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Turning challenges into opportunities with "MatiKalp": A Ceramic Pot Filter

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Abstract
In many developing countries, access to safe drinking water is limited. Contaminated water, poor hygiene,and sanitation practices are the reasons behind the increase in the spread/rate of waterborne diseases, especially among children,burdening the economy. Bihar is the Indian state that faces the most challenges when it comes to the quality of water, despite being rich in water availability. MatiKalp, a ceramic pot filter (CPF) is a technology at the household level that not only addresses the most prominent issues in drinking water in the area (iron, TDS, and microbial contamination), but also revives the diminishing craft, skill, and livelihood of struggling potter families. CPF treats water and stores the treated water safely to eliminate the risk of recontamination. This paper highlights the production technology at the cottage scale, quality control, effectiveness, and community response; and its outcome in terms of the household economy,particularly resulting in an increase in health.

Keywords: *waterborne diseases, MatiKalp, ceramic pot filter, health, potter. livelihood*

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I. Introduction

Water security and water safety are serious challenges faced bylow and middle-income countries. With an increasing population and urbanization, thewater demandis increasing, while the availability of water is decreasing. Further, the depletion of groundwater is causinga lack of access to safe drinking water, which isresultingin an increased incidence of waterborne diseases:a problem for many. According to the latest report by UNICEF and World Health Organization (WHO) 2022, 2.2 billion people lack access to safely managed drinking water, and 3.6 billion people lack safely managed sanitation services. Contaminated water and poor sanitation are linked to the transmission of waterborne diseases, particularly 1.3 billion cases of diarrhea in children occur every year (UNICEF and WHO, 2022). In 2015, the World Health Organization reported that improving the access to safe drinking water and sanitation could prevent nearly 4% of the global disease burden (Kumar, et al., 2022).

In India, economic growth is greatly impacted by the high disease burden of waterborne diseases (Pathak, 2015). The rate of these waterborne diseases increases abruptly during summer and rainy seasons due to mishandling and management of water, particularly for drinking purposes and sanitation (Chabba, 2013 and Oguntoke, et al., 2009); 37.7 million people are under the prevalence of waterborne diseases and 1.5 million children's death are reported due to diarrhea (UNICEF, 2019). The National Family Health Survey from 2016 to 2022 reports that the prevalence of childhood diarrhea increased from 9% to 9.2% (Ghosh, et al., 2021).

Bihar is one of the poorest states in India and faces tremendous challenges in ensuring access to safe drinking water. Bihar's groundwater is the pivotal source of water for fulfilling the needs of the domestic, industrial, and agricultural sectors. The state is blessed with abundant surface and groundwater resources and also receives an annual rainfall of 1,027 mm in a normal monsoon season. Recurrent floods are a serious problem in Bihar thataffects a quarter of the population (Mishra, 2009). The occurrence of floods results in high fecal contamination in the shallow groundwater, which increases the incidents of waterborne diseases such as diarrhea, dysentery, and typhoid fever. The state suffers from more than ten thousand cases of diarrheal disease in children less than age five (Sushma, 2020). The presence of chemical contamination in groundwater also poses a serious health impact.

In 2019, World Health Organization stated that Household Water Treatment and Safe Storage (HWTS), when used correctly and consistently, can reduce diarrheal diseases efficiently by 61%. HWTS systems are being developed and promoted to create barriers in order to make water safe for drinking. The main objective of HWTS interventions is to ensure safe drinking water at the household level to reduce the burden of waterborne diseases. When the drinking water source is distant, unprotected, or not reliable; HWTS holds an edge over community-based treatments. HWTS has proven to be a boon in case of emergencies like flooding, earthquake, and conflicts, and has been widely recommended in the outbreak of diseases such as cholera (Doocy and Burhnam, 2006 and Lantagne, and Clasen, 2012).

HWTS technologies include sedimentation, filtration (such as biosandfilter, ceramic pot filter, candle filter, or membrane filter), and disinfection (such as boiling, chlorine, SODIS, or UV) (CAWST manual, 2008 and Xiao, et al., 2020). Access to safe drinking water at the point of use can also be enhanced by using two or more treatment steps (Agrawal and Bhalwar,2009). Several studies have assessed that, depending on the method, treatment at the household level can remove, kill, or inactive microbiological pathogens (Sobsey, 2002).

For treating water at the household level, various methods have been developed and implemented in developing countries to provide safe drinking water (Craver and Smith, 2008). Ceramic pot filter (CPFs) is one such technology that is simple and affordable, and has been used over the years mostly in rural parts of developing countries to make water safe for drinking (Plappally and Lienhard, 2018). CPFs showed great potential in drinking water treatment in rural areas due to their low operating and maintenance cost (Murindababisha, et al., 2018). Various studies on CPFs showed the effective reduction of protozoan >99% (Lantagne, 2009; van Halem, 2006) and 90–99.99% of bacterial organisms from drinking water (Brown &Sobsey, 2006; Brown, et al., 2008; Johnson, et al., 2008). Hunter (2009) studies show that CPFs are proven to be most effective and serve long-term over other household water treatment technologies. The majority of studies have proven the performance of ceramic filters to be effective in reducing microbiological and fecal contamination (Clasen, et al., 2007b).

CPFs can be produced locally or industrially, using local materials, skills, and labor. In addition, CPFs are suitable and accepted socially and culturally as well. Theeasy-to-use and affordable technology integrate safe storage in a single unit at the point of use to eliminate the risk of secondary infection to provide safe drinking water (Rayner, 2009).

In India, pottery is a skilled art, prevalent in a majority of villages. These skills have beenpassed on for generations. With the changing lifestyle and increased mechanization, clay pot production by potters has been taken over by the organized sector. As a result, local artisans have lost their livelihood, diminishing the art of pottery. In villages where drinking water quality is a challenge, the production of CPFs can turn the challenges at hand into opportunities by providing safe drinking water as well as reinstating livelihood for potters.

Potters hold knowledge of locally available raw materials and their processing to produce ceramic products, and traditionally open furnace firing practicesare followed in the making of a pot (Gupta, et al., 2018). Little scientific support can capacitate them for the production of ceramic pot filters.

II. Materials and Methodology

Study area: The case study took place in the Desari block of Vaishali district in the Bihar state of India. Desari village has a geographical area of 304 hectares and a population of 11,184 (Census, 2011). The district falls under the Burhi Gandak sub basin, a part of the Ganga River basin. The district receives about 85% of total rainfall from the southwest monsoon, with an annual rainfall of 1,168 mm. The district is surrounded by surface water and thereby has ample groundwater as well as surface water. As the district is bound by two major rivers, flooding is a major problem in the area (CGWB, 2013). Bihar experienced severe floods in 2019, when almost 20 lakhs hectare of an area covering 34 districts were observed to be affected by floods, and Vaishali district was one of them. The district has patches of the area that receive flood water and are submerged for a longer period.For domestic water supplies, the village population is mostly dependent on groundwater.Villages are predominantly densely populated, and the distance between the water source and the toilet is mostly unsafe,further adding to the cause ofmicrobial contamination in the groundwater.

The objective of the research is to study community response to low-cost water treatment by CPF technology and its impact on health.

- Materials:
  - *Clay*. Clay is the basic material for manufacturing pot filters because it can easily be molded and, when passed through high temperature, the clay changes its structure and properties to become hard enough to hold the water and not deteriorate.
  - *Combustible material*. It is sometimes known as "burn-out material" that is added with clay to develop porosity. Materials like sawdust, rice husk, or other agricultural by-products are preferred.
  - *Sand*. A small amount of sand is added to the clay to improve the workability of the mix and the porosity of the filter. However, high sand content can cause filters to break.
  - *Colloidal silver*. Silver is known as an antimicrobial that has been used to kill bacteria, fungi, and viruses. Colloidal silver, a suspension of nanoparticles, acts as a disinfectantto enhance microbial disinfection.
- Manufacturing process:

o *Mixing*: The clay used in the production of ceramic pot filters is procured locally, milled, and sieved to remove impurities such as calcified nodules and organic material. The combustible materials are processed to the 0.6 mm graded size and added to the clay in 55:45 ratios in a dry state to make a homogenous mixture. Clay, combustible material, and sand are mixed uniformly by hand in dry conditions. Water is added gradually and kneaded to make the moldable paste.

o *Pressing*: Place the kneaded paste in the manual hydraulic press molding machine, Use LDPE bags for easy release of the molded filter from the mold. Apply the mechanical pressure through the screw jack and hydraulic pressure subsequently forms the kneaded mix into a filter shape. Release the pressure and remove the filter mold from the press. The molded filter is taken out from the mold,using a releasing mechanism. The collar of the filter is repaired and shaped in green conditions, and the sides of the filter are scraped to remove fine clay particles on the surface.

o *Drying*:To avoid any cracks or deformation, place the green filter body first in shade for seven days to ensure uniform and slow drying. Afterward, the filters are sun-driedfor a minimum of seven days for complete drying.

o *Firing*: The dried filters are placed in the kilnfor the firing process and exposed to the high temperature of the kiln; the burn-out material gets gasified and escapes from the body, leaving behind pores in the filter. Make sure that the filters are completely dried before firing. If the filters are not completely dried, there is a possibility of cracking or de-shaping of the filter during firing. Temperature probes are used during this process to note the temperature of the kiln.The kiln is slowly fired for three to four hours until the temperature reaches 100º–120ºC to remove any residual moisture in the filter. Thetemperature is then raised fast up to 300ºC by adding more fuel. Between 350ºC and 400ºC, the volatiles in the burnout material gets vaporized and produce a lot of smoke. During this period, fuel is added very limitedly, as burnout material itself acts as fuel. The temperature is slowly raised from 600ºC to 700ºC, after which the fuel door is closed airtight to retain the heat within the kiln and let it cool down slowly overnight.

o *Quality inspection:* Once the filters are fired and cooled down to room temperature, the filters go through quality inspection which is visible to note audacity, cracks or breakage, and flow rate. First, the filters go through visual inspection followed by an audacity test to determine the incomplete firing or cracks in the filter wall. The filters are then dipped in water upto the brim to observe any water entering in the filter or uneven patches of water by submerging the filter upto the brim for ten seconds. The flow rate test is to determine the filtration rate of the filter. It is important to soak fired and cooled filters to ensure water saturation level before testing for flow rate. Those filters that pass the requirements are sent for further action, and those that do not are destroyed.

o *Silver impregnation*: As mentioned above, silver impregnation is carried out to improve the microbiological effectiveness of the filter. Filters are coated with a colloidal silver solution after going through quality inspection.

These processes should be followed sequentially. The glimpses below represent the manufacturing process of ceramic pot filters:

Mixing dry ingredients

Adding water to dry ingredients

 Kneaded paste	  Filter press
Edge  repair	Fresh green  filter
 Air drying	 Stacked for firing
 Firing process	 Visual inspection

Audacity test

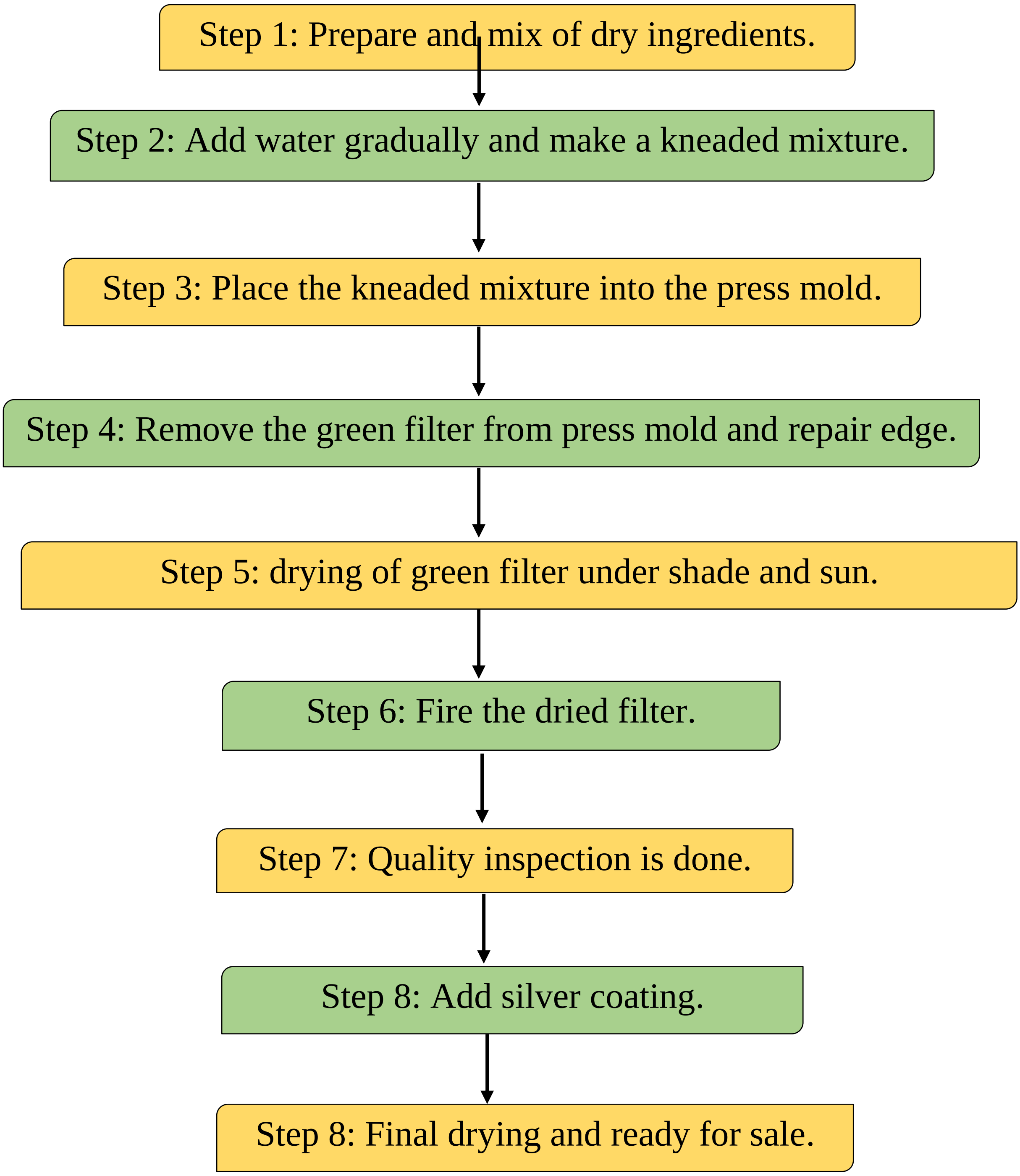
Dip test

Silver impregnation

Wet and dry filter

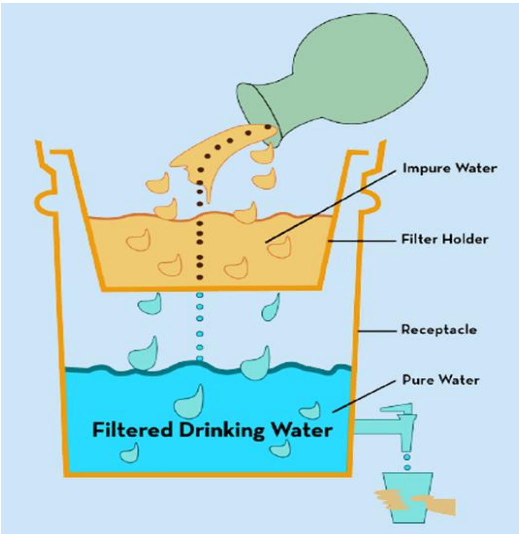
Ready to use

The flow chart below describes the production process for ceramic pot filter.



- <u>Experimental and quality assurance procedure</u>:
  - *Visibility test:* the fired filters are visuallyinspected for cracks or deformation.
  - *Audacity test:* the audacity of the filter is checked by producing a sound resonance test by tapping on it. Depending on the sound it produces, the potter can determine if the filter is underfired and can possibly detect any internal crack.
  - *Cracks and leakage test:* the filters go through a pressure test to check the internal cracks. In this test, the filter element is dipped in water and observed for 10 secondswithout letting water flow into the filter. If the water seeps through the walls of the filter, there is internal cracking, and the filter element needs to be discarded.
  - *Flow rate test:* to perform a flow rate test, it is important to soak the filters in water prior to it. The flow rate test is carried out by filling the filters with water and measuring the amount of water percolating through the filter in an hour.
  - *Iron removal test:* the iron removal efficiency is performed using the Hechcolor meter test.
  - *Total Dissolved Solid (TDS):* TheTDS is measured regularly of raw water and filtered water, using HM digital meter. The carry case of the meter is filled with sample water and the digital meter is dipped into the case. The reading is recorded digitally.
  - *Microbial efficiency:*Presence-absence test (H_2S Vial) is a simple kit test to indicate the microbiological contamination in drinking water. Dry and sterile media are provided in the capped bottles where the sample is poured into the marked level. Incubate the bottle at room temperature for 24–36 hours. After the incubation, the following change may be observed: if there is no change in the color of the water or it turns yellow, that means water is fit for drinking; and if the color of the water turns black after the incubation, it indicates the presence of pathogens and must not be used for drinking.

S M Sehgal Foundationtrained a few potters in order to rebuild their livelihood options by producing ceramic pot filters named "MatiKalp" so that by using the affordable water filter option (MatiKalp), the poor community can have access to safe drinking water at their household. The schematic diagram and real picturesof MatiKalp are represented below:



Raw water is poured into the ceramic pot filter. The water slowly passes down through the fine pores and is collected in the receptacle. When the pot filter is full, flow rate is highest. The treated water is stored in the container until needed and is protected from recontamination. The tap at the receptacle is usually preferred for fetching treated water. The CPFs are capable of removingiron, microbial contamination, and turbidity. CPF also reduces TDS to some extent. The regular use of a filter and the accumulation of contaminants within the filter pores might reduce the flow rate. So the filter should be regularly cleaned with a soft scrub to remove any accumulated material. Byscrubbing, the filter element retains the flow rate by removing the deposited particles from the pores. Any visible cracks or leaks must be checked over time to ensure effectiveness. Iron contamination,pathogens, and suspended particles are removed through processes such asoxidation, mechanical trapping, and adsorption. The size of combustible material used in the mixture is used to ensure that pore size is small enough to prevent organic contaminants from passing directly through the filter body. Colloidal silver acts as an antimicrobial shield, breaking the cell wall of the microbe and ultimately kills, or inactivates microbiological pathogens.

Robustness

- Receptacle container is used to collect filtered water and store it safely.
- There are no moving or mechanical parts to break.
- Care should be taken because small cracks that are not visible to the naked eye can occur due to impact or mishandling, but may allow pathogens to pass through the filter.
- Poor transportation of filters can also cause cracking and/or breakage.
- Plastic taps in the receptacle container can break; metal taps last longer but increase the cost.
- Supply chain and market availability are required for replacement of filters and taps.
- Construction quality control process is required to ensure effectiveness.
- Recontamination is possible during cleaning; care should be taken to use clean water, not to touch the ceramic with dirty hands, and not to place the filter on a dirty surface.

Maintenance

- Filters are cleaned by lightly scrubbing the surface witha soft brush when the flow rate is reduced.
- Soap and chlorine should not be used to clean the filter.
- Receptacle container, tap, and lid should be cleaned on a regular basis.

III. Results and Discussion

- Flow rate: a total of eight MatiKalp filters were evaluated and observed the flow rate. The water percolated through the filter in an hour was observed in the range of 2–3 liters. The average flow rate of ceramic pot filters can be considered around 2.5 liters per hour.
- TDS: Twenty MatiKalp filters were observed for TDS and all the filters were found to reduce the TDS, but the amount of reduction was not consistent. It may be dependent on the ionic composition and needs further investigation.

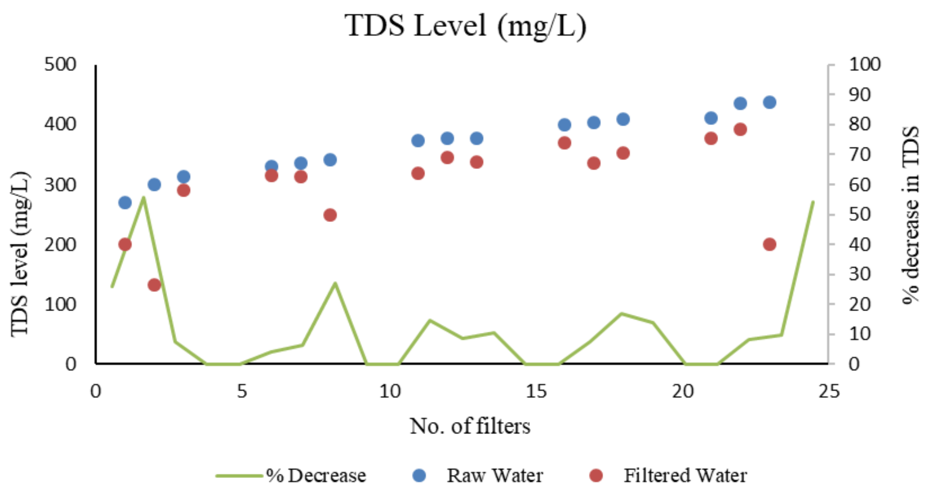


Figure 1: Representation of TDS removal through MatiKalp

● Iron: Twenty MatiKalp filters were validated for iron removal, and it was observed that the highest concentration of iron present in raw water was 5 ppm;and after the treatment, the concentration was lowered down to below the permissible limit, which is 0.3 ppm in drinking water. In the figure below, it is noticeable that one filter shows the iron concentration of filtered watermore than the permissible limit. The filter was further examined and observed that there were certain cracks, and the raw water was leaking through the side of filter wall.

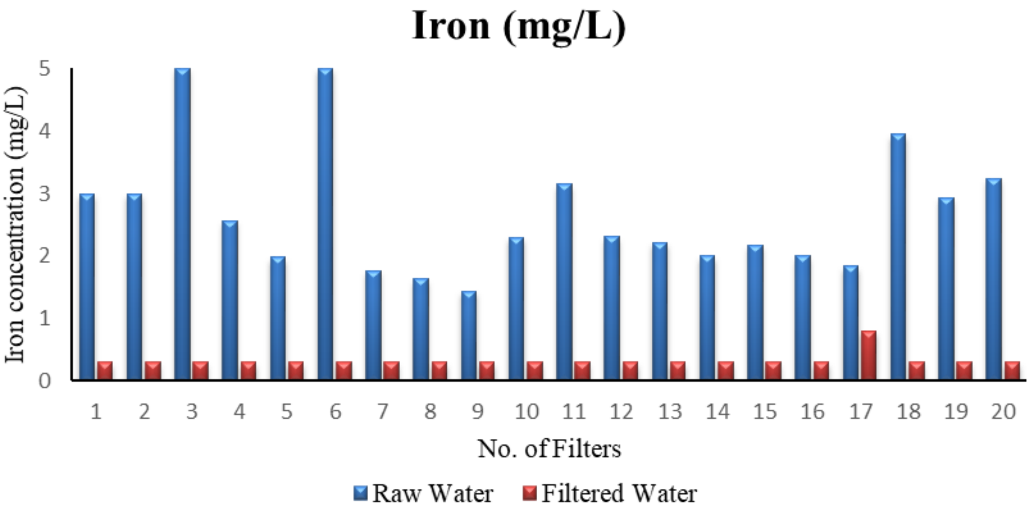


Figure 2: Representation of iron removal through MatiKalp

● Microbiological: a total of twenty-two filters were taken under study to analyze the presence and absence of coliform bacteria before and after the raw water from the hand pump source was passed through the MatiKalp filter using an H_2S vial kit. The raw water used for drinking purposes showed apresence of coliform bacteria. However, the filtered water showed the absence of coliform bacteria thus resulting in the confirmation of safe water at the point of use.

IV. Case study/impact/community response

Ceramic pot filter user experience indicates that this low-cost technology in providing safe drinking water to the community in the Vaishali district is proving to be a great help to overcome the problems they faced with contaminated consumption of drinking water. Some of the community members came forward and recorded the benefits of safe drinking water.

● Shanti Devi, a resident of Village Lakhanpur Lal, district Vaishali, tells that there are ten members in her family with four small children whose age is two to five years. She and her husband are daily wage laborers. Shanti Devi said that she and her family were suffering from gastrointestinal ailments and could not eat properly. She saidthat seven hundred rupees a month was spent on medicines, and even after taking medicinesmany times there was no relief.In addition, she said that usually during the rainy season, children often fell ill, mostly vomiting and fever, "I had to take them to the doctor's clinic and missed work, resulting in a loss of wages. We were getting trapped in the poverty cycle due to taking loans from the Mahajans and not being able to repay them." Shanti Devi said that after going to social meetings, it was found that whatever problem is happening, it could be due to drinking contaminated water. In these meetings, information about safe drinking water and hand hygiene was given. Earlier, she did not know about the concept of safe drinking water and the benefits of using a Matikalp filter that could cure all the health problems related to gastrointestinal diseases. Shanti Devi says that now they do not get gastrointestinal diseases and the biggest thing is that they are saving 700 rupees a month. Now her family has got rid of the doctor's clinic. She has been using Matikalp Filter foreightmonths and advises others to useMatikalp and always drink filtered water.

● Shobha Devi is an ASHA worker (local health worker) in KhokshaKalyan. She shares that, before using MatiKalp, she used to drink water directly from the hand pump, due to which she and her family suffered from gastrointestinal diseases and used to spend five hundred rupees a month on medicine. She said that whenever she used to go into the field, she felt very ashamed because of frequent burps. After being a part of group meetings, she got to know that gastrointestinal issue is a result of drinking unsafe water. Shobha Devi later adopted MatiKalp and usedit for about eight months and feels better now.

● RanjuDevi is another resident of Khoksa Kalyan village and a beneficiary of MatiKalp. She says that her children often facedstomach pain and other related problems but after knowing about the health benefits of using MatiKalp, her children are healthy, and the approximately 800 rupeesthatwere spent on medicine are saved. She said now they rarely visitthe doctor. Ranju Devi says she also received education on cleanliness and hygiene in group meetings, such as why, how, and when to wash her hands. Now she is using filtered water for drinking and cooking purposes.

- Parmila Devi ofKailachak village has been using MatiKalp for more than two years. Her source water contains high concentrations of iron and microbiological contamination. With this, she and her family suffered from gastrointestinal illness, and a large sum of money is spent on medicines and visits to doctors. Since the adoption of the filter, she reports no gastrointestinal issues and is able to save 790 rupees on medicines. Seeing the benefits, she has recommended the use of MatiKalp to her near ones and convinced them to install the filter.
- During the household survey and water testing in the area, Meena Devi, from Lakhanpur Lal village, found out that her source water has iron and microbiological contamination. After attending the meeting, she came to know about the adverse effects of iron on health and the reason for frequent gastrointestinal issues. She added that on a monthly basis, 800 rupeeswere spent on medicines.Seeing the advantages of MatiKalp, her son bought the filter from a potter immediately after the sensitization session. Since then, she has been relieved from gastrointestinal ailments. She now strongly advocates the use of MatiKalp and has sensitized other householdstosafe water.
- Anita Devi of KhoskaKalyan village was concerned about iron contamination in water after the color change that she noticed in their drinking water after it was stored for some time. In the sensitization session organized as a part of the project, she discussed the color change in water, the difficulty in cooking rice, and yellowing of white clothing. After a lot of discussions, she came to know about the ceramic water filter and decided to buy one. She had been suffering from acute gastrointestinal pain and diarrhea which cost her 720 rupees per visit to the doctor. The ceramic pot filter helped in the reduction of health issues and reduced the money spent by the family on doctors and medicines.

V. Conclusion

Ceramic pot filters can be considered one of the best low-cost sustainable technologies to provide safe drinking water even to the poorest of the poor. The low cost of the filter and its efficiency in removing iron and coliform bacteria have resulted in the gain of many community members' health and has even influenced the growth of the economy, which was earlier spent on doctors and medicines.

Declaration of Interest

The authors declare no conflict of interest.

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