Passive Chlorination of Drinking Water at Handpumps in Kenya & India:

Overall Insights

Team 8

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Introduction

In 2015, the United Nations set the Sustainable Goal 6.1 - safe and affordable drinking water for all…by **2030**.

We are **not on track** to meet this goal. Over **2 billion** people lack access to safe drinking water at home.

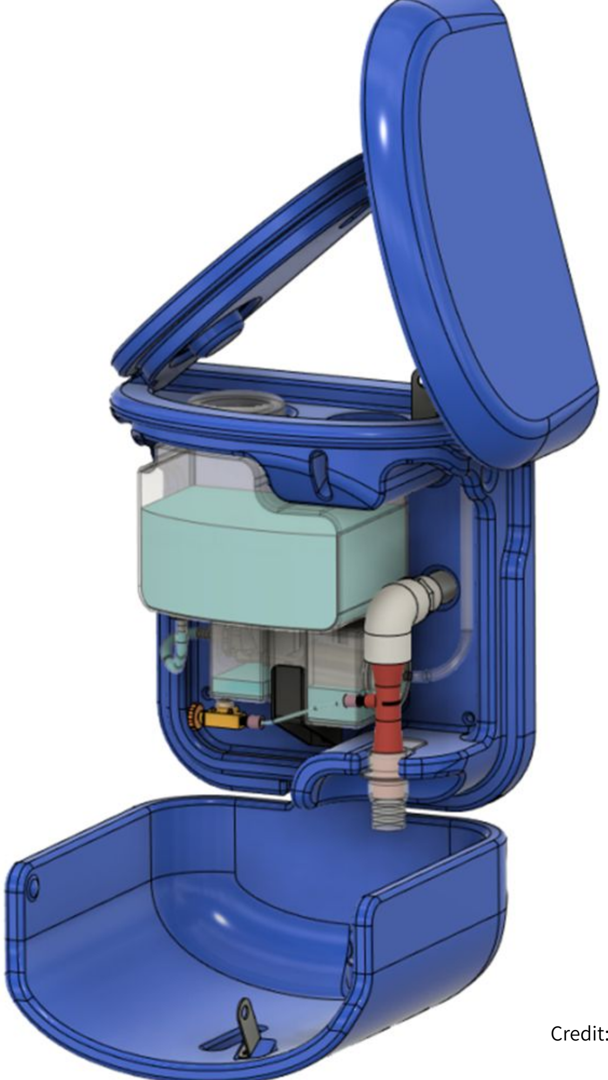
Passive chlorination technologies can help bridge this gap. The devices add chlorine to disinfect drinking water "passively", meaning active user input is not required on a daily basis.

https://pfd.org/tag/wash/

The Pickering Lab at UC Berkeley has been developing and studying the **Venturi passive chlorination device** for almost 10 years.

This device requires **liquid chlorine** (e.g., common household bleach) and does not use electricity or moving parts.

Originally created for receiving constant flow rates from pipes, the Pickering Lab wants to now adapt the device for use at **handpumps**.



Credit: Pickering Lab

MOU Goals

How can the existing Venturi passive chlorination technology be adapted for use at handpumps?

- What types of handpumps are most commonly used in Kenya and India?
  Goal #1
- What is the estimated population of handpump users in Kenya and India?
  Goal #2
- What types of handpump-compatible passive chlorinators already exist?
  Goal #3
- What are the primary water quality concerns at handpumps reported in Kenya and India?
  Goal #4
- How can we modify the Venturi or handpump interface to address issues related to inaccurate chlorine dosing at low flow rates?
  Stretch Goal

Types of Handpumps

Goal #1

https://www.unicef.org/india/stories/history-unicef-work-water-sanitation-and-hygiene-india

Types of Handpumps

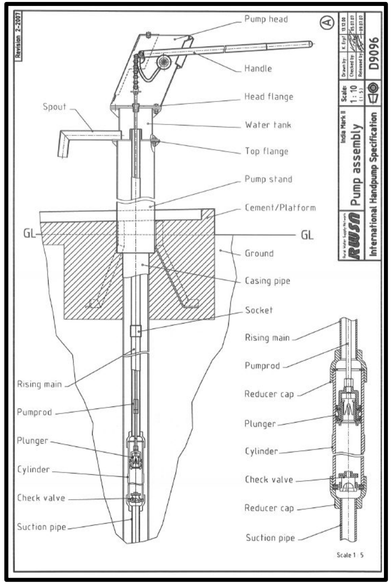
Big Key Players

Modifications of Big Players

Niche Players

Improvements (Or Not)

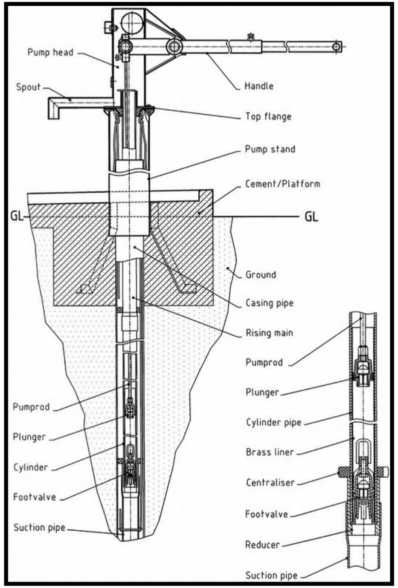
Two Titans:
India Mark II and Afridev



https://www.rural-water-supply.net/en/implementation/public-domain-handpumps/india-mark-ii

India Mark II

- Dominant in India (most famous in world)
- Costs $850-$1600
- Heavy-duty use for communities of 300 people
- Disadvantages: corrosion, special installation requirement



https://www.rural-water-supply.net/en/implementation/public-domain-handpumps/afridev

Afridev

- Dominant in Kenya
- Costs $1400-$1700
- Heavy-duty use for communities of 300 people
- Disadvantages: degradable parts, borehole installation requirement

Mark II and Afridev Have Received Multiple Iterations

1 **India Mark II: Extra Deep-Well Pump**

Increased lift to 80m

2 **India Mark III**

Open-Top Cylinder for Easier Maintenance

3 **Modified India Mark III**

Increased lift, decreased diameter size

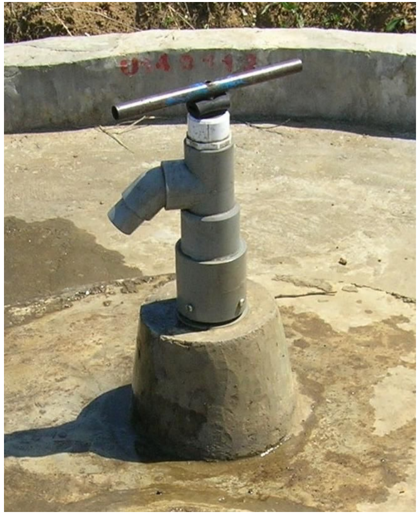
1 **Afridev with Bottom Support**

Increased lift to 80m

2 **Indus, Kabul, & Pamir Pumps**

Specific to Afghanistan & Pakistan

Niches Have Evolved in the Handpump Marketplace



Canzee Pump

- Used in Kenya
- Meant for family use (100 people)
- Pumps from 10m down
- Costs $100-$200

https://www.rural-water-supply.net/en/sustainable-groundwater-management/handpump-technologies

Tara Pump

- Used in India
- Meant for small-scale use (20-100 people)
- Pumps from 15m down
- Costs $100

https://unicphscat.blob.core.windows.net/images-prd/s0005822.png

Non-Profits (So Far) Can't Beat Governments at Handpumps

The non-profit Dutch organization FairWater Foundation created the BluePump to combat the prevalence of non-functional handpumps.

6%
Non-functional handpumps in India

24%
Non-functional handpumps in Kenya

The BluePump breaks down 50-70% less per year than the Mark II and Afridev, but suffers from heaviness, high upfront cost, and specialized maintenance that has 2-3x longer downtime.

https://supplycentre.oxfam.org.uk/product/pump-hand-for-water/

Estimated Population of Handpump Users

Goal #2

https://www.hindustantimes.com/mumbai-news/a-summer-scare-one-hand-pump-and-5-000-people-in-maharashtra-s-ghanichamata/story-cBhxgJVj54gasXIyJItgGK.html

Kenya

The Big Picture

- Groundwater is one of the primary water sources in rural Kenya.
- Untreated water is used directly from the well.
- Afridev is the dominant handpump in Kenya, which serves communities of up to 300 residents.

Impacted population

- Women and children are the primary beneficiaries of this proposed work.
- Populations which historically have lacked access to adequate water and sanitation will also benefit.
- The project will start from four counties in Kenya, which cover most of the rural communities & more than 2 million residents

54%

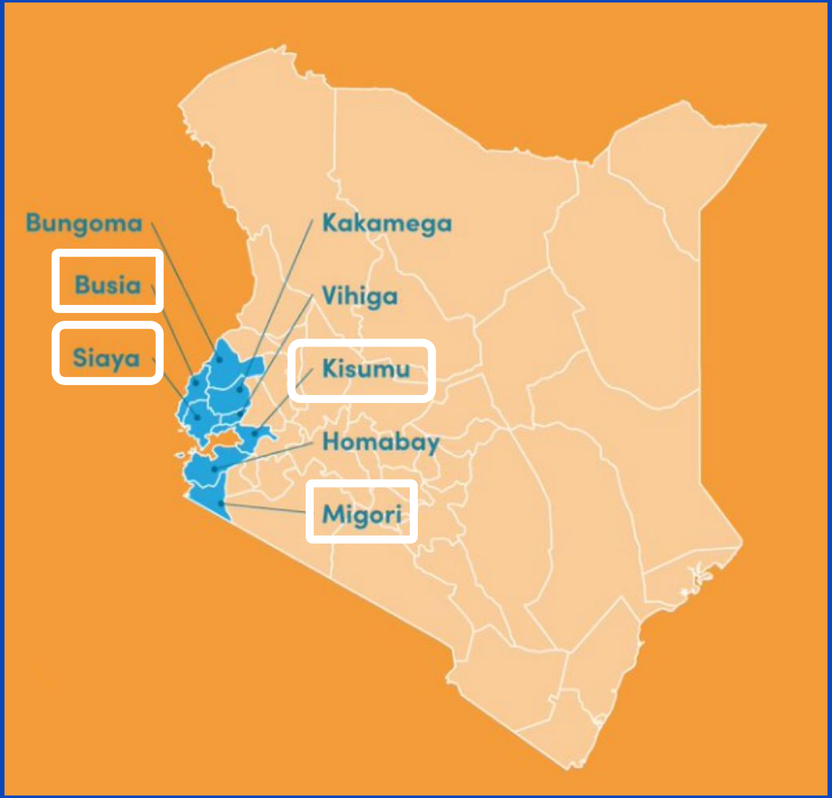
Population use untreated well water across Eastern and Southern Africa.

19400

Handpumps currently implemented in Kenya

2 million

Will receive water treatment opportunities



India

The Big Picture

- Rural India is densely populated, while the amount of handpumps is not adequate. 443.5 million people get water from handpump in rural India.
- India Mark II is the dominant handpump in India, which serves communities of up to 300 residents.

Impacted population

- Women and children are the primary beneficiaries of this proposed work.
- Ensure each village/community has available handpumps that will be enough to support their daily needs.
- **2.2 million** handpumps unevenly installed in India.

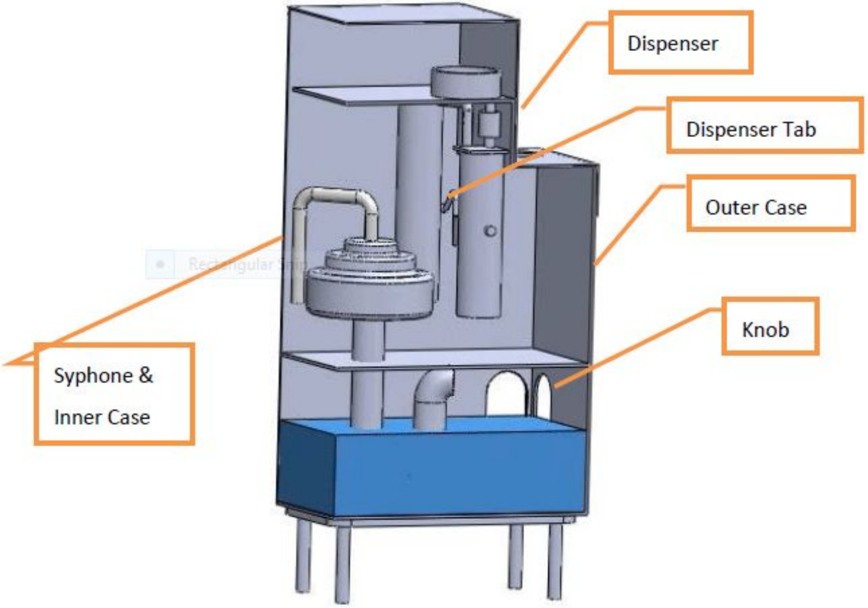
- Less than 25km from Nashik city, India, more than 5000 residents waiting for 1 handpump.
- Waiting time longer than 4 hours each day.

Existing Passive Chlorinators

Goal #3

https://pbs.twimg.com/media/CklJX
tyWEAEF3-p.jpg:large

Zimba



https://www.engineeringforchange.org/solutions/product/zimba-automatic-chlorine-dispenser/

https://www.researchgate.net/figure/Zimba-Automated-batch-chlorination-System_fig4_293328752

Zimba (Batch Chlorinator)

- Doses 0.3 mL NaOCl per L H2O
- Requires chamber to be filled prior to dosing
- Produced in India, used in Bangladesh, Ethiopia, Zambia, Dominican Republic

$230
Retail price of one unit

8,000L
Water disinfected by one refill

26 lbs
Weight of one unit

1.5 mil
Potential child deaths avoided 2015-2030

Zimba

Benefits	Costs
Compatibility with handpumps	Complicated to refill/maintain
High water-to-bleach ratio	Obtrusive due to weight and size
Guaranteed accurate dosing	Costly
No electricity needed	Longer wait time due to increased pumping

Aquatabs

Aquatabs Tablets

Aquatabs Flo

Aquatabs InLine

All images credited to aquatabs.com

Aquatabs (Passive chlorination tablets)

- Aquatabs doses HOCl into a body of water, killing bacteria
- Aquatabs Flo automatically doses at a pipe outlet
- Aquatabs Inline doses at higher pressure outlets

1 billion
Aquatabs sold yearly

$58-$66
Total cost of unit (Flo vs In-line)

14
Countries using or in trial phase

#1
Global purification tablet

Aquatabs

Benefits

Simple to use, no moving parts

Proven effectiveness at killing waterborne parasites

Relatively low cost compared to other solutions

Versatile

Costs

Not as widely available for refills as chlorine bleach

Voluntary usage left vulnerable to user error

Wait time required for tablet dosing

Currently incompatible with handpumps but Aquatabs claims compatibility in near future

Takeaways

1

In order to overcome adoption hurdles, device must be cheap, easy to use, and cannot impact traditional routines.

2

A means to dose proprietary bleach through a hand pump would have an enormous use case worldwide

3

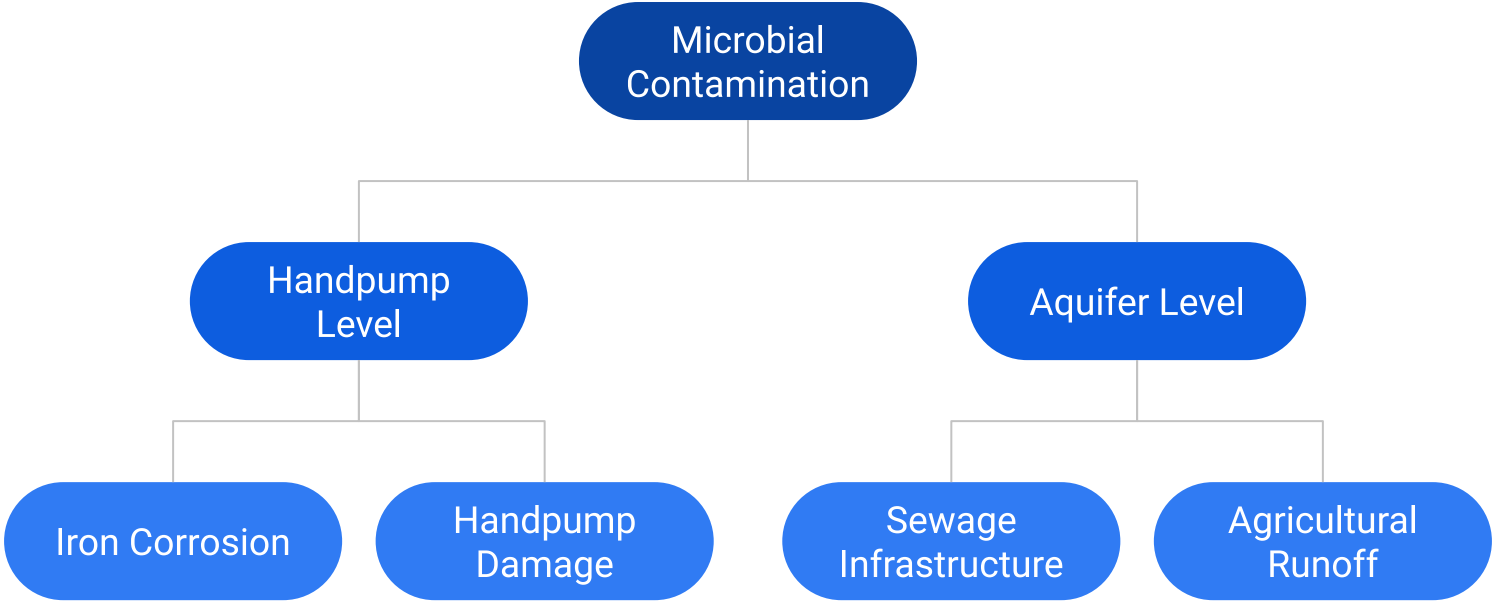
Future possibilities of solar-powered functionality

Water Quality Concerns

Goal #4

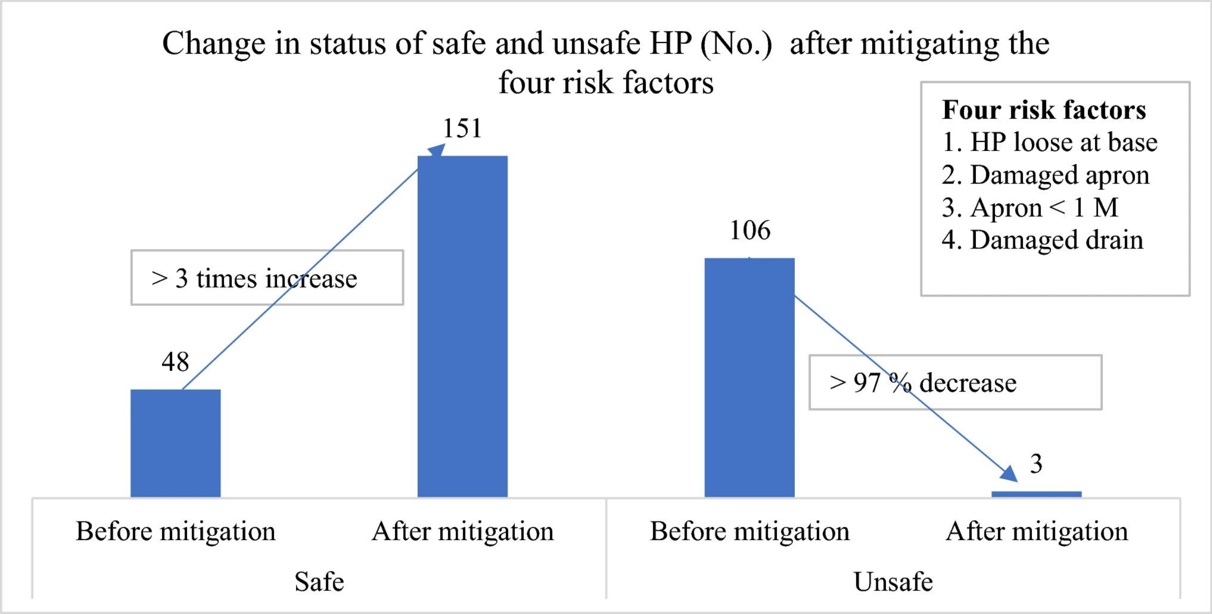
https://wbaconsulting.com/2016/06/irrigation-water-quality/

4. Water Quality Concerns at Handpumps



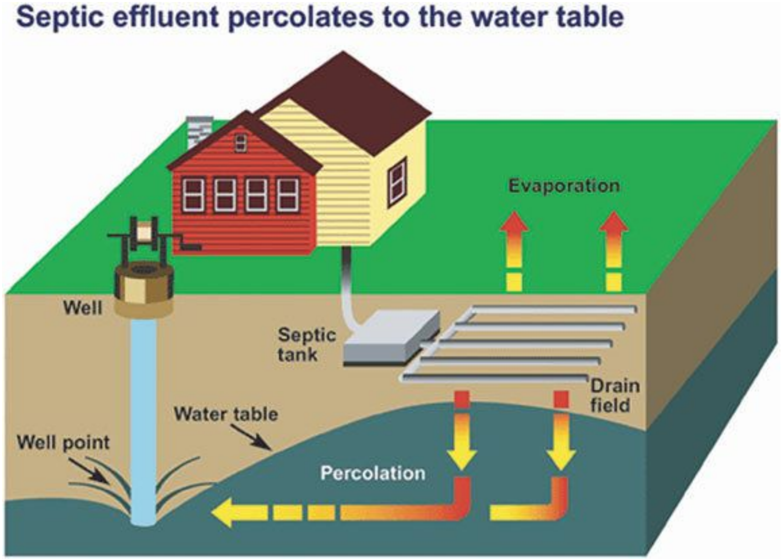
Corrosion in handpumps increases chances of iron contamination

Broken handpumps contribute to higher microbial contamination rates

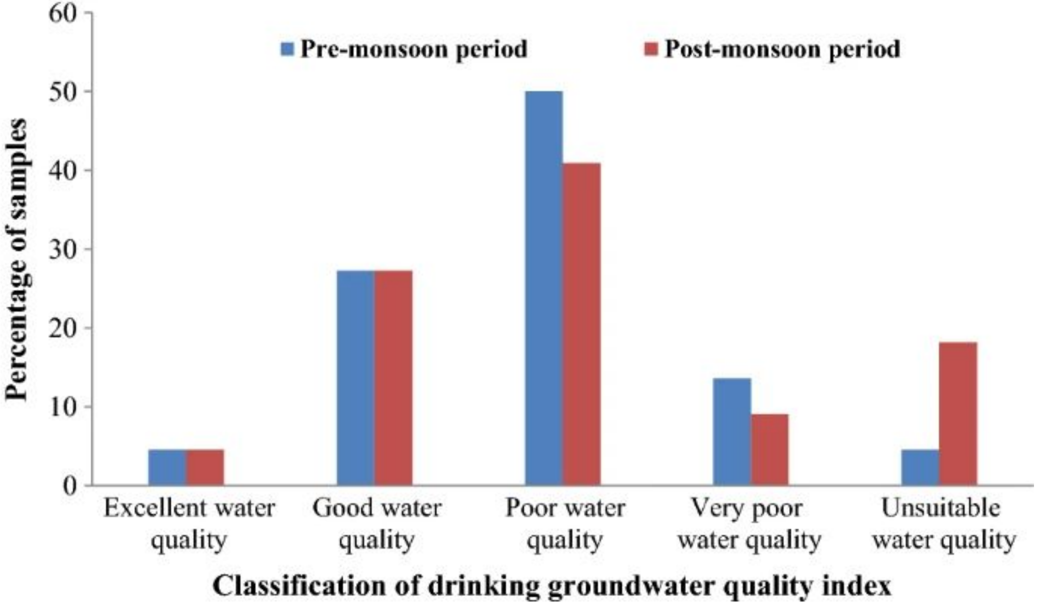


Singh, N. et al. *Management of Risk Factors for Breaking Localised Pathways of Microbial Contamination in Tubewells with Handpump: A Case study from India*. July 2021.

Handpumps are susceptible to leaking sewage systems



Agricultural runoff is seasonal and typically unmitigated

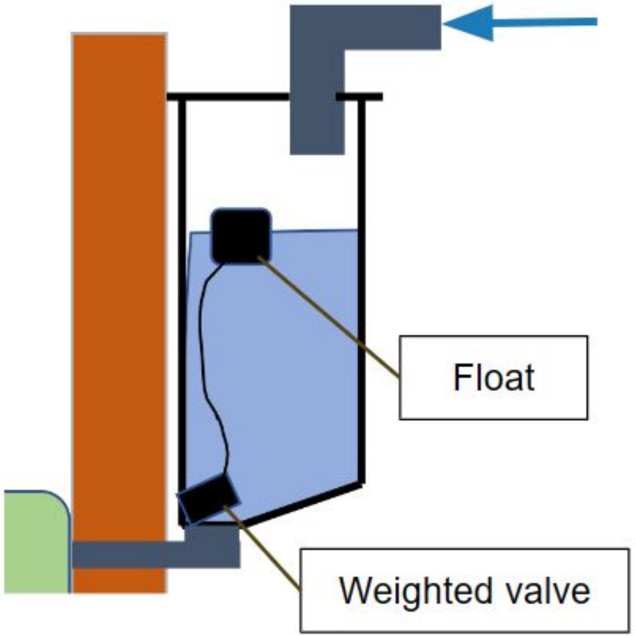


Subba Rao, N. et al. *Seasonal and Spatial Variation of Groundwater Quality Vulnerable Zones in Telangana, India*. Nov. 2020.

There is potential to improve handpump human-factors

Modifying the Venturi/Handpump Interface

Stretch Goal

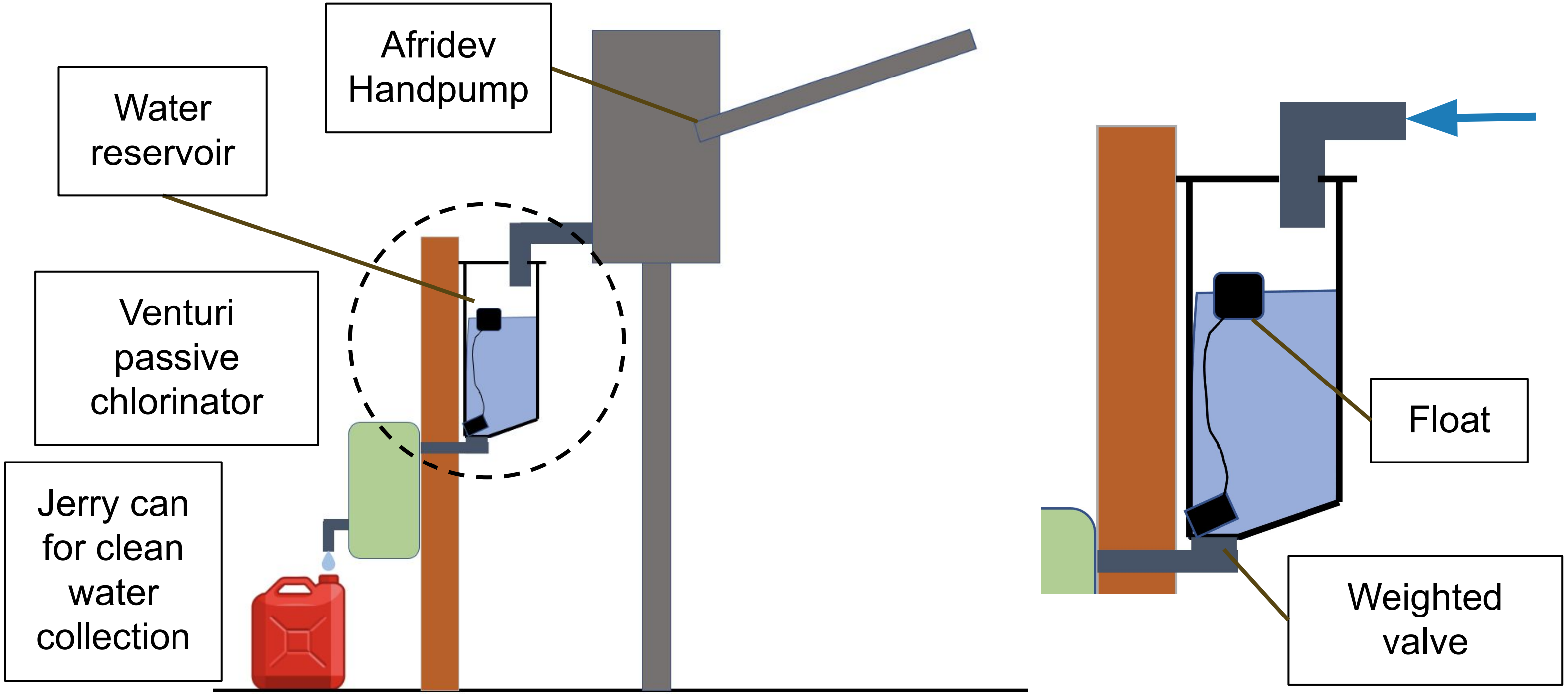


A Recap of our Stretch Goal: Handpump to Venturi

Key Considerations

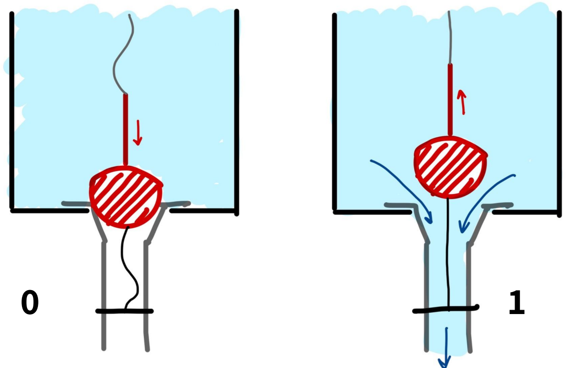
- Low - cost
- Low-maintenance
- No drastic change to UX
- Compatible with prevalent handpump models - Afridev & India Mark II

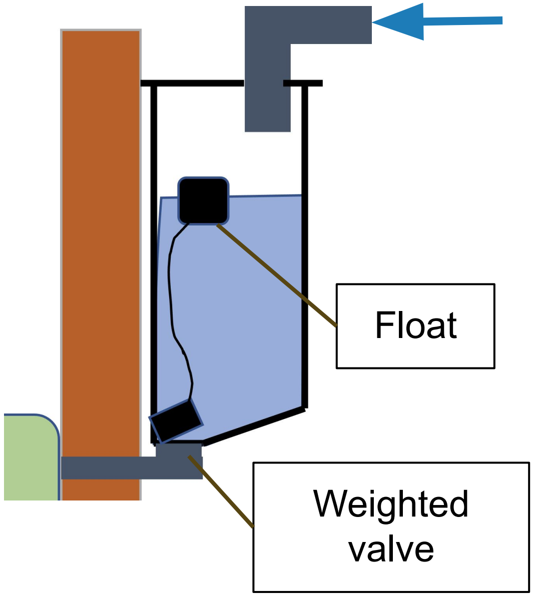
Our Prototype Idea: Float Tank



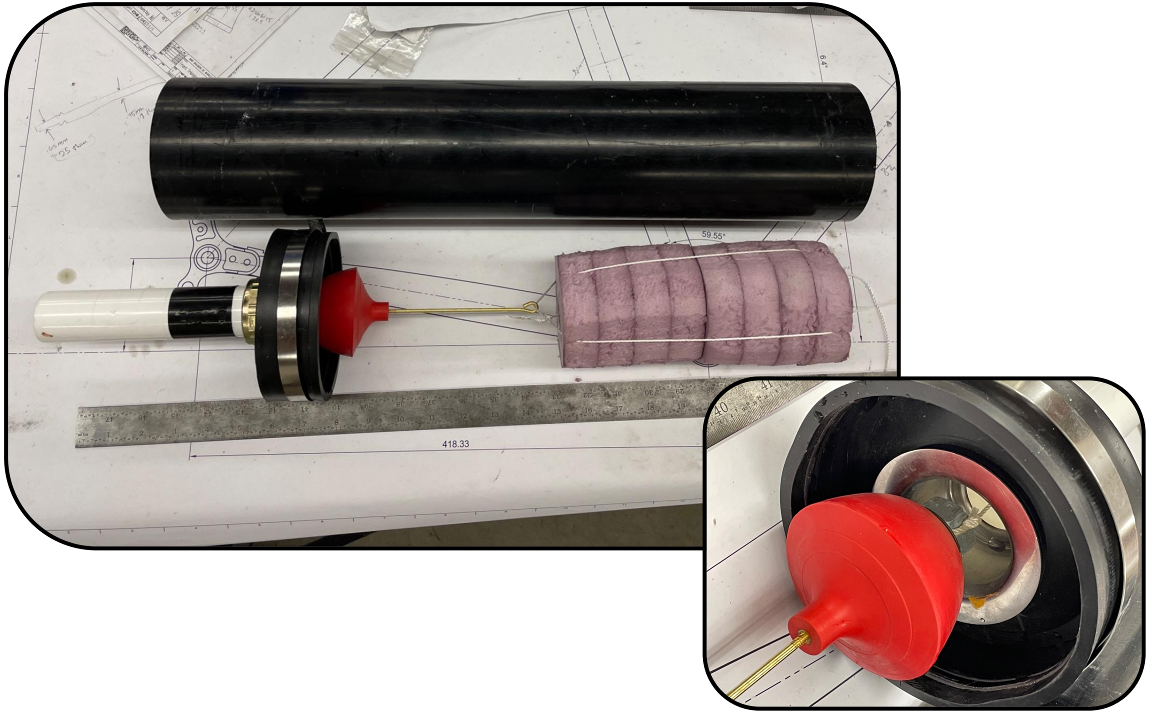
Why add a reservoir?

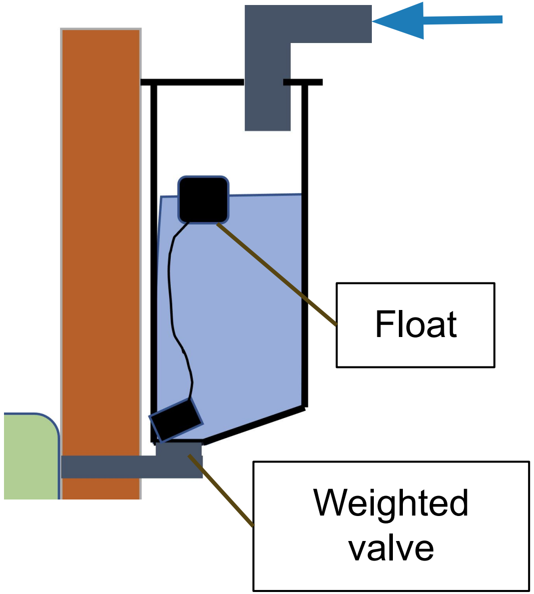
- Smooth inconsistent pressure & flow rate out of pump
- Float valve can be calibrated to required static head
- Consistent flow rate into Venturi chlorinator - >4L/min



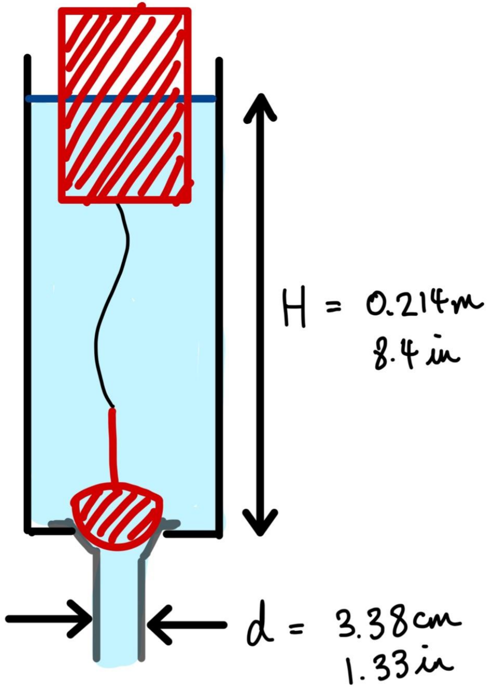


Our prototype: Components



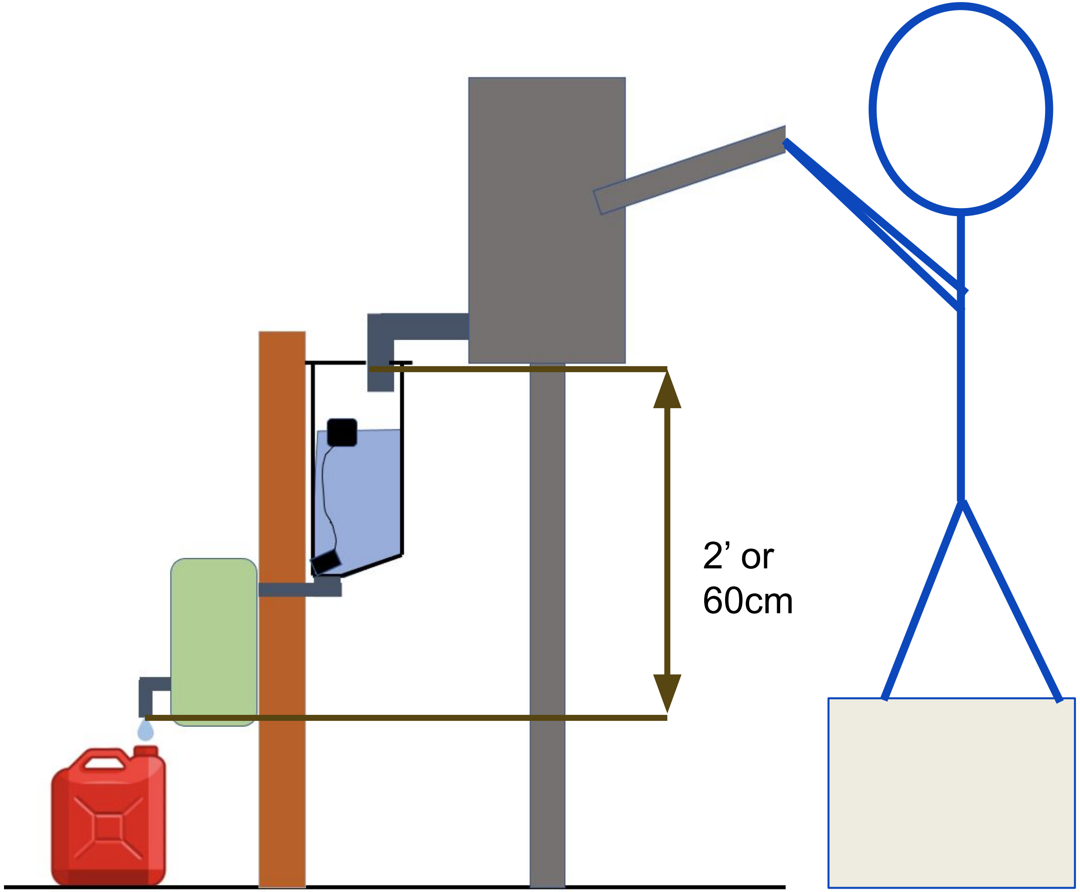


Quantifying our Prototype

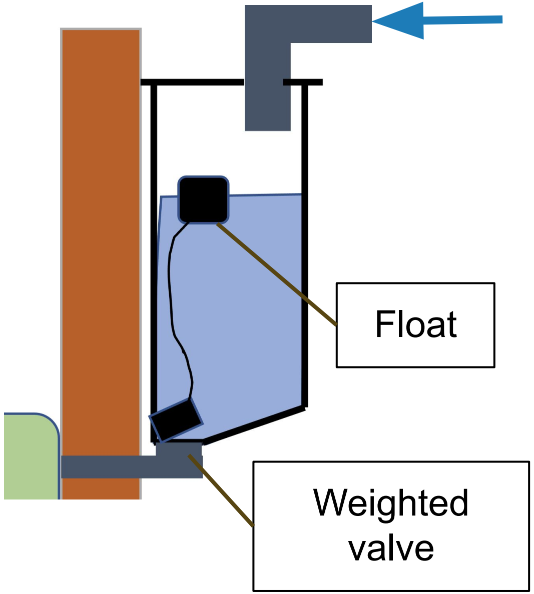


- Static head above opening: 21.4cm or 8.4”
- Pressure at opening: 2 kPa or 0.3 Psi (100x lower than municipal water)
- Volume of reservoir before discharge: 1.7L
- Approximate discharge of 6-10L/min

Physical Considerations: Added height

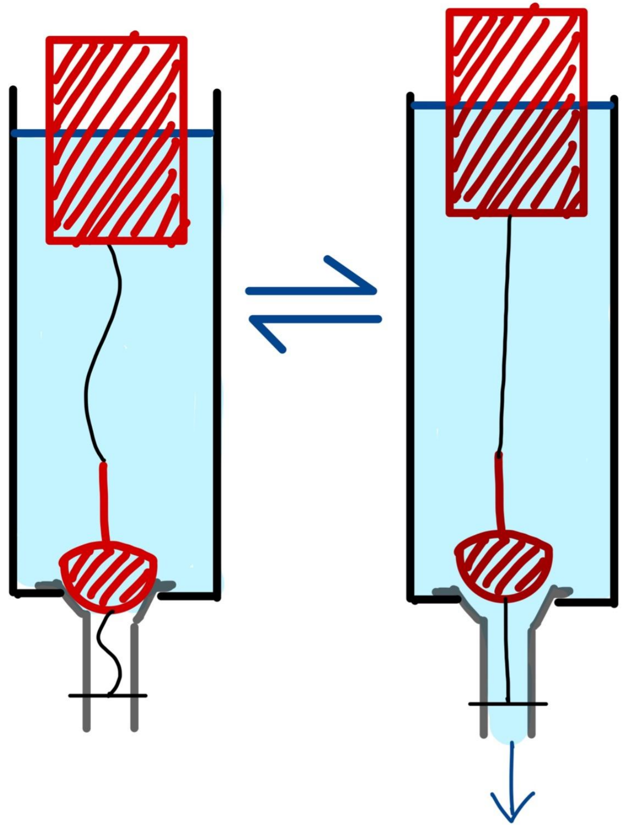


Testing Our Prototype



Video link: https://drive.google.com/file/d/1VMxnm_7XB6lLo9m4Qlwfv7sCdAgJgkWB/view?usp=share_link

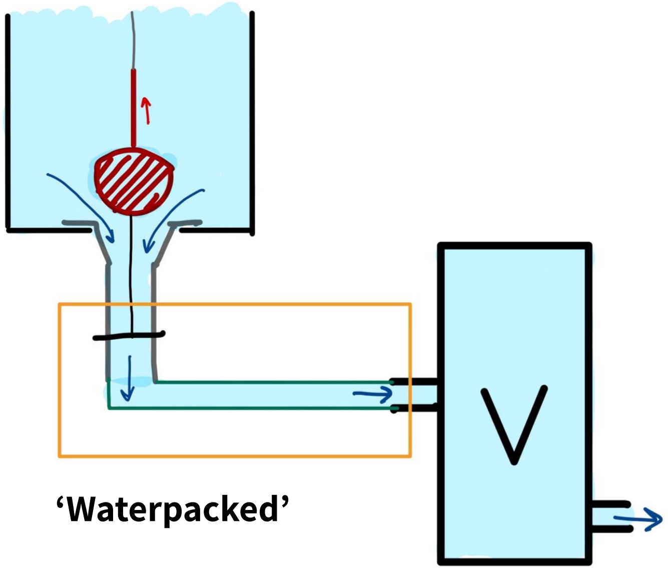
Physical Considerations: Output flow regime

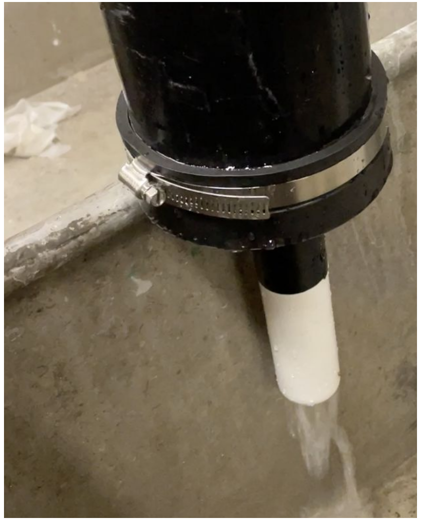


Physical Considerations: Output flow regime

Video link: https://drive.google.com/file/d/1aXuk1c5jTBIn48a-1k6glDFdn-YZI2Q_/view?usp=sharing

Next steps: Connection to Venturi

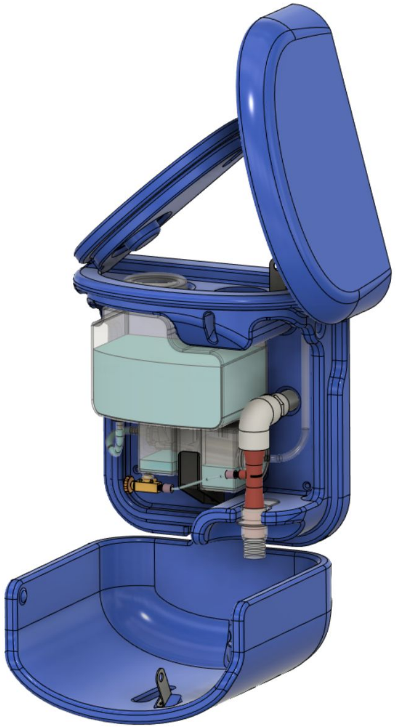




- Understand back-pressure & other hydrostatic implications
- Restrict reservoir exit diameter to match Venturi inlet (¾")

Future Considerations

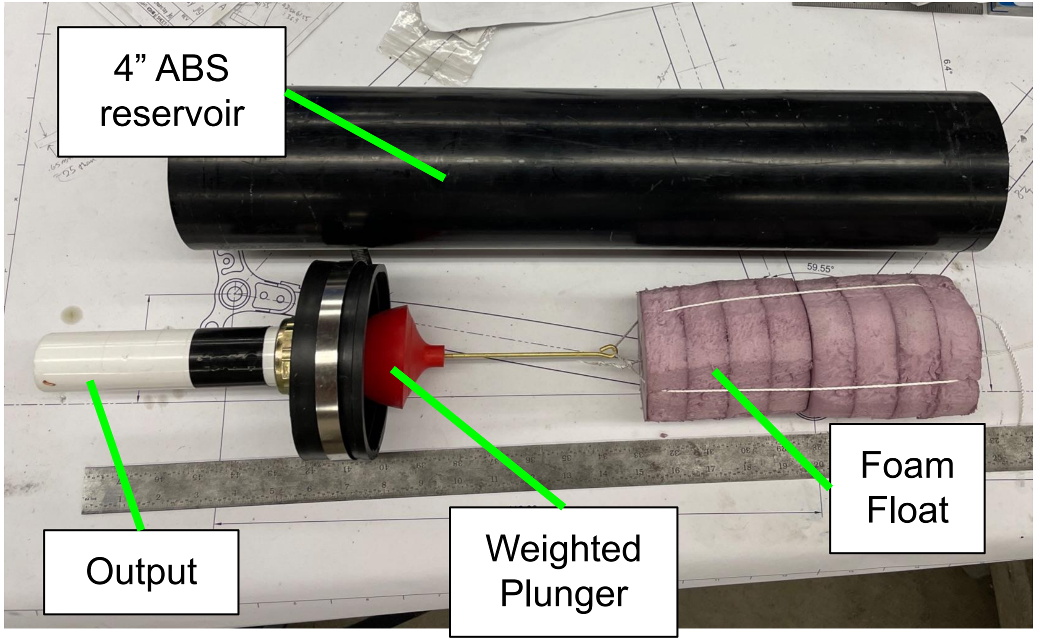
- Further prototyping with safe materials
- Longevity in adverse conditions
- Maintenance and Installation responsibility
- Value engineering
- Future tech - small scale solar

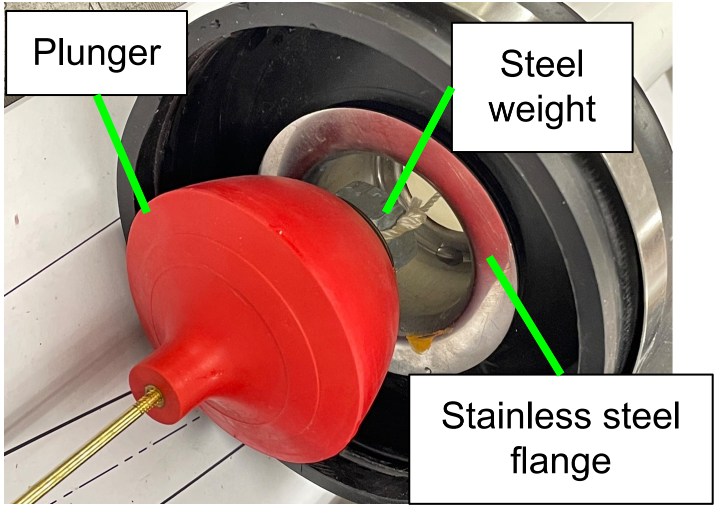


Thank you! Any questions?

Citations

- Goal 6: Clean water and sanitation - The Global Goals
- Passive In-Line Chlorination for Drinking Water Disinfection: A Critical Review | Environmental Science & Technology (acs.org)
- Design, performance, and demand for a novel in-line chlorine doser to increase safe water access | npj Clean Water (nature.com)
- https://www.rural-water-supply.net/en/implementation/public-domain-handpumps/india-mark-ii
- https://www.rural-water-supply.net/en/implementation/public-domain-handpumps/afridev
- https://www.researchgate.net/publication/311592514_An_Evaluation_of_the_BluePump_in_Kenya_and_The_Gambia
- https://www.pseau.org/outils/ouvrages/rwsn_the_2019_rwsn_directory_of_rural_water_supply_services_tariffs_management_models_and_lifecycle_costs_2019.pdf
- https://rural-water-supply.net/en/implementation/proprietary-handpumps/canzee-pump
- https://www.rural-water-supply.net/_ressources/documents/default/307.pdf


4” ABS reservoir
Output
Weighted Plunger
Foam Float


Plunger
Steel weight
Stainless steel flange