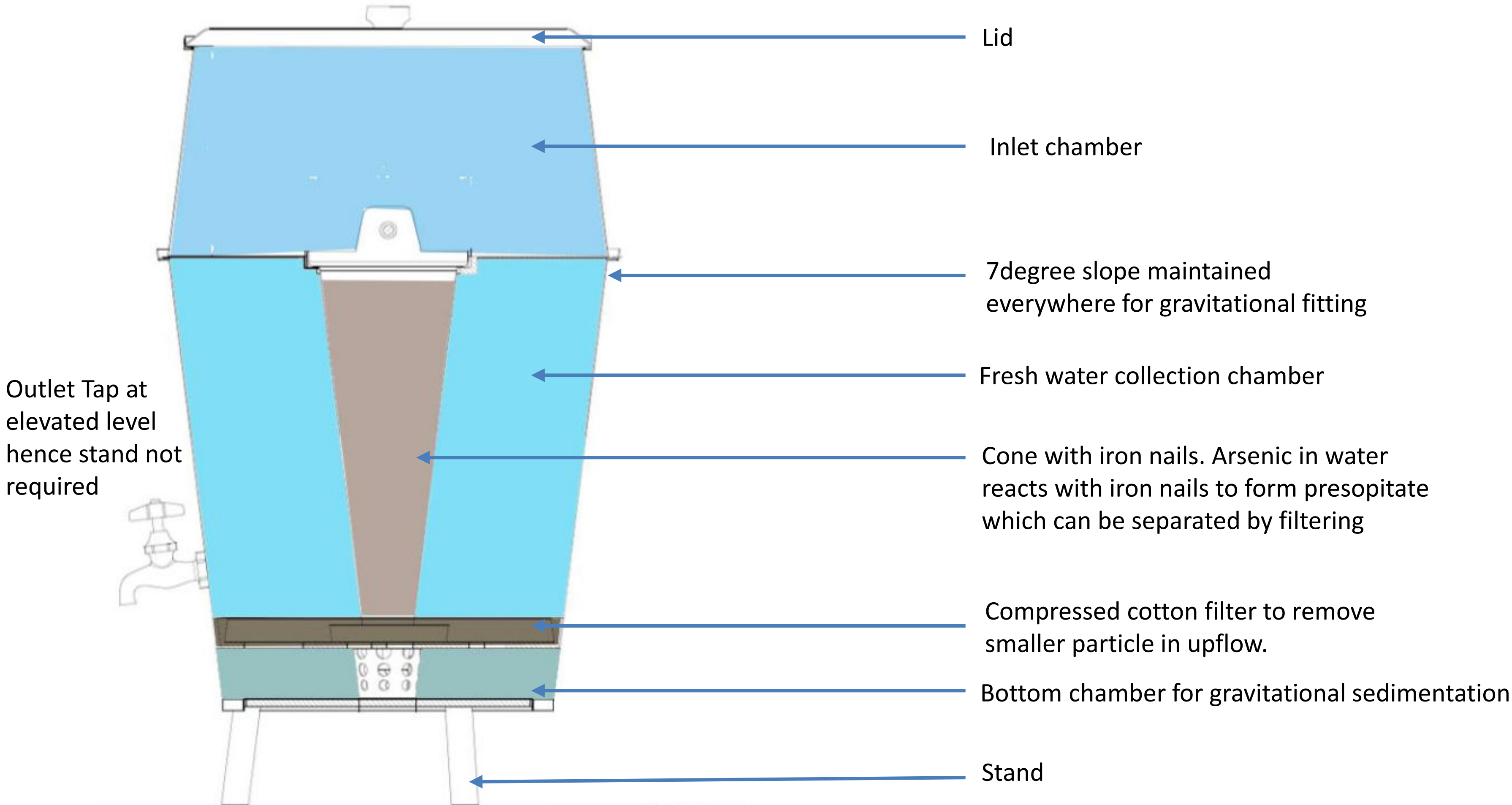


Figure 52: working of filter

visualisations

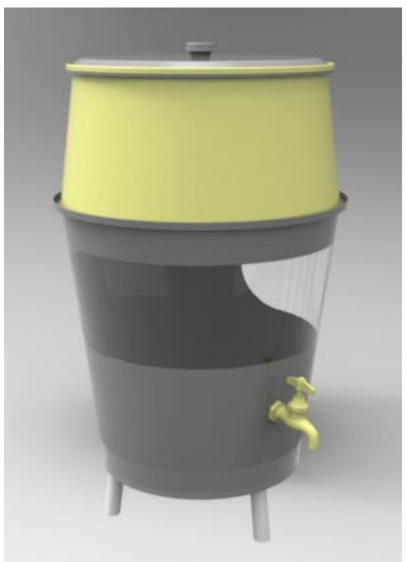


Figure 52: renders

Handling

Figure 53: handling of various parts

Water Sealing

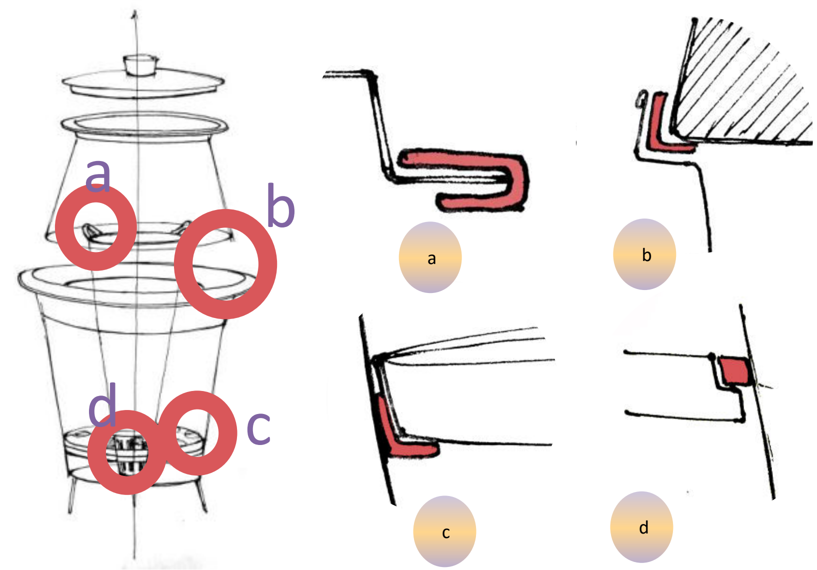


Figure 54: water sealing in various parts

Prototype and testing

Figure 55: prototyping

TESTING

Handling and Assembly

Figure 56: handling and assembly

TESTING

Handling and Disassembly

Figure 57: handling and disassembly

PRODUCT AND ENVIRONMENT

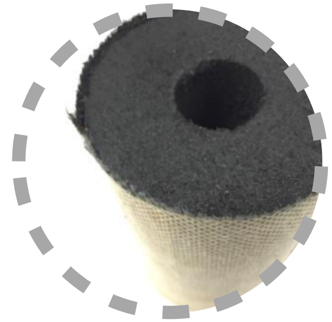
Figure 58: renders

Filter

Filtration media is required for filtering out the iron oxide reacted water which forms precipitate.

Filteration options

Fine sand



Carbon filter

Ceramic Filters

Finalised option
(Cotton Filter)

Cotton filters

Figure 59: Filtration options

Scale model

Figure 60: 1:5 model

Prototype

Figure 61: working prototype

Final Design

- Separate container(central pipe) for containing media. Easy to replace and clean
- Media container porous bottom, fixed to the perforation medium via threading.
- Perforation media forms the base of the filter. Works as stand and filter doesn't need additional stand structure for stand
- Water collection chamber is the central chamber. It can be transparent, in copper, steel or any other material based on the users preference. Many possibility in the water chamber.
- Top raw water chamber is separable unit and the user can have many such units which they might keep replacing alternatively.
- The filter works on atmospheric pressure and gravity. The raw water level is always above the treated water level. Hence, there will always be filtration happening if raw water chamber has water.
- Filter has 3 parts, easy to manufacture and assemble.
- Rubber sealing gasket seals the joining between raw water chamber and media pipe.

Market Strategies

The Product can be brought into market in 3 ways:

Private Dealership
The filters are sold at retail shops along with other home appliances and products. The user pays full amount. Price of product kept low with minimal taxes applicable.

Subsidised selling
Government gives subsidy on the product or CSR funding agencies pay for some amount of a product. The user pays minimum for the product (eg. 20% of total cost). By taking money from the user, some amount of ownership and responsibility is given to them.

NGO/Government/CSR distribution
The agencies manufacture product in their facility and distributes the products. The users get it for free. This is mostly for survey and study of product in limited field.

Costing

NGO/Local manufacturer approach

- Special design option with users maintaining product
- SS body, cotton filter

Cost: Rs.4600

Industry approach

- Large scale manufacturing
- Replacable cartridge
- SS body, plastic disc

Cost: Rs 2200 + 600-800 yearly maintainance

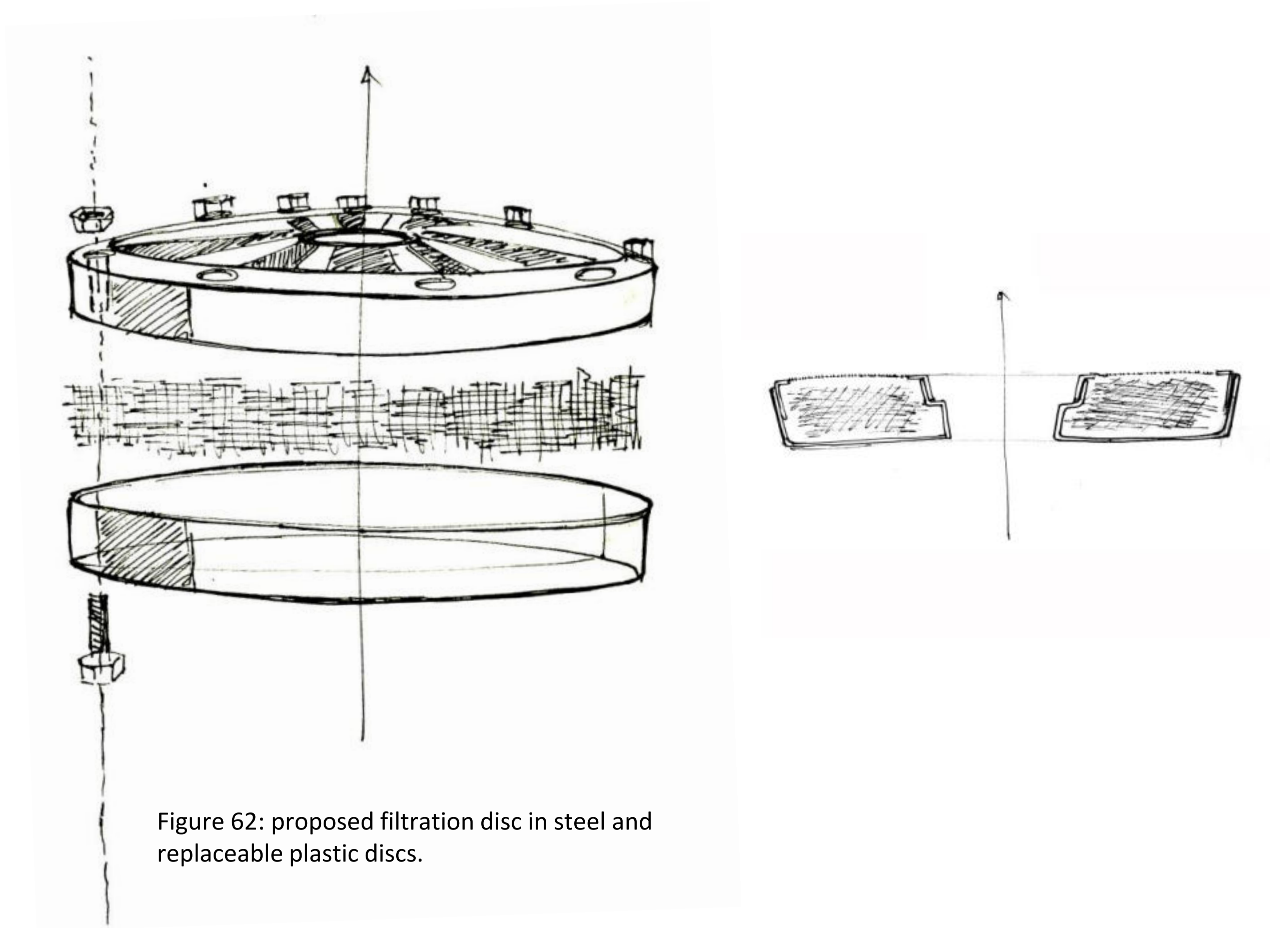


Figure 62: proposed filtration disc in steel and replaceable plastic discs.

Post PIII Jury

C13

Discussion held with Prof Sanjeev Chaudhary of CESE Department. In the Discussion, Prof Chaudhary commented on few design Flaws of which the major one was:

"Access of oxygen to the Iron nails and passed water is very important. The current Design doesn't allow enough oxidation to iron nails and the ferrous reacted water".

This important comment resulted in numerous design changes. The Design was modified and several options were made to try and adjust to the old requirements as well as new requirement of Air contact.

Ideations

Firstly the idea was outlined to previous model with slight modifications with iron chamber coming up in the direct contact of air. A narrow pipe was added in the centre of the chamber to supply air to the filter medium.

Limitations- Water would come up in the narrow pipe due to atmospheric pressure and filter medium would be rendered without air.

Sketches were then rendered keeping in mind simple manufacturing and easy assembly/disassembly. Ideas were developed wherein the water would travel simply downwards due to gravity. Also the iron and filter medium should be aerated all the time. The chambers could be connected by various options such as dismantlable stand, chains or simple edge to edge fitting.

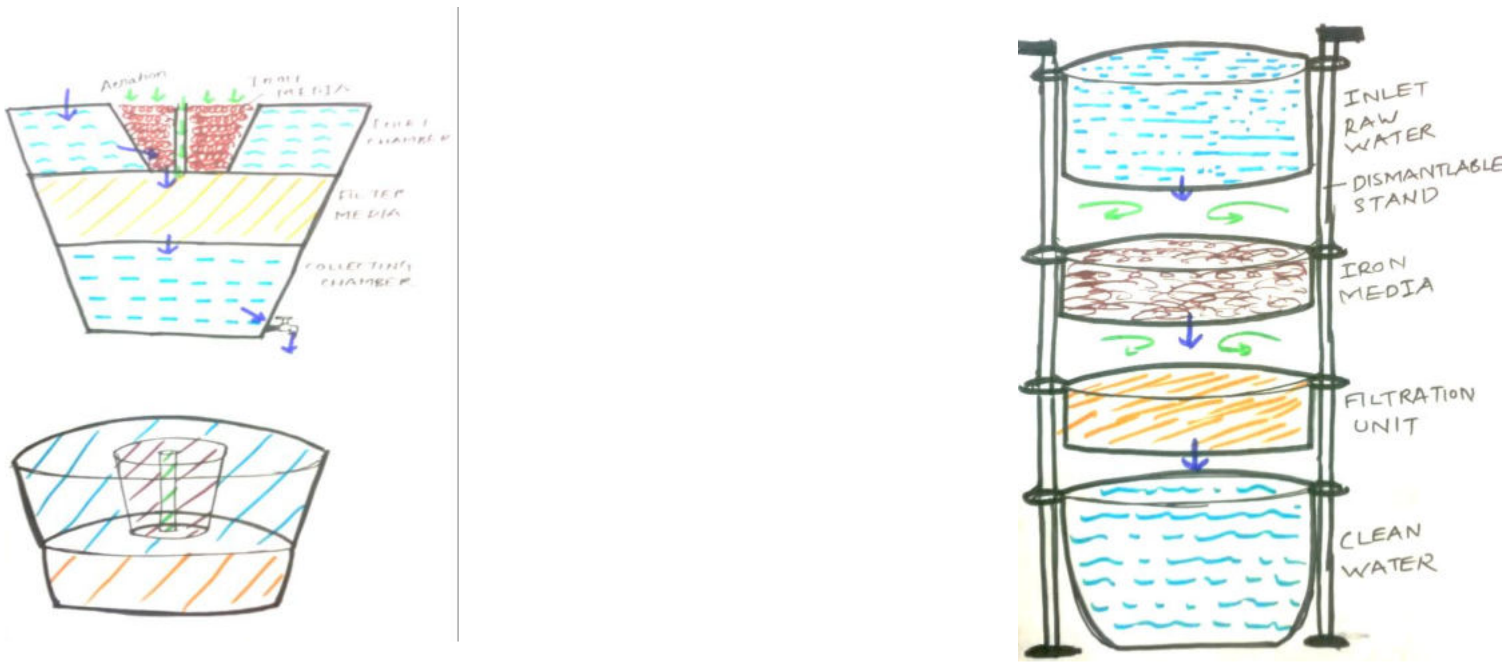


Figure 63: Ideations for new approaches (details in text)

Ideations

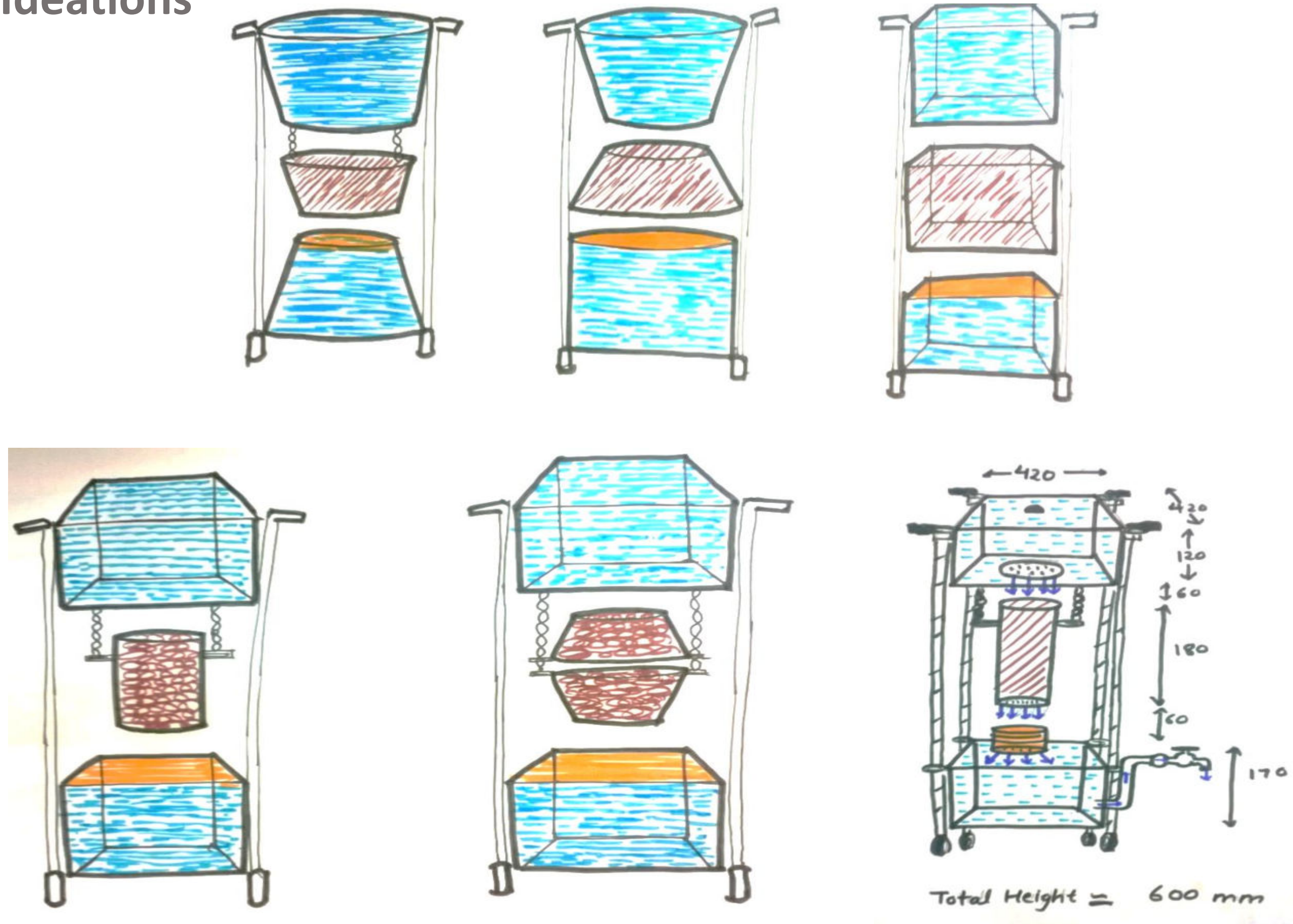


Figure 64: ideations in various approaches to efficiently fit the 4 chambers

Ideations

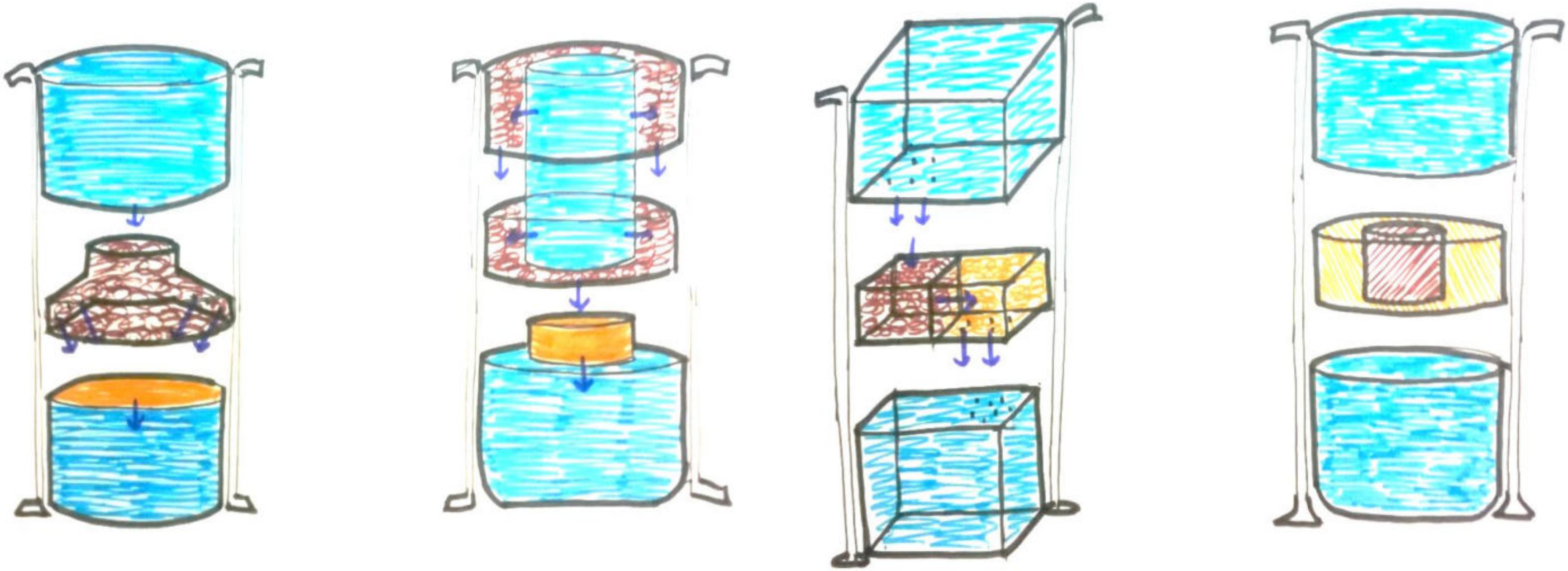


Figure 64a: ideations in various approaches to efficiently fit the 4 chambers

Ideations

For ease in manufacturability and easy handling, chambers were reduced to **two**. The upper chamber would be divided in two sections with **holes for aeration** on the top of iron medium section. The two sections would be separated by a perforation disc with tiny holes. After evaluating two chamber concept, methods of joining the two chambers were explored. For ease in manufacturing the lower chamber was extended in height with holes at top for aeration of iron chamber from below.

The upper chamber would then **gravitationally fit** inside the lower chamber through **a tapered bottom**. Then the frustum structure of the model was converted into a **round structure** for ease in manufacturability.

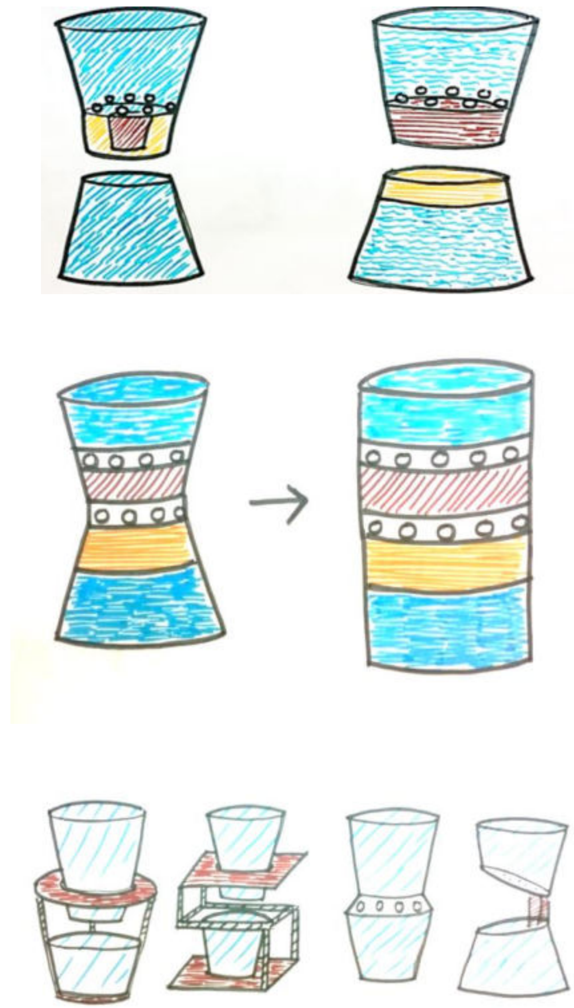


Figure 65: finalised ideation of using 2 containers with holes for airflow and its variations

Design Development (Final design)

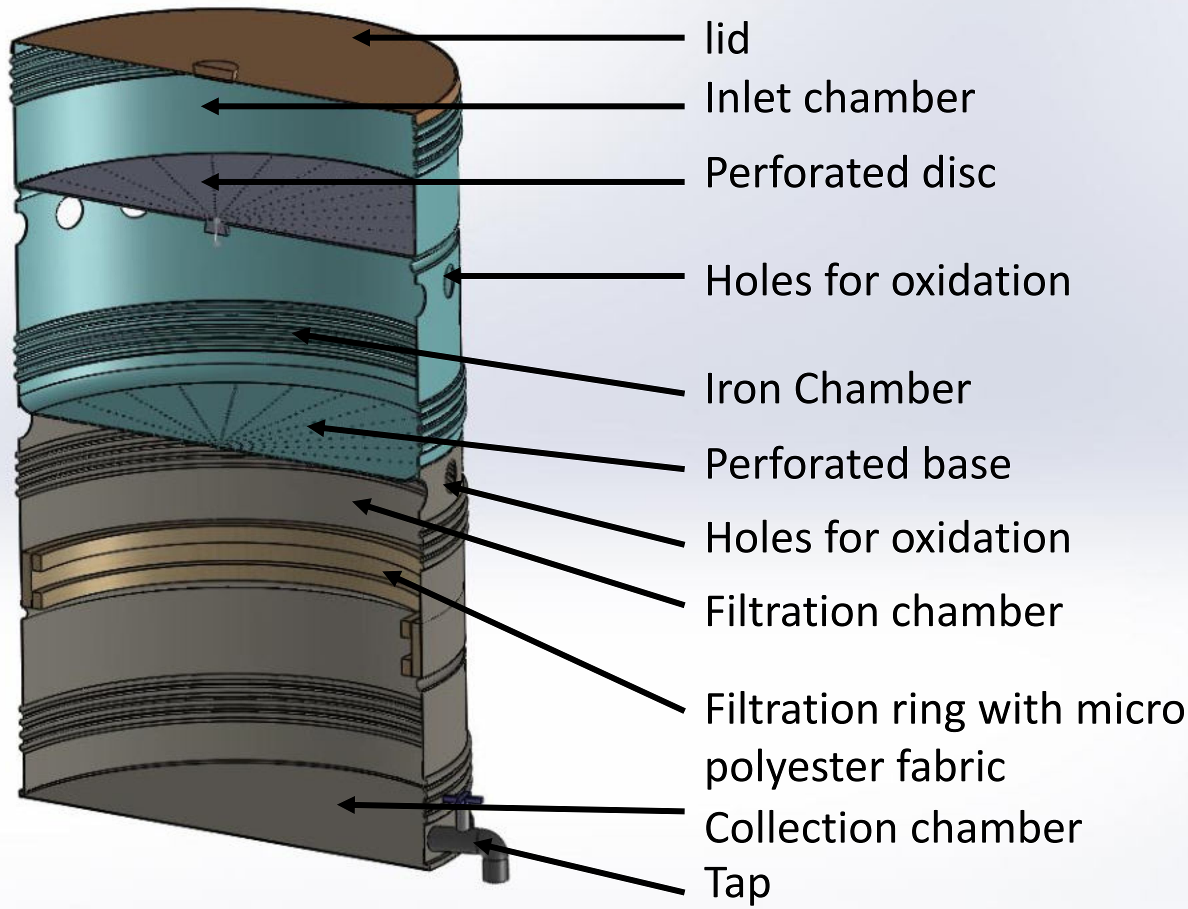


Figure 66: working of new filters

Final design Drawings

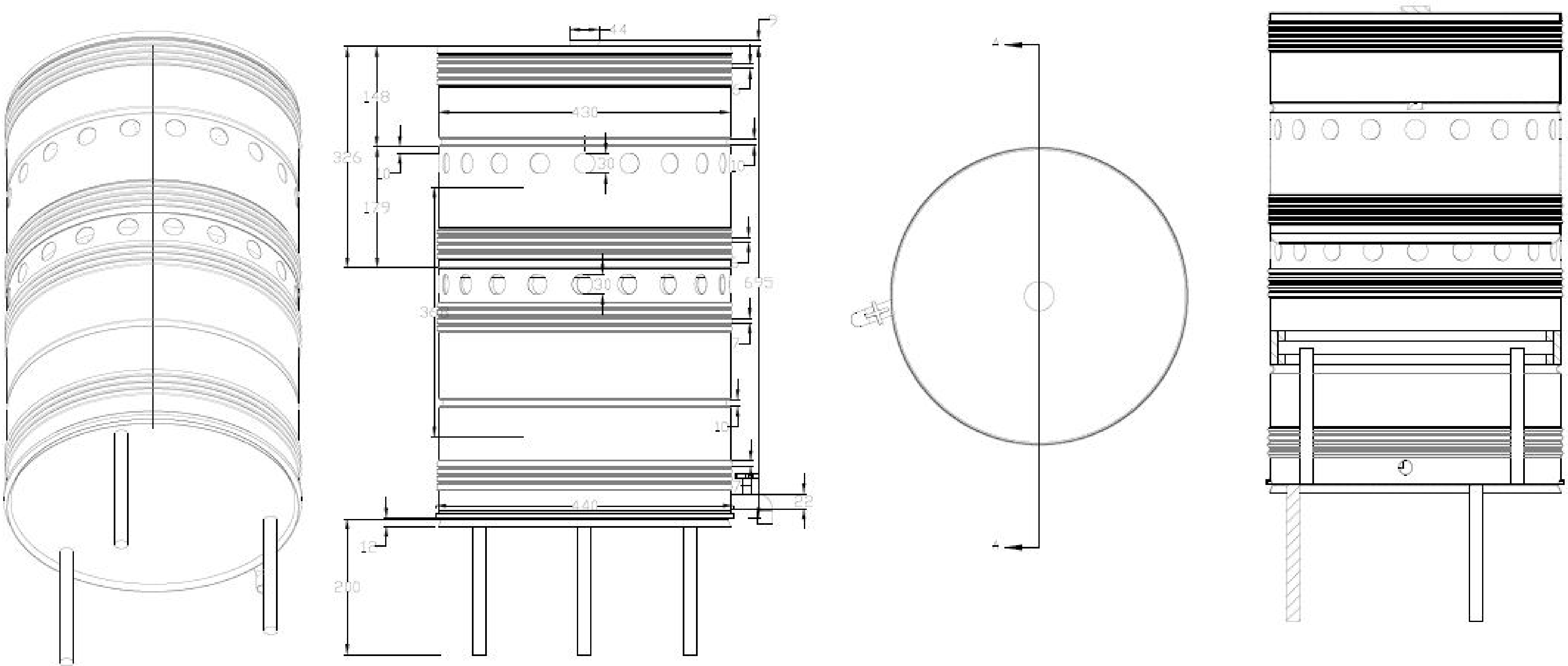


Figure 67: Drawings

Design Development (Final design)

Figure 68:visualisation in a Ballia Kitchen

Part Details

UPPER CHAMBER

Its height is 290mm and radius 215mm. It further comprises of three sub units- A. Raw water chamber of height 140mm. The volume is **20.3 litres**

B. Aeration unit of height 50 mm which contains 20 holes of 15mm radius.

C. Iron chamber of height 150mm and laser cut holes at the bottom of 0.5mm radius. A round fillet of 15mm radius is given at the bottom.

LOWER CHAMBER

Its height is 365mm and radius 215mm. It also comprises of 3 sub units-

A. Aeration unit of height 50mm containing 20 holes of radius 15mm for oxygenation of iron chamber from below.

B. Filter chamber of height 150mm where a filter unit is deployed below of height 50mm.

C. Clean water collecting chamber of height 155 mm. A step of 10mm is further given at the bottom. The combined volume of filter chamber and clean water chamber is **44.2 litres.**

Figure 69a: Top lcontainer

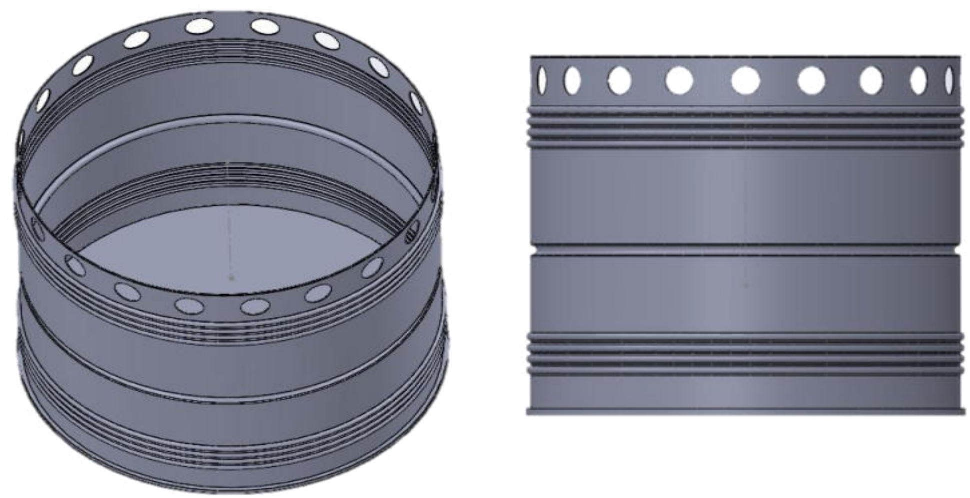
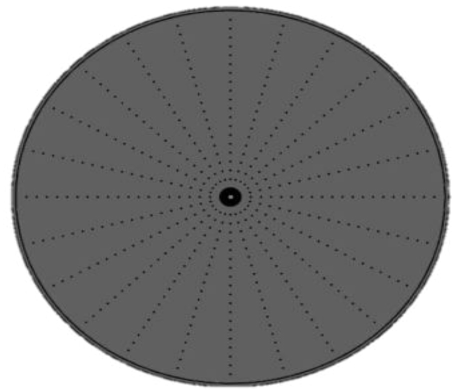
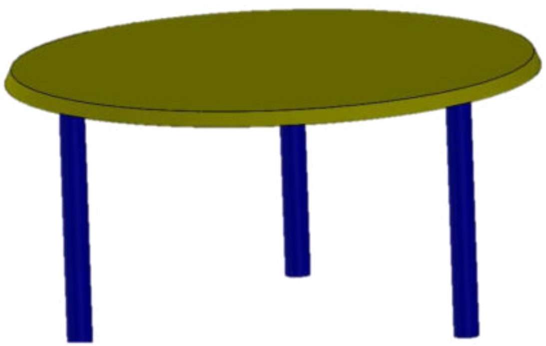


Figure 69b: bottom lcontainer

Additional Parts

- **PERFORATION DISC**
- **FILTER MEDIA**
- **BODY STAND**
- **BODY LID**
- **TAP.**





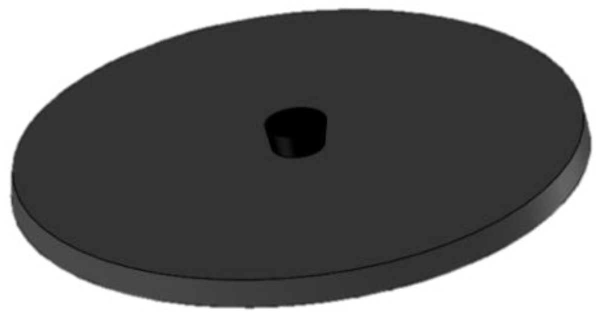
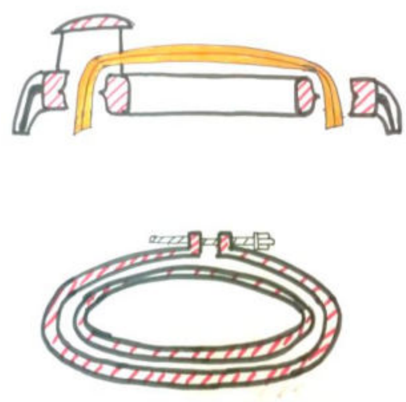


Figure 70: other parts

Design For The Filter Media

A design solution was suggested where there would be a **inner cylindrical ring** of height 50mm and the two layers of filter would be attached at top and bottom with outer ring with hoop.

The design was **improved** where there would be **outer cylindrical ring** and two inner ring with hoops at top and bottom. This was done due to possibility of **water clogging** in the filter medium.



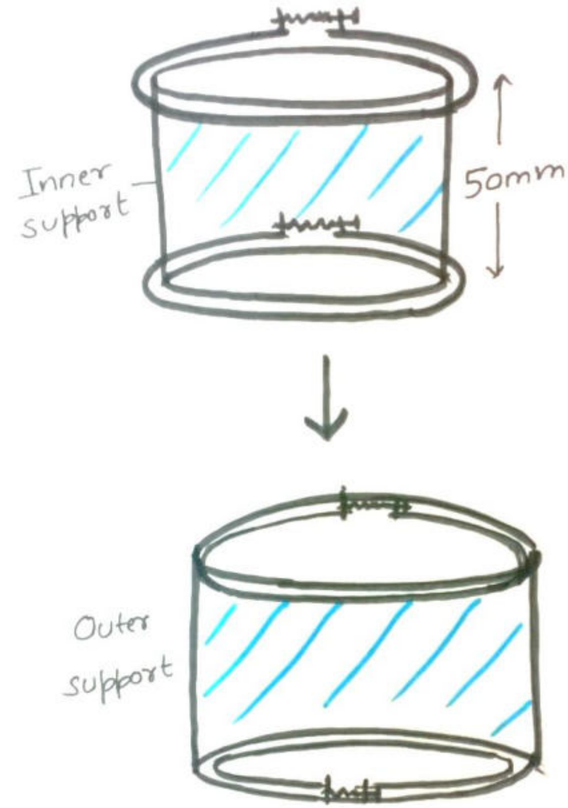


Figure 71: development of filtration ring from embroidery ring concept

Choosing Filter Medium

Among various options, **Polyester Filter Fabric** was chosen as the filter medium because of the following advantages-

- **High performance resistance** against most organic acids except high concentrations of nitric, sulfuric and carbolic acids;
- **High tensile strength**;
- **Elongation**: 20% - 50%;
- **High operating temperature**: up to 302°F;
- **Excellent abrasive resistance**;
- Good resistance to weak most oxidizing agents;
- Good filter cake release;
- **Long life span.**

Two layers of **20micron** and **5micron** each of polyester filter fabric would be deployed in the filter media.

Figure 72: polyester micro filter fabric

Prototyping

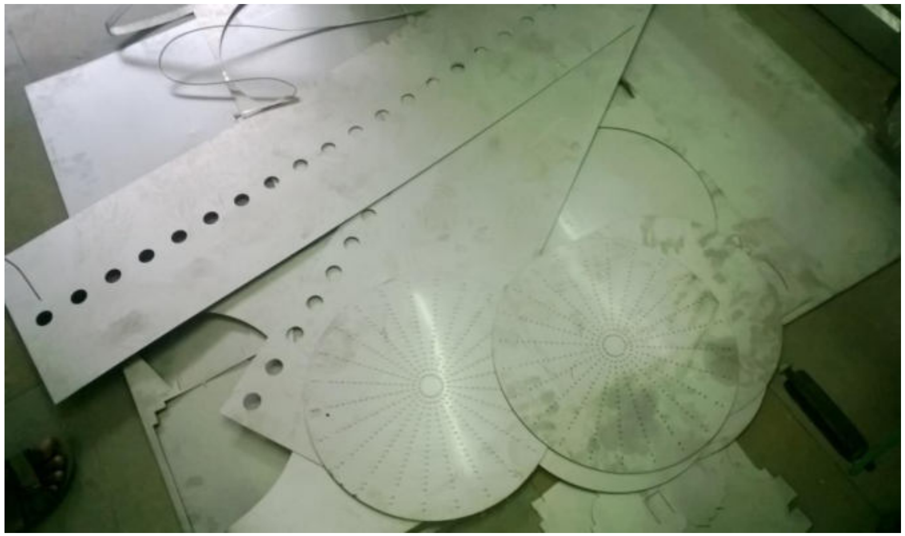


Figure 73: prototyping

Prototype pictures

Figure 74: Finished prototype

Final design details

Following details were added to the model-
1. **Inward beading** in upper chamber to provide support to the perforation disc and in lower chamber to support the filter medium.
2. **Tapering** the bottom of upper chamber to facilitate gravitational fitting on the lower chamber.
3. A **step** was provided at the bottom of lower chamber to provide base.
4. **Outward beading** on upper and bottom section of both chambers to provide strength to the structure. This is because the **plastic deformation of stainless steel results in work hardening** and the structure becomes more resistant to breaking.
5. A **knob** on perforation disc to provide handling.

Figure 75: Filter view

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