A FIELD TRIAL ON THE PREVENTION OF COLOUR FORMATION IN TUBE WELL WATER OF CHAVAKCHCHERI AREA

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In Chavakachcheri (Jaffna district), an unpleasant odour, taste, and reddish-brown colour developed with time when clear water was drawn out from some tube wells. The coloured water has created problems in carrying out essential daily work. The previous research (paper 66, OURS 2020) findings reveled that brown colouration is due to $Fe(OH)_3$ and both coconut shell (CSC) and rice husk charcoal (RHC) of 212 µm (0.025 g in 25 mL of water) were effective in preventing colour formation by adsorbing iron (>78%) from tube well water within one minute of equilibration. The objective of the study was to apply these findings on a large scale in a user-friendly manner with respect to particle size, filtering medium and shaking to the community and get their views for further development. In this study, water samples were taken directly from the tube wells and total [Fe] was determined using the thiocyanate colourimetric method. Since RHC did not settle and could not be filtered using household filtering methods, a study was carried out with CSC only. In optimising studies of CSC, different weights of hand crushed (approximately 1 cm^2 area) and uncrushed charcoal were added to 500 mL and 5 L of water and were shaken 10 times every 5 minutes for 1 hr., filtered using a single cloth strainer and total [Fe] was determined before and after equilibration. The applicable least weight of biosorbent/volume of water ratio of crushed and uncrushed CSC was 0.3 – 4.0 g /500 mL and 20 g/5 L. The community trial for 6 houses was done in the rainy season with 20 g/5 L shaken 10 times /every 5 minutes for 1 hr., and nearly 50% of Fe could be removed. Treated water was used to wash a white pillowcase 3 times and allowed to sun-dry. Kept treated water in white porcelain cups for 6 hrs. Neither pillowcases nor porcelain cups were discoloured. The trial was repeated, and the results were the same. Face-to-face interviews with the householders showed that they were satisfied with the process and the outcomes, but wanted to simplify shaking and improve the filtering strainer type. The effect of shaking on Fe adsorption on CSC was determined with unshaken and shaken samples at different time intervals for different time durations. There was no effect of shaking. When applied to the community, Fe adsorption >50% resulted. To avoid filtering, a sack of different material (cotton, cotton + polyester) filled with CSC were applied but was unsuccessful since the sac materials used reduced the adsorption of Fe by CSC. The treated water was tested for drinking water quality chemical parameters, and the results showed that CSC can reduce the [Fe] to an acceptable level even in larger volumes of water without shaking. In addition, CSC can reduce the turbidity, Cl^-, TDS, SO_4^- and total hardness levels, but some only to the accepted level. This study shows that hand-crushed CSC can be used as a cost-effective, environmentally friendly biosorbent in a simple way to prevent colour development by Fe in water, with other additional advantages.

Keywords: coconut shell charcoal, Iron adsorption, coloured water, tube wells

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INTRODUCTION

In Chavakachcheri (Jaffna district), the major water resources for daily consumption of water are from normal wells and tube wells. An unpleasant metallic odour, taste and reddish-brown colour in water have been observed in some shallow wells and in tube wells. When water was drawn out from tube wells, the colour developed with time. This has created problems in carrying out essential daily work, which has finally become an economic problem. Using commercially available bottled water and water purification filters has been the popular solution for drinking water problems in this area. However, the cost, sustainability, regeneration and disposal of water purifying material are still in question in the case of filters. At the same time, the requirement of non- coloured water for other domestic purposes is still not resolved. Therefore, it is very much needed to find a low-cost, user-friendly and environmentally friendly water filtering method.

Previous research carried out (paper 66, OURS 2020) revealed the following:

- Ferrous [Fe^{2+}] is oxidised by dissolved oxygen to Ferric [Fe^{3+}].
- Brown colouration is due to the presence of $Fe(OH)_3$.
- When [Fe^{2+}] < 2 ppm and [Fe^{3+}] < 4 ppm, no colouration occurs.
- Freely available and of low-cost biosorbents: charcoal of coconut shell and rice husk were effective in removing iron from tube well water (>78%) within one minute of equilibration.

To make use of these findings, a field trial is very much needed to see the effectiveness of these findings in natural tube well water undergoing seasonal variations, usability of purified water for domestic purposes and acceptability by the users. It can be followed by suitable changes, if necessary, before applying them to the community.

Objectives: (For natural tube well water)

1. Determination of settling time of biosorbents and a suitable filtering medium
2. Finding a suitable particle size of the biosorbents to be used with a suitable filtering medium
3. Determination of the most suitable weights of biosorbents for smaller (500 mL) and larger (5 L) volumes of tube well water for the field trial.
4. Carrying out field trials in the rainy season
5. Determination of the suitability of treated water for domestic usage
6. Getting feedback on the purification method from the community
7. Carrying out feasibility studies addressing the concerns of the community

8. Carrying out field trials in the dry season with the new adjustments
9. Determination of the drinking water quality chemical parameters of the treated water

METHODOLOGY

1.Determination of settling time of biosorbents and suitable filtering medium: Both biosorbents-Coconut shell Charcoal (CSC) and Rice Hull Charcoal (RHC) were prepared by burning followed by grounding and sieving to have particle size less than 212 µm; 0.5 g were added separately to each 5 L bottle of tap water; shook 3 times upside down; allowed to stand for 8 hours.; filtered using general household filtering media-plastic strainers, double layer face mask, terin cloth, silk cloth, poplin cloth.

2. Finding a suitable particle size to filter using a single-layer cotton cloth strainer: Used two sizes of particles- (4-6 cm^2) hand crushed (CR) and (> 6 cm^2) uncrushed (UCR) biosorbents and filtered using poplin cloth (the most cheap and common).

3. Determination of the most effective weight of CSC for 500 mL and 5 L of tube well water for the field trial: To each 500 mL and 5 L of tube well water bottles, different weights of CR and UCR of CSC were added (control-without the biosorbent) and was shaken 10 times /every 5 minutes for 1 hr., filtered and total iron was adsorbed was determined using thiocyanate colourimetric method. The experiment was carried out in triplicate.

Determination of total Fe using thiocyanate colourimetric method[2]:

To a 10.0 mL of water sample, a drop of dil. H_2SO_4 was added, followed by 0.15 M $KMnO_4$ until a pale pink colour; added 10 mL of ammonium thiocyanate; diluted to 25.0 mL; measured absorbance after 15 minutes at 490 nm.

4. Field Trials 1 & 2- Rainy season: Each household was given 20 g of CSC, a single cloth strainer and a 5 L plastic bottle to fill well water with proper instructions (direct filling from the tube well shaken 10 times every 5 min. for 1 hour) in use. Observations were made with and without our presence. Of the filtered tube well water, total Fe was analyzed before and after treatment.

5. Determination of the suitability of treated water for domestic usage: Treated water was used to wash a white pillowcase 3 times and allowed to sun-dry. Kept treated water in white porcelain cups for 6 hrs.

6. Getting feedback on the purification method from the community: Face-to-face interviews were carried out with the householders.

7. Carrying out feasibility studies addressing the concerns of the community

(i) Shaking-A Feasibility study to determine the effect of unshaking on the adsorption of iron:

Two houses in which intense colour was developed in tube well water were selected as samples; 20 g of CSC in 5 L of well water were shaken once every 5 min. for one hr., shaken once every 30 min. for one hr. and unshaken. Repeated three times. Of the filtered tube well water, total Fe was analysed before and after treatment.

(ii) Filtering-A Feasibility study to determine the effect of biosorbent in a cloth sac on Fe adsorption: To avoid filtering, a sack of different material (cotton, cotton + polyester) filled with CSC (20 g/5 L and 200 g/ 50 L) were applied to the tube well water of a house, which usually had more colour development.

8. Field Trials 3 & 4 -Dry season: The same procedure applied for the rainy season (4) was followed for the Dry season for the same six sample households, but kept water unshaken for 1 hr. and used a double cloth for filtering; 3 replicates were used.

9. Testing for drinking water quality chemical parameters: Samples of treated water, as stated in 8, and untreated water were sent to the National Water Supply and Drainage Board for analysis.

RESULTS AND DISCUSSION

Particles (less than 212 μm) of both biosorbents did not settle down even after 8 hrs. Most of the particles of RHC were on the surface, floating with a few coagulations. In the case of CSC, most were floating. It indicated that removal of the biosorbent after use, from the bottom of the container, which is easy to handle, was not possible. Filtering from the top was another alternative, but particles of both biosorbents passed through the filter media. It was decided to increase the particle size of the biosorbents and try to filter again. Both crushed (4-6 cm^2) and uncrushed (> 6 cm^2) CSC were able to filter through single-layer cotton cloth stainer, but not both crushed and uncrushed RHC. The uncrushed RHC were easily broken when wet, resulting in smaller particles unable to filter. Therefore, it was decided to use only crushed CSC (4-6 cm^2) for the field trials.

The weight optimization studies (Tables 1 and 2) revealed that crushed 0.3-0.4 g/500 mL and 20 g/ 5 L can be considered as the most applicable weights of crushed CSC. No Colour was developed even after 4 days, indicating good storage time of treated water.

Table 1. Results of weight optimisation of CSC for 500 mL of water

- Average concentration of controls (without biosorbent) =2.994 ppm

Particle size (cm^2)	Average weight of CSC (g)	Average Amount of Total Fe adsorbed (ppm)	Average amount Total Fe adsorbed (ppm/g)
4-6	0.371(±0.025)	0.337	1.37 (45%)
	1.04 (±0.12)	0.540	0.519
	3.09 (±0.18)	0.845	0.273
>4-6 (bigger)	1.06 (±0.16)	0.553	0.522
	3.38 (±0.15)	0.207	0.061
	5.40 (±0.16)	0.718	0.133

Table 2. Results of weight optimization of CSC for 5 L of water

- Average concentration of controls (without biosorbent) =2.76 ppm

Average weight of CSC (g)	Average Amount adsorbed (ppm)	% adsorbed	Observation	
			Just after filtering	4 days after filtering
5.05 (±0.21)	0.256	9.3	Light yellow	Light yellow
10.12 (±0.23)	1.11	40.2	No Colour; Little turbid.	No Colour; Little turbid.
20.25 (±0.14)	2.76	100	No colour; Not turbid	No colour; Not turbid
30.31 (±0.33)	2.76	100	No Colour; little dark due to charcoal deposition	No Colour; little dark due to charcoal deposition

The results of the community trials 1and 2 in the Rainy season are in Table 3. This study was done in the rainy season with 20 g/5 L shaken 10 times /every 5 minutes for 1 hr. It was observed that nearly 49% of Fe was removed by 20 g of CSC in 5 L in both trials.

Table 3: Results of community Trial 1 and 2- Rainy season

Sample House No.	Av: % of total Fe adsorbed in Trial 1	Av: % of total Fe adsorbed in Trial 2	Observations
1	49.8 (±0.2)	48.2	No colour
2	48.8 (±0.1)	49.0	
3	49.0 (±0.5)	48.2	
4	47.2 (±0.2)	48.1	
5	49.7 (±0.4)	49.0	
6	49.3 (±0.1)	48.9	
Average concentration of controls (without bio-sorbent) =5-12 ppm			

When treated water was used to wash pillowcases, they remained white in colour; no stains were in the porcelain cups. Interviews with householders encountered two problems in the treatment process-shaking once every five minutes and filtering using a single cloth was not satisfactory since it allowed fine particles of charcoal (might have resulted due to shaking or with wetting) to go through. If the above problems can be solved, they will be satisfied with the treatment. Therefore, a feasibility study had to be carried out to see the effect of shaking. The results of the Feasibility study on the effect of shaking are given in Table 4. It showed that there was no significant effect of shaking on Fe adsorption by the CSC.

Table 4: The effect of shaking on Fe adsorption.

Sample No.	Av: % of total Fe Adsorption		
	Shaken twice	Shaken every 5 min.	Unshaken
1	39.5 (± 0.5)	49.8 (±1.2)	49.2 (±0.2)
2	39.0 (±0.3)	49.8 (±0.8)	50.5 (±0.7)

Table 5: Results of the effect of CSC in a sac on Fe adsorption

Sample 1 (5L)	**Average [Fe] (ppm)**	**Av: total Fe Adsorption**	**Av: % of total Fe adsorption**
Control	2.200 (±0.1)		
Sac only	1.624 (±0.2)	0.531	25
Sac + adsorbent	1.268 (±0.1)	0.887	42
Adsorbent only	(Sac+ ad.)- Ad. only	0.356	17

The results for the effect of using sac are given in Table 5. It shows that sac is also adsorbing a significant amount of total iron, thus reducing the adsorption by CSC. However, this must be tried with a different sac material in future. For the time being, it was decided not to use the sac. Therefore, Trials in the dry season were decided to carry out without shaking but with filtering (not using CSC in a sac). The results of the community trials in the dry season (3 & 4) are given in Table 6. In most cases, the Fe adsorption was more than 50%.

Table 6: Results of community trials 3 and 4- Dry season

Sample House no.	Average [Fe] (ppm) in water	Average % of total Fe adsorbed by 20g
1	2.2 (±0.2)	53
2	1.5 (±0.1)	37
3	1.6 (±0.1)	78
4	3.8 (±0.3)	90
5	1.8 (±0.2)	76
6	2.8 (±0.3)	64

Test results of treated water for drinking water chemical parameters (Table 7) confirmed the Fe reduction by CSC, and in addition, it showed that Cl^- and turbidity are also reduced to below the allowable level, while TDS, total hardness and SO_4^- levels are also reduced.

Table 7: Test for drinking water quality chemical parameters[3]:

Water sample	Color (Haz.)	Turbidity (NTU)	pH	TDS (ppm)	[Cl^-] (ppm)	[$CaCO_3$] (ppm)	[F^-] (ppm)	[PO_4^-] (ppm)	To. Hardness (ppm)	[Fe] (ppm)	[SO_4^-] (ppm)
Untreated	8	21	7.16	1760	428	400	0.02	0.5	555	1.40	45
Treated	0	0.4	7.63	**1062**	**183**	450	0.09	0.7	**300**	**0.03**	**31**
Max limit	15	2	6.5-8.5	500	250	200	1	2	250	0.3	250

Free NH_3, NO_3^-, and NO_2^- were lower than the detection limit.

CONCLUSIONS/RECOMMENDATIONS

- Crushed 20 g of CSC was able to adsorb 49%-50% of total Fe in 5 L of tube well water without shaking, preventing colour formation for at least 4 days.
- Treated water can be used for washing without discolouration.
- Crushing 20 g of CSC can bring down the level of Fe, Turbidity and Chloride to accepted level.
- Further studies have to be carried out to make the purification method more user-friendly.

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