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CLEAN WATER FOR BETTER HUMAN LIFE: CONSTRUCTING ECO-FRIENDLY WATER FILTERS AND ASSESSING THEIR WATER FILTRATION ABILITY AND WATER QUALITIES

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ABSTRACT

Clinical reports of rising renal complications in Anuradhapura and Kurunegala districts have caused major concerns in the groundwater quality. The majority of the rural population directly consume this water from wells, which are not tested or treated. Many studies point to contamination of these groundwater sources due to pesticide leaching, weathering of rocks and farming malpractices. The objective of this study was to produce an eco-friendly, low-cost water filter suitable for a low-income rural population. Thus, the filter consisted of Strychnos potatorum seeds, Coconut Charcoal, Laterite, Dolomite, River sand and Activated Carbon, arranged in glass bottles in a cartridge system with taps to control flow rate, mounted vertically on a wooden structure, with a flow rate of 500 mL per hour. Biochemical and Microbiological tests were carried out for four wells in Anuradhapura and two wells in Kurunegala, before and after filtration. While majority of wells were within guideline limits of WHO, titrimetric analysis revealed high sulfates (5350 mg/L), total hardness (159.17 mg/L) and chlorides (704.52 mg/L) in certain wells which were reduced to guideline range after filtration. Nitrate values obtained by spectrophotometric analysis of samples were within guideline values (50 mg/L) and were dependent upon the geographical location of sampling. The microbiological analysis showed high counts (200 CFU) of gram-negative bacteria in well samples and a combination of boiling and filtration was suggested. The designed filter was suitable to reduce Total hardness and Chloride levels and can be improved by changing the position of filter material or adding modifications.

Keywords: Water filter, Eco-friendly, Low-cost, Water, Purification

INTRODUCTION

Sri Lanka, an agro-economic country cultivates tea, paddy, vegetables and fruits, majority of which are in dry zone, irrigated by rivers and well water supplies (Withanachchi et al., 2014). Despite NWS&DB supplying pipe-borne water tested in ISO 17025:2005 accredited laboratories and bottled water companies producing SLS 614:2013 certified water bottles, 80% of the rural population access their drinking water requirements, through groundwater sources such as dug and tube wells, where no systematic testing is done (Panabokke and Perera, 2005; Sayanthan et al., 2015). Groundwater is subjected to leaching of agrochemicals, chemical weathering of rocks and even human and animal wastes (Bandara and Hettiaratchi, 2010; Knipe, 2016; Nikagolla et al., 2020). Deterioration of groundwater quality due to anthropogenic activities, has led to many diseases, necessitating an efficient water filtration system at domestic level a dire need (Dharmawardana et al., 2014; Aravinna et al., 2016).

An efficient water filter should be able to remove/minimize physical, chemical and biological agents, enhancing water quality (Sobsey et al., 2008). Water filters commercially available at present are high cost (ranging from LKR 5000 – 45000) and non-eco-friendly (primarily plastic). While the accumulation of non-eco-friendly materials such as micro plastics signify a high pollution level detrimental to human health, it portrays the need for an eco-friendly filter (Eriksen et al., 2014; Seltenrich, 2015; Athawuda et al., 2020; Prata et al., 2020). The rural population of these areas cannot afford high-cost water filters and to constantly replace filter cartridges. The designed filter in the proposed project accesses both these criteria by being low-cost (Approximately LKR 500) and eco-friendly with domestic materials freely available even in rural areas. The filter is built in a cartridge system with each bottle carrying individual filter material to facilitate an easy cleanup/refill process.

Table 1: Materials used with their respective filtration property

Material	**Filtration Property**
Strychnos potatorum seeds	Reduce turbidity, Cadmium adsorption and Reduce coliform count (Saif, Kumar and Prasad, 2012).
Coconut Charcoal	Reduce Cl^-, Pb^{2+} (Bhatnagar *et al*., 2010).
Laterite	Reduce BOD, COD, turbidity and nitrite-N (Kadam *et al*., 2009).
Dolomite	Reduce Mn, Cu^{2+} and Pb^{2+} levels (Pehlivan *et al*., 2009).
River sand	Reduce COD and removal of Ammonium-N, Nitrate-N, Phosphorous (PO_4-P) (Prochaska and Zouboulis, 2003).
Activated Carbon	Reduce BOD, COD, Cu^{2+}, Zn^{2+} (Reungoat *et al*., 2010).

Water quality is dependent upon parameters such as Dissolved Oxygen, pH, conductivity, total coliform levels and ions such as Nitrate, Sulfate, Chloride, Magnesium and Calcium and heavy metals (Wijeyaratne and Subanky, 2017). Studies conducted on groundwater quality, show deviations from the World Health Organization guideline values (Refsgaard et al., 1999; Babiker, 2004; Samarasinghe and Samarakoon, 2018; Udeshani et al., 2020).

Table 2: Guideline values for Chemical parameters (Adapted from WHO; 2003; WHO, 2011; Puri and Kumar, 2012; Lin et al., 2017)

Chemical Parameter	Guideline Value
pH	6.5-8.5
Conductivity	250 mV
Dissolved Oxygen	13-14 mg/L
Chlorine (Cl^-)	250 mg/L
Fluoride (F^-)	1.5 mg/L
Nitrate (NO_3^-)	50 mg/L
Sulfate (SO_4^{2-})	150 mg/L
Calcium (Ca^{2+})	100 mg/L
Magnesium (Mg^{2+})	50 mg/L

Chandrajith et al., 2010 suggests the close association of hydro-geochemistry with the onset of chronic kidney disease, especially in the North Central and North Western provinces. This study is mainly focused on the Anuradhapura district of the North Central Province in the dry zone (Wickramarathna et al., 2017) and the Kurunegala District of the North Western Province, in the Intermediate Zone, which are reported to contain significantly high ionic values in groundwater (Dharmaratne, 2015; Dissanayake and Chandrajith, 2018).

Table 3: Comparison of high ion concentrations in each area and the respective diseases caused.

District	Ion (High)	Disease/Effect	Reference
Anuradhapura	Nitrate (NO3-)	Infant methemoglobinemia Thyroid disease Breast and Colorectal cancer	(Dissanayake and Weerasooriya, 1987) (Mahagamage and Manage, 2019)
	Total Hardness (Ca2+ and Mg2+)	Cardiovascular problems Renal dysfunction Neural diseases	(Kumara et al., 2019) (Sengupta, 2013)
	Fluoride (F-)	Dental fluorosis Skeletal fluorosis	(Dissanayake, 1991) (Kumara et al., 2019)

		Kidney damage in children	
Kurunegala	Fluoride (F-)	Dental fluorosis Skeletal fluorosis Kidney damage in children	(Indermitte, Saava and Karro, 2009) (Dharmaratne, 2015)
	Total Hardness (Ca2+ and Mg2+)	Cardiovascular problems Renal dysfunction Neural diseases	(Jayasena, Chandrajith and Dissanayake, 2007)
	Chloride (Cl-)	Detectable taste change in water/ No detected effect	(Samarasinghe and Samarakoon, 2018)

Many clinical studies point to developing renal complications of these areas (Wanigasuriya et al., 2007; Jayasumana et al., 2015) and progression of diseases such as Chronic Kidney Disease of unknown origin (CKDu) with no confirmed etiology (Jayasumana, Gunatilake and Senanayake, 2014; Wijetunge et al., 2015). According to Senanayake et al., 2020, urinary tract diseases was the 8th leading cause of hospital deaths in 2017, and the rising CKDu cases signify the importance of immediate action and suitability of the area of study (Jayasekera, 2013; Weragoda and Kawakami, 2016; Kafle, Balasubramanya and Horbulyk, 2019).

People in these areas obtain drinking water from shallow wells subjected to pollution. The purpose of this project is to bridge the gap between clean water and rural population by introducing a low-cost eco-friendly water filter to provide better sanitation. For this, well water samples from four wells in Anuradhapura (Well 1- Saliyawatte, Well 2 – Kurundankulama, Well 3 – Pandukabayapura, Well 4 – Parasahgasweva) and two wells in Kurunegala (Well 5 and 6 – Yaggapitiya) were analyzed by biochemical tests and microbiological analysis before and after filtration.

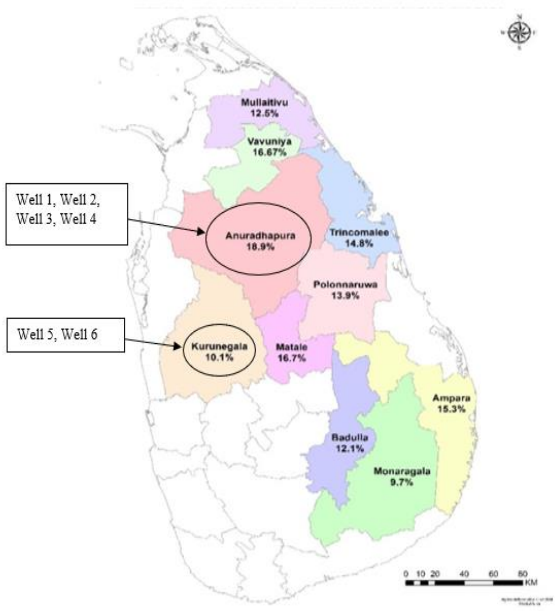

Figure 1: Map depicting the sampling sites in the North Central and North Western provinces (Kafle, Balasubramanya and Horbulyk, 2019).

OBJECTIVES

General Objectives

- Assessing water filtration ability of eco-friendly, low-cost water filter composed of natural ingredients (Seeds and Minerals) and determining well water qualities using biochemical tests.

Specific Objectives

i. To design and develop a low cost, eco-friendly water filter.

ii. Analyze by titrimetric and spectrophotometric methods the quality of well water, from 6 wells in the Saliyawatta, Kurundankulama, Pandukabayapura, Parasahgasweva regions of Anuradhapura District and Yaggapitiya region of Kurunegala District.

iii. To compare the concentrations of ions such as Nitrate, Sulfate, Chloride and Total Hardness present among filtered water and unfiltered water.

iv. To check parameters such as Dissolved Oxygen, pH and ORP of filtered and unfiltered water.

MATERIALS

All chemicals used were of analytical grade, from Hi-Media, SRL Chemicals and Sigma-Aldrich brands, and were purchased from Analytical Instruments Pvt. Ltd.

METHODOLOGY

Sample collection

5 L plastic bottles and their lids were placed under the safety cabinet with the UV light on for 20 minutes for sterilization. The bottles were then transported to Anuradhapura and Kurunegala and filled to the top to prevent leaving any air spaces for atmospheric Oxygen mixing with water. Water samples were then brought back to Colombo and stored under room temperature.

Procedure of Filter Design

The basic structure of the filter was constructed with 4 wooden planks. 2 wooden planks were fixed perpendicular with 0.5 inch No.5 self-tap screws, while an additional plank acted as a support. A plank was also attached at the top for the placement of the water sample, which was retrieved to the filter system via an air-stone suction mechanism. The filter constituted 6 low cost eco-friendly 375 mL glass bottles. The base of each glass bottle was drilled and they were aligned and attached to the wooden plank with metal brackets and screws. The bottles were capped with a lid, which constituted airline taps to control the flow rate. The bottles were easily removable thus facilitating as a cartridge system, preventing clogging, and making cleaning up easy. The bottles were initially washed with boiling water and left to dry. They were then filled with Strychnos potatorum seeds, coconut charcoal, laterite, dolomite, river sand, and activated carbon respectively. Neck regions of the bottles consisted of cotton, to hold materials in place.

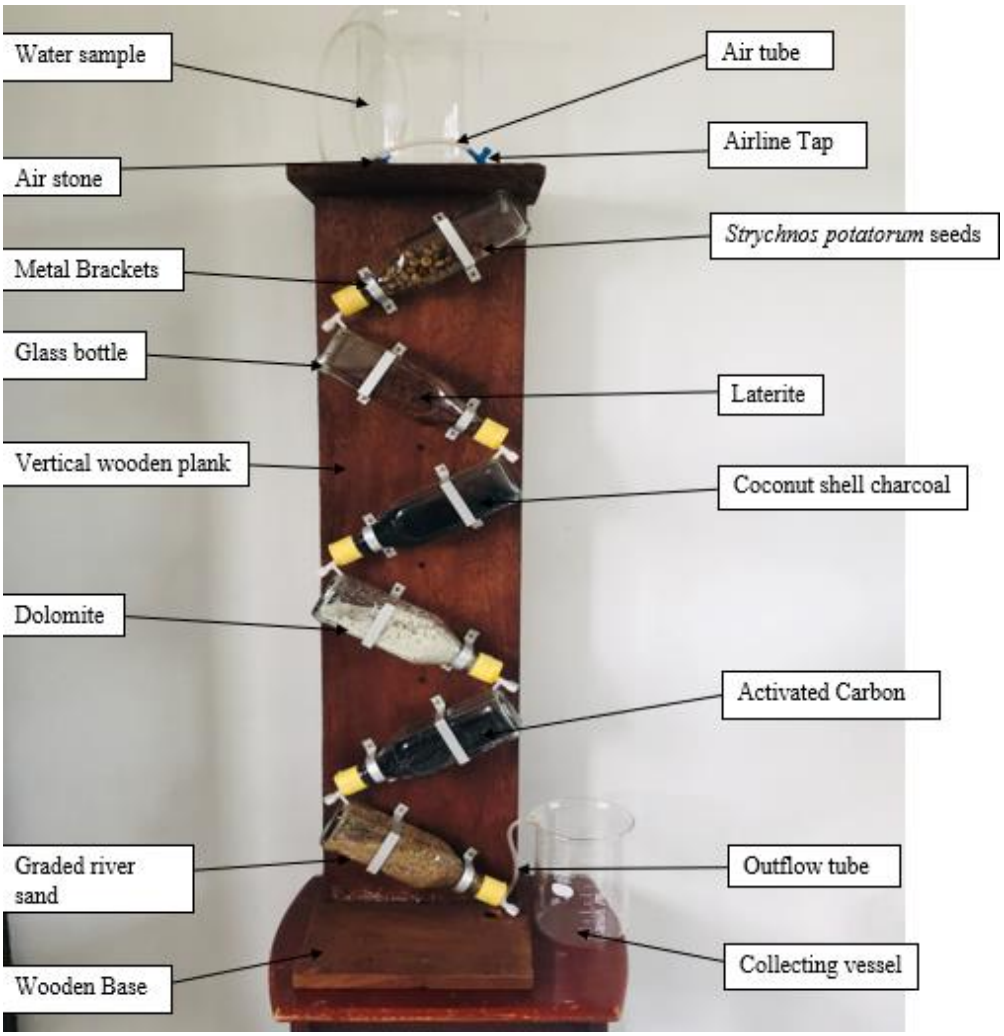

Figure 2. Eco-friendly low-cost water filter

pH and Oxidation-Reduction potential

A HANNA HI-8424 model digital pH meter was used to determine the pH and ORP. The calibration was done by using 80 mL standard solutions of pH 7 and 4 respectively. The probes were washed with distilled water, dipped in the pH 7 solution and calibrated, then were washed with distilled water and calibrated with 80 mL of pH 4 standard solution. Again the probes were then washed and the samples from well 1, 2, 3, 4, 5 and 6 were measured.

Determination of Sulfate – Gravimetric Method

Glass beakers numbered 1-6 were weighed and 50 mL of sample water was added to each beaker and left to boil. The beaker was removed from the fire and 3 drops of concentrated HCl were added. 5 mL of 10% $BaCl_2$ was then added upon

reduction of volume to half and stirred continuously, till precipitate formation. Once the solution evaporated, the precipitate was cooled and measured. (Adapted from: Uddin et al., 2015).

Determination of Total Hardness

50.0 mL of the sample was pipetted into a 250 mL conical flask and diluted to 100 mL using distilled water. 4 mL of the ammonium buffer solution (pH=10.20) and 6 drops of Eriochrome Black T was then added. The burette was filled with a standardized EDTA solution. The titration was performed until a distinct blue endpoint was obtained (v mL) (Pal et al., 2018).

Calculations were done using,

$$E\ (CaCO_3) = \frac{20 \times 1\ mg\ CaCO_3}{t}$$

$$CaCO_3\ content\ (mg/L) = \frac{v\ mL\ \times\ E\ (CaCO_3) \times 1000}{50}$$

Determination of Dissolved Oxygen

250 mL of sample was transferred into a 250 mL volumetric flask. 1 mL of MnSO4 was added by a pasteur pipette and the solution was mixed by inverting. 1 mL of Iodine was then added onto the surface of the water and the solution was mixed by inverting after placing the glass stopper. 1 mL of concentrated H2SO4 was added along the neck of the flask. The stopper was replaced and inverted. 201 mL of the treated water sample was transferred into a 250 mL conical flask. A few drops of Na2S2O3 was added until the color changed to a pale yellow. 1 mL of the starch indicator was added and mixed, observing a color change to blue. The resulting solution was titrated against Na2S2O3 and the volume required to observe a color change from blue to colorless was recorded (Montgomery, Thom and Cockburn, 2007).

Determination of Chloride

20 mL of water sample was transferred to a conical flask and 0.5 mL of K_2CrO_4 was added and mixed. The sample was then titrated against AgNO3 until the color changed to red from yellow, and the volume of AgNO3 used was recorded (Korkmanz, 2001; Shukla and Arya, 2018).

Determination of Gram-negative bacteria

Slightly cooled agar was poured into sterilized petri dishes within the biosafety cabinet. The petri dishes were labeled with the date, type of water sample, and name. 50 µL of well water sample was pipetted onto the agar plate and spread using a glass spreader close to a flame. The glass spreader was sterilized by dipping it in absolute ethanol and flaming it before and after use. The petri dishes were sealed using parafilm and incubated at 37°C overnight (Chowdhory et al., 2016).

Determination of Nitrates

10 mL of water sample was transferred to a measuring cylinder. 0.1 mL of H2SO4 was added and mixed using a micropipette. 3 mL of sample was then transferred to a glass cuvette that was previously washed with distilled water. The spectrophotometer was blanked at 220 nm with distilled water. The absorbance of the sample was measured and the same was repeated at 275 nm wavelength (APHA, AWWA and WEF, 1998).

RESULTS

pH and ORP

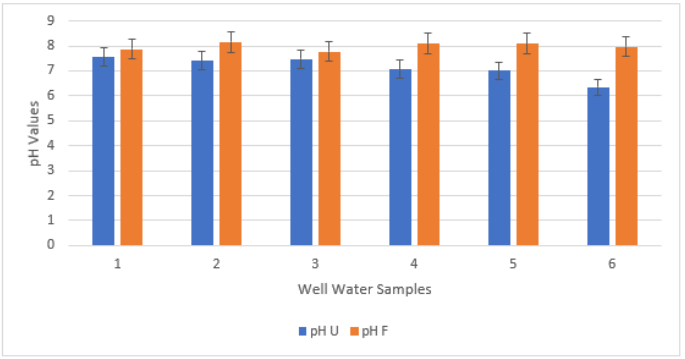

Figure 3: Comparison of pH of unfiltered and filtered water.

Table 4: Single factor ANOVA analysis for pH of unfiltered and filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	42.85	7.141667	0.204817
Column 2	6	47.94	7.99	0.02292

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.159008	1	2.159008	18.96057	0.001434	4.964603
Within Groups	1.138683	10	0.113868			
Total	3.297692	11				

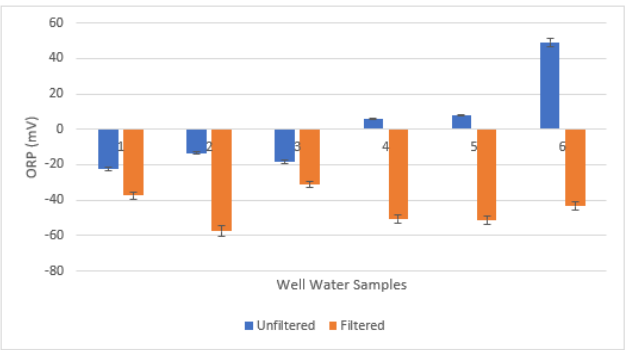

Figure 4: Comparison of oxidation-reduction potentials of unfiltered and filtered water.

Table 5: Single factor ANOVA analysis for oxidation-reduction potential for unfiltered and filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	9.7	1.616667	702.8857
Column 2	6	271.5	-45.25	96.547

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6589.453	1	6589.453	16.48532	0.002286	4.964603
Within Groups	3997.163	10	399.7163			
Total	10586.62	11				

Sulfates

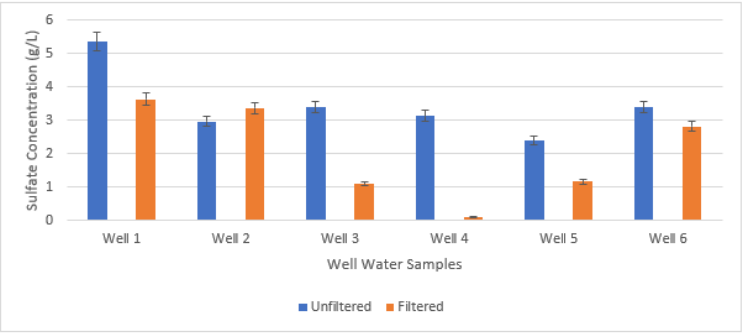

Figure 5: Comparison of Sulfate concentration of unfiltered and filtered water.

Table 6: Single factor ANOVA analysis for Sulfates of Unfiltered and Filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	20.59	3.431667	1.016777
Column 2	6	12.14	2.023333	2.060067

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.950208	1	5.950208	3.867736	0.077574	4.964603
Within Groups	15.38422	10	1.538422			
Total	21.33443	11				

Total Hardness

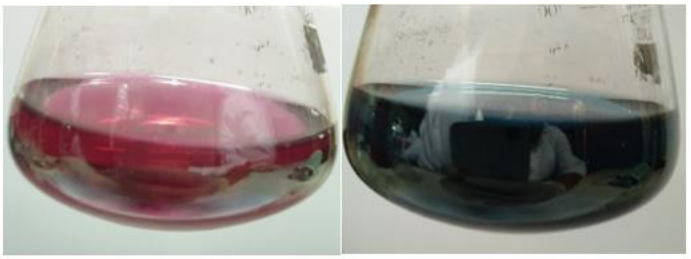

Figure 6: Colour change from violet to blue, before and after titration with EDTA.

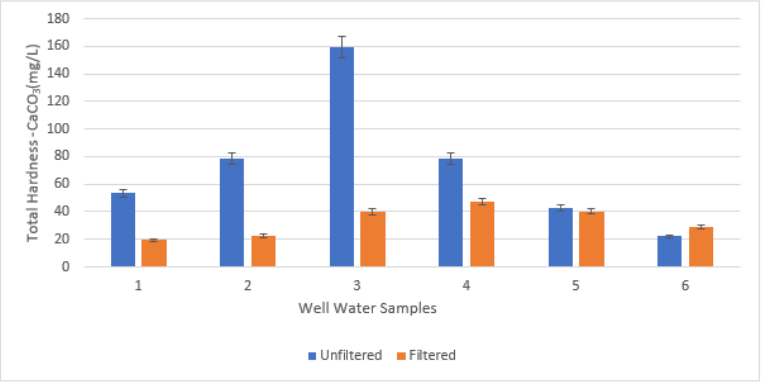

Figure 7: Comparision of total hardness of unfiltered and filtered water

Table 7: Single factor ANOVA analysis Total Hardness of unfiltered and filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	434.43	72.405	2271.046
Column 2	6	198.69	33.115	125.84

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4631.112	1	4631.112	3.864274	0.077688	4.964603
Within Groups	11984.43	10	1198.443			
Total	16615.54	11				

Dissolved Oxygen

Figure 8: Colour change from pale yellow to blue after the addition of starch and blue to colorless at endpoint.

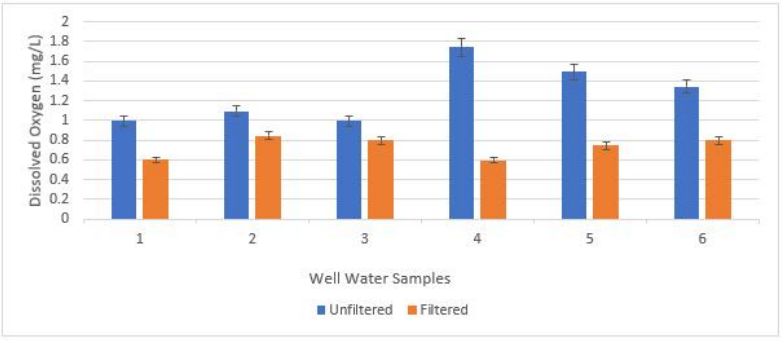

Figure 9: Comparison of the Dissolved Oxygen concentration of unfiltered and filtered water.

Table 8: Single factor ANOVA analysis for Dissolved Oxygen of Unfiltered and Filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	7.662	1.277	0.091696
Column 2	6	4.381	0.730167	0.011403

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.89708	1	0.89708	17.40238	0.001913	4.964603
Within Groups	0.515493	10	0.051549			
Total	1.412573	11				

Chloride

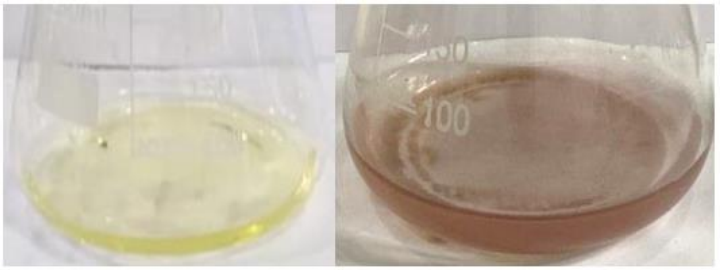

Figure 10: Colour change from yellow to brick red, before and after titration with $AgNO_3$.

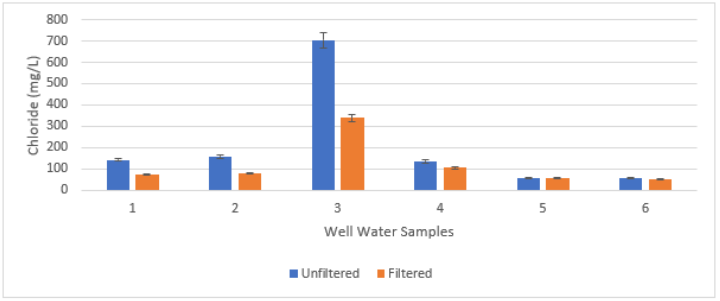

Figure 11: Comparison of Chloride concentration of unfiltered and filtered water.

Table 9: Single factor ANOVA analysis for Chlorides of unfiltered vs filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	1252.62	208.77	60934.06
Column 2	6	699.51	116.585	12247.04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25494.22	1	25494.22	0.696743	0.423373	4.964603
Within Groups	365905.5	10	36590.55			
Total	391399.7	11				

Gram Negative Bacteria

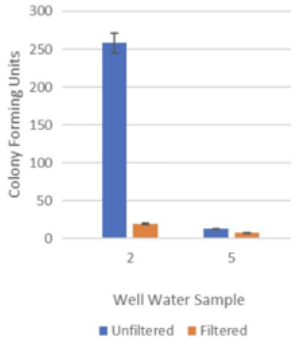

Figure 12: Comparison of Colony Forming Units of unfiltered and filtered water

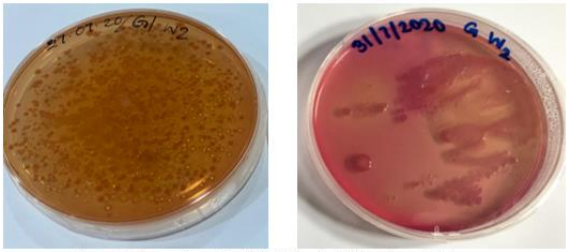

Figure 13: Comparison of well 2 unfiltered and filtered spread plates.

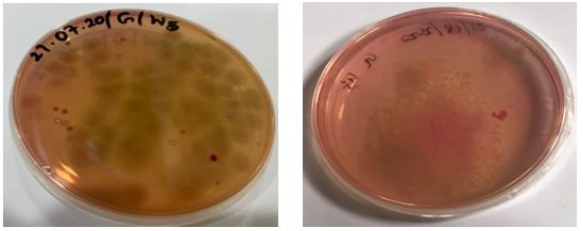

Figure 14: Comparison of well 5 unfiltered and filtered spread plates.

Nitrate

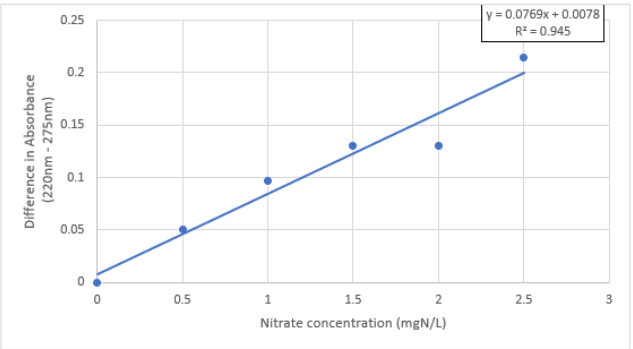

Figure 15: Standard Curve for Nitrate.

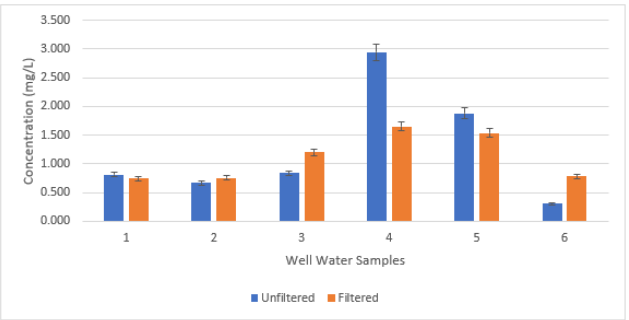

Figure 16: Comparison of Nitrates of unfiltered and filtered water.

Table 10: Single factor ANOVA analysis for Nitrates of unfiltered and filtered water samples

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	7.204986	1.200831	1.102355
Column 2	6	6.401662	1.066944	0.193343

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.053777	1	0.053777	0.083009	0.779143	4.964603
Within Groups	6.47849	10	0.647849			
Total	6.532268	11				

Unfiltered vs Filtered water

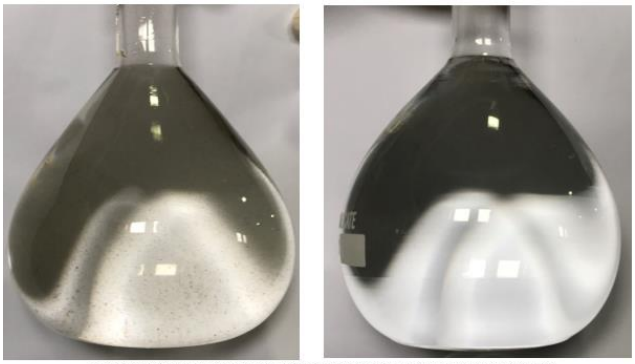

Figure 17: Comparison of the physical appearance of unfiltered and filtered water.

DISCUSSION

Groundwater sources are the primary source of drinking water in rural areas of Anuradhapura and Kurunegala (Balasooriya et al., 2019), where the same sources are used for irrigation of agricultural lands (Bandara et al., 2010; Young, Pitawala and Ishiga, 2010). Many studies point out the deteriorated water quality of these regions to have a direct impact on the amount of rising renal complications (Dharmawardana et al., 2014; Cooray et al., 2019). Since these rural population directly consume groundwater, a low cost and eco-friendly water filter for domestic use was a viable option to attempt to rectify the prevailing situation. The designed filter constituted minerals and seeds.

Table 11: Filter material and their respective filteration properties.

Filter Material	Filtration Property	References
Strychnos potatorum seeds	Clarify turbid water, Increased heavy metal absorption and reduced coliform count	(Babu and Chaudhuri, 2005; Yin, 2010; Saif, Kumar and Prasad, 2012)
Laterite stones Crushed and sieved – 3 mm	Reduced turbidity, COD, nitrates, fluorides and phosphates.	(Sarkar *et al*., 2006; Kadam *et al*.,2009; Kpannieu *et al*., 2019)
Coconut charcoal Crushed and sieved – 3 mm	Reduces chlorides, lead and iron.	(Beenakumari, 2009; Bhatnagar *et al*., 2010)
Dolomite Crushed and sieved – 1 mm	Reducing manganese, lead and copper.	(Pehlivan *et al*., 2009) (Yuan *et al*., 2015)
Activated carbon	Reduced BOD, COD, Cu^{2+}, Zn^{2+} and removes toxins such as pesticides and herbicides	(Ormad *et al*., 2008; Reungoat *et al*., 2010)
Graded river sand	Reduces COD, ammonium, nitrate and phosphorus	(Prochaska and Zouboulis, 2003)

The air stone at the top of the filter denies solid contaminants from entering the filter system preventing any clogging. According to Aziz and Smith, 1996, the smaller particle size and greater depth of dolomite layer provides an increased removal efficiency. Activated carbon technology can be further improved in the future as a nanotechnology-based approach to nanotube-based water filtration (Sweetman et al., 2017). According to Bagundol, Awa and Enguito, 2013, increasing depth and slowing filter rate, improved Escherichia coli removal efficiency, which acts as an indicator organism in water quality testing (Stauber et al., 2006; Ishii and Sadowsky, 2008). The filter contains each material in a glass bottle (cartridge system) ensuring water flows through all materials at a constant flow rate of 500 mL per hour, providing sufficient time for water to be in contact with the filter material ensuring maximum filtration efficiency. Filter material are domestically available in abundance and are eco-friendly, providing greater convenience and minimal cost to the rural population.

The pH and ORP were measured by a HANNA model HI-8424, pH meter. Hydrogen ion activity determines the pH of a solution (Puri and Kumar, 2012). According to WHO, 2011, the guideline pH range is 6.5 – 8.5 and both unfiltered and filtered water from wells 1- 5 were within guideline limit. Well 6 from Kurunegala showed a slight deviation (pH = 6.34) in unfiltered water, but was brought within the guideline range after filtering (pH = 7.97). The one way ANOVA generated (Table 4) for pH of unfiltered and filtered water samples shows a $p < 0.05$ (0.001434) and also F > F crit (F- 18.96057, F crit - 4.964603) indicating there is a significant difference. The Oxidation-Reduction potential is a measure of the ability of a liquid to oxidize or reduce resulting in contaminant breakdown. The one way ANOVA generated (Table 5) for ORP of unfiltered and filtered water samples shows a $p < 0.05$ (0.002286) and also F > F crit (F - 16.48532, F crit - 4.964603), indicating there is a significant difference. Lin et al, 2017, suggests that ORP of around 250 mV is suitable for drinking water. While a positive ORP indicates oxidizing agents, negative indicates reducing agents. Well 4, 5 and 6 had positive values in unfiltered samples, which were negative after filtration, indicating an increase of reducing agent concentration. The filter made all ORP values more negative giving it antioxidant properties to battle free radicles (Goncharuk et al., 2010).

Sulfate determination was carried out by Gravimetric analysis in which BaSO4 was precipitated in a medium acidified by HCl, with the addition of BaCl2.

$$BaCl_2+SO_4^{(2-)} \rightarrow BaSO_4\downarrow+HCl$$

The precipitation was done in a boiling solution to prevent occlusion of other species in the precipitate, improving accuracy. The WHO, 2011, guideline value was 250 mg/L for sulfates. Unfiltered samples displayed extremely high values with the highest being in well 1 - Anuradhapura (5350 mg/L). This is also confirmed by Rubasinghe, and his coworkers in, 2015, recording higher sulfate values in the dry zone than other regions. In well 4, unfiltered water showed 3130 mg/L sulfates while after filtration it was successfully brought below guideline limit (110 mg/L). 250 mg/L is also the taste threshold of sulfates and its addition can be due to geochemical weathering of rocks and anthropogenic activities (Wickramaarachchi, 2018). The one way ANOVA generated (Table 6) for the sulfates of unfiltered and filtered water samples shows a $p > 0.05$ (0.077574) and also F < F crit (F - 3.867736, F crit - 4.964603) indicating there is no significant difference.

Total Hardness is a measure of the dissolved Magnesium and Calcium ions

(divalent cations) in water. This was determined by a complexometric titration, carried out against titration with EDTA. Titration was performed in a pH = 10 solution with an ammonium buffer to encourage the complexation of the Ca2+ and Mg2+ ions. Eriochrome Black T was used as the indicator to demonstrate the endpoint, as it forms deep red-wine colored complexes. At the equivalence point, once all the Ca2+ and Mg2+ ions have been complexed in the solution, further addition of the titrant caused a change in equilibrium reaction of the Mg-Eriochrome Black T complex, which once it was free, turned a cobalt blue color. Water containing calcium carbonate at concentrations below 60 mg/L is generally considered as soft; 60–120 mg/L, moderately hard; 120–180 mg/L, hard; and greater than 180 mg/l, very hard (WHO, 2011). Total hardness consists of a guideline limit of 250 mg/L and all well samples were within the limit. Well 3 unfiltered exhibited the highest hardness (159.17 mg/L), which reduced to 40.05 mg/L proving the filter effective. Kumara et al., 2019 recorded similar high hardness values which were reduced by a reverse osmosis filter from 844.33 mg/L to 42.07 mg/L. The one way ANOVA generated (Table 7) for the total hardness of unfiltered and filtered water samples shows a p > 0.05 (0.077688) and also F < F crit (F - 3.864274, F crit - 4.964603) indicating there is no significant difference.

The amount of gaseous Oxygen dissolved in an aqueous sample is determined as the dissolved oxygen concentration and is higher in flowing water subjected to aeration (Puri and Kumar, 2012). Dissolved oxygen was determined by the Winkler method (APHA, AWWA and WEF, 1998). Dissolved oxygen is fixed by the addition of MnSO4, resulting in a brown precipitate, manganic hydroxide (MnO(OH)2).

$$2Mn(OH)_2 + \frac{1}{2}O_2 + H_2O \rightarrow 2MnO(OH)_2$$

Acidifying with H2SO4, causes the complex to dissolve liberating free Iodine.

$$2Mn(OH)_3 + 2I^- + 6H^+ \rightarrow 2Mn^{+2} + I_2 + 6H_2O$$

The amount of free iodine is proportional to dissolved oxygen in the sample. Iodine forms a complex (I_3^-) with surplus iodide ions. The complex is then titrated with thiosulfate; iodine is reduced to iodide while thiosulfate is oxidized to tetrathionate.

$$I_2 + I^- \rightarrow I_3^-$$

$$I_3^- + 2S_2O_3^{-2} \rightarrow 3I^- + S_4O_6^{-2}$$

Therefore, stoichiometry between S_2 O_3^(-2):O_2 is 4:1. The ICMR sets the DO guideline value at 5 mg/L, and all unfiltered and filtered samples were within this value (Singh and Kamal, 2014). The one way ANOVA generated (Table 8) for dissolved oxygen of unfiltered and filtered water samples shows a p < 0.05 (0.001913) and also F > F crit (F - 17.40238, F crit - 4.964603) indicating there is a significant difference. Well 4 exhibited the highest value (1.741 mg/L) which reduced to 0.597 mg/L after filtering. All filtered water samples showed low DO values and could be erroneous since they were tested two weeks later. Immediate testing after filtration can be followed to prevent this (Siriwardana et al., 2019).

The Mohr method was used for the determination of Chlorides by titrating samples of well water against Silver nitrate. Addition of silver nitrate results in a Silver chloride precipitate.

$$Ag^+ + Cl^- \rightarrow AgCl$$

The occurrence of the endpoint depends on precipitation of all chloride ions. The additional silver ions then react with the chromate ions of K_2CrO_4 indicator giving a reddish-brown precipitate.

$$2\,Ag^{+} + CrO_4^{-2} \;\rightarrow\; Ag_2CrO_4 \downarrow$$

The guideline limit for Chlorides is 250 mg/L and all other well samples were within the guideline limit. Well 3 in Anuradhapura showed significantly high values for unfiltered water (704.52 mg/L) which was reduced to 339.12 mg/L. Paranagama and his coworkers, 2018, also suggest a similar study where only some individual wells exceeded the chloride guideline limit. The one way ANOVA generated (Table 9) for Chlorides of unfiltered and filtered water samples shows a $p > 0.05$ (0.423373) and also $F >$ F crit (F - 0.696743, F crit - 4.964603) indicating there is no significant difference.

The Nitrate concentration was determined by a UV spectrophotometric analysis in which the samples were analyzed at 220 nm and 275 nm. At 220 nm Nitrates and organic acids were absorbed and at 275 nm only organic acids, thus the difference giving the Nitrate absorbance. The nitrate calibration curve was made from dilutions of Nitrate stock solutions and follows Beers Law (APHA, AWWA and WEF, 1998). H2SO4 was used to acidify the sample preventing interference from carbonate or hydroxide concentrations. The WHO, 2011, guideline value stands at 50 mg/L and all values obtained were below this. Well 4 from Anuradhapura showed the highest value at 2.941 mg/L and was reduced to 1.654 mg/L after filtration. According to Herath et al., 2017, Nitrate concentration exceeds guideline values in wells near intense agricultural zones. Dhanapala, Asanthi, and Gunarathne, 2015, recorded values from 1.01 to 23.4 mg/L among 30 wells which varied upon geographic location. Well 2, 3 and 6 recorded increased levels after filtration, which could be caused by not washing the filter between successive filtrations, causing nitrate accumulation in the filter material. Guan et al., 2010, states that Surfactant modified Zeolites are a natural and low-cost adsorbent and can be used as a filter material to enhance nitrate removal (Zhan, Lin and Zhu, 2011). The one way ANOVA generated (Table 10) for Nitrates of unfiltered and filtered water samples shows a $p > 0.05$ (0.779143) and also $F <$ F crit (F - 0.083009, F crit - 4.964603) indicating there is no significant difference.

Microbiological analysis was conducted to measure the gram-negative bacteria in the samples by using Mac Conkey media. Gram-negative bacteria were differentiated by pink strains which were lactose fermenters giving out acid from lactose and dropping the pH below 6.8. Lactose non-fermenting strains display colorless to yellow color. Well 2 - Anuradhapura showed the highest CFU of 258 with it reducing to 20 CFU after filtering. While the WHO recommends zero CFU per 100 mL in drinking water, all well water samples had CFU and according to Mahagamage and Manage, 2019, indicate pathogenic contamination. One well from Anuradhapura and Kurunegala each were tested due to the limited time availability. According to Kulasooriya, 2017 although boiling water kills coliform bacteria, it alone is not sufficient. Hence, boiling plus a filtration system is most effective (Baumgartner, Murcott and Ezzati, 2007).

CONCLUSION

Eco-friendly, low-cost water filter was produced from domestic material. Well water samples from Anuradhapura and Kurunegala were filtered through it. Although no significant difference was

observed in their ion levels before and after filtration, the filter was effective against sulfates, total hardness and chlorides. Natural zeolite, a low-cost adsorbent could be used as a modification to reduce Nitrate levels further, increasing filtration efficiency. Thus this filter would be ideal for a rural community, as an effective and economical approach to minimize the rising renal complications.

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