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Local technologies for removal of hardness in groundwater

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ABSTRACT

Groundwater is the major natural resource in Jaffna peninsula and it is used for all purposes. Jaffna peninsula is underlain by a Miocene limestone aquifer which is the main source for hard water. Considering problems of water hardness its removal is essential to prevent from health hazards and to get soft tasty drinking water. Five treatments were selected during the preliminary test as 30 minutes boiling, four hours aeration, overnight aeration, two hours aeration plus ten minutes boiling and electrocogulation running time for 20 minutes. Different hardness content groundwater sources were selected. Raw water samples and treated water samples were analysed for pH, electrical conductivity, chloride, alkalinity and hardness. Aluminium residue also was checked to electrocoagulated water. Raw water hardness was varied from 244 mg/l to 883 mg/l but the SLS maximum desirable level is 250 mg/l which express the severity of the hardness problem . Very low average reduction of 36.7% was got in electrocogulation but it is mostly suitable for high degree of hardness area. The reduction range varied from 10.7 to 68.2% in four hours aeration. The reduction percentage was greater than 40 to 80% of the selected well in overnight aeration. Reduction pattern is nearly equal to boiling and two hours aeration plus ten minutes boiling. Highest average percentage reduction of 56.5 was achieved in boiling. Reduction level was higher than other treatment in boiling to 65% of the selected well water. In addition to hardness test chloride, alkalinity was not significantly changed to treated and fresh raw water. Treated water alkalinity and electrical conductivity were less than raw water. Boiling and boiling with aeration were selected as a suitable treatment to most of the area water and boiler was design without evaporation loss of water. The 50% of hardness was reduced by designed filter. Design filter can be used as domestic treatment to get soft water with low cost.

INTRODUCTION

The groundwater is dynamic, replenishable and dependable earth resource which acts as a viable substitute to the surface water supply in many countries (Sharma *et al*., 2007) which is expected to be one of the most critical natural resources in the twenty-first century.Groundwater is an important source of water for human consumption in many parts of the world and is occurring in large quantities in the rock formation in the earth crust (Cooray, 1984).Groundwater constitutes 97% of global fresh water and is an important source of drinking water in many regions of the world including Sri Lanka (Panabokke and Perera, 2005).A great deal of emphasis has been given to the study of hydrogeological systems in the dry zone areas of Sri Lanka, as the consumption of groundwater for domestic and agricultural purposes has increaseddramatically over the last few decades (Christensen and Dharmagunawardhane, 1986).Groundwater is the major natural water resource in the Jaffna peninsula and it is used for domestic, agricultural and industrial purpose. Jaffna peninsula has a source of groundwater store in the sub terrain layer of the limestone is the main aquifer. It is an excellent aquifer for storage because the aquifer has several isolated caves and caveins capable of storing groundwater without evaporation losses (Arumugam, 1970). However, the region experiences groundwater problems as the resource is limited and its quality has deteriorated over the years (Navaratnarajah, 1994)

The hardness of the water is much high in Jaffna peninsula becauseof miocene limestone aquifer.The groundwater contains dissolved salts and other constituents depending on the geochemistry.Therefore, groundwater must have an important bearing on the health of the population (Dissanayake, 2005). The presence of different chemical andphysicalconstituents in excess of their permissible limits for various uses can create health hazard and environmental problems (Al – zarah, 2007).

Among water quality parameters, hardness has always been investigated as an important factor (Saurina *et al*., 2002). Moreover, water hardness is an essential parameter in industrial water consumption in manufacturing of high quality products (Viero *et al*., 2002).Water hardness originates from existence of cations such as calcium, magnesium; and in lower traces; aluminium, iron and other bivalent and trivalent cations. Among them hardness causes ions, calcium and magnesium are identified as main factors of hardness (Padmasiri and Jayawardene, 2011). Probably high value of hardness indicates the richness in the calcium and magnesium. If hardness is greater than 150 mg/l, it called as hard water. High amounts of calcium and phosphate in the drinking water may accelerate stone formation in the bladder. Due to the hard water consumption, people in the area suffer from calculi in the urinary tract (Sivarajah, 2003).

Hard water causes many problems in domestic and industrial consumptions like scale formation in hot water pipes, kitchen devices, water supply facilities, boilers, cooling towers, membrane clogging, dealing efficiency of heat exchangers (Saurina*et al*., 2002).The water hardness are above 200 mg/l may cause scale deposition in the distribution system. According to the National Water Supply and Drainage Board records, most of the supplywells groundwater hardness is greater than SLS maximum desirable level.Public acceptance of hardness varies from community to community, which creates a lot of problems for life and industry (Mameri, 1998). Considering the problems of water hardness, its removal is essential (Kawamura, 2000).Hence removal of hardness for drinking is essential to prevent from the health hazards and to get tasty soft water for drinking. There are various techniques for removal of hardness each with its own special advantages and disadvantages (Malakootian*et al*., 2010). However, most are high cost technology. A large scale treatment for hardness is highly expensive and complicated. Hence the study was aimed to find suitable low cost technology to remove the hardness from the drinking groundwater and design of filter with local methods of hardness removal for drinking groundwater with sustainability and local economic stimulus.

MATERIALS AND METHOD

Selection of wells and collection of water sample

Altogether twenty wells were selected, in which twelve wells from National Water Supply scheme wells and other from randomly selected wells from Jaffna Peninsulla with different hardness value. Each water samples were poured into plastic bottles after rinsing several times with the sample water. Sample water EC, pH and temperature were measured on spot and the sample bottles was tightly closed and labelled. Then samples were taken to the National Water Supply and Drainage Board, Jaffna for chemical analysis. Samples were drawn from the selected wells at bottom level from 2011 December to 2012 February.

Preliminary study

Boiling, aeration, aeration after boiling, boiling after aeration, electrocoagulation and filtration were used in preliminary study to select the appropriate treatments.The processing time was changed in aeration and boiling to find the low cost and high efficient treatment time. Electrocoagulation unit which is 20 V and has six aluminium plates was used to treat the water sample for a period of 20 minutes.

Chemical Analysis

Water samples were analyzed for pH, electrical conductivity, chloride, total alkalinity, and total hardness, based on Sri Lanka standards 614: part 1 (1983) before and after the treatment process. Table 1 shows the methods of analysis and chemical used in each analysis of parameters. Residual aluminium in treated water was analysized and compared with SLS drinking water standard.

Table 1 - Drinking water quality parameters and method of analysis

Parameters	Method	Chemicals used
1. Chloride	Mohr's titration	0.02N AgNO3 solution
2. Total alkalinity	Acid-base titration	0.02N HCl
3. Total hardness	EDTA titration	0.01N EDTA
4. pH	pH meter	-
5. EC	EC meter	-
6. Residual aluminium	spectrophotometer	-

Design of filter

Designed filter has three component; as aeration unit, boiler and sand filter. The bubble aeration type was given to the aerator can which has the outlet tap near the bottom part. A boiler was designed with two vessels to ensure the loss of water due to evaporation. Small vessel was kept on the top of the other vessel. An inlet and outlet were given to both vessels. Valves were fitted to the inlet and taps were used in outlets. A pipe was connected between the outlet tap of top vessel to inlet of bottom vessel to pass the top water to bottom vessel. Inlet of the top vessel pipe was connected with aerator water can tap water tap to get the aerated water. An outlet tap was fitted on the middle of bottom vessel which was used to collect the boiled water.A sand filter was designed to remove the suspended particles and calcium scale of the boiled water. The pebbles were placed to six centimetre and then sand was placed to 20 cm height finally charcoal in the top to three centimetres.

Analysis

Hardness reduction percentage was calculated. Values of water hardness, EC, pH, alkalinity, and chloride were compared for raw and treated water to see the effect of treatment in the parameter. Statistical analysis was done to compare the mean hardness reduction percentage among the treatments.

RESULTS AND DISCUSSION

Distribution of hardness of selected wells

Figure 1 shows the total hardness of selected wells ea raw water. The value of hardness varied from 244 mg/l to 883 mg/l. Of the twenty wells measured, result showed that 95% of the wells were above the recommended SLS maximum desirable level of 250 mg/l, in which 5% of wells had above SLS maximum permissible level of 600 mg/l. Probably high value of hardness indicates the richness in calcium and magnesium. The highest value of hardness was observed as 883 mg/l at Karainagar. Only Velanai well water hardness was less than SLS maximum desirable level and all other well waters were hard which confirmed that there was a problem of hardness in Jaffna Peninsula and is a necessary to remove the hardness from the groundwater.

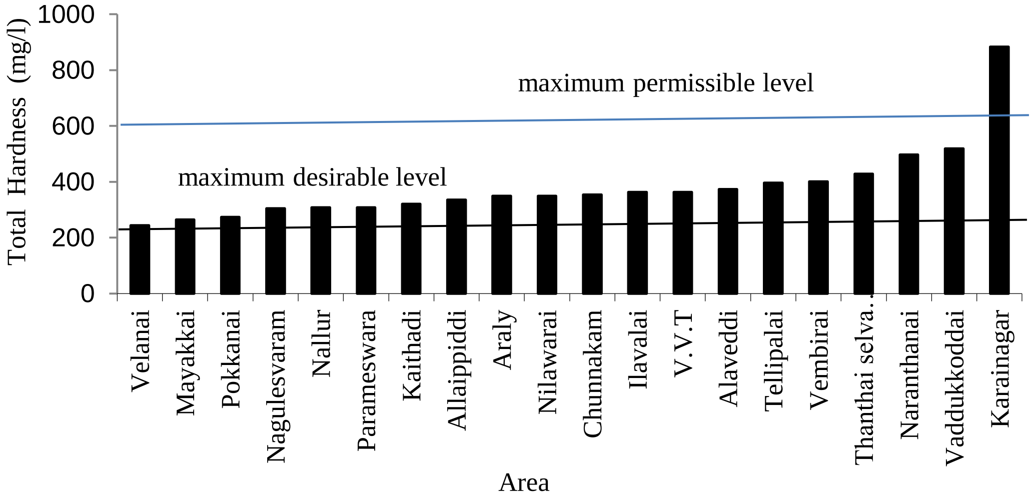

Figure 1 - Total hardness of the selected wells

Selection of treatment from preliminary test

From the preliminary study, five efficient and effective treatments were selected considering with running time and percentage reduction of hardness which were electrocoagulation (20 minutes running time), four hours aeration, overnight aeration, two hours aeration plus ten minutes boiling and thirty minutes boiling. Percentage reduction of total hardness was increasing in decreasing rate with boiling time, in addition to that water loss also increasing in increasing rate with time. Water loss in 5 minutes boiling was negligible however, the % reduction of hardness was very low but in one hour boiling 94% of hardness reduction was achieved with the water loss of 51%.Mean time it wasn't an economic one due to loss of water and cost of boiling. At the same time concentration of chloride was double of the raw water due to the saturation of water. Again this creates the problem of acceptance and suitability for drinking purposes so that 30 minutes boiling was selected as a treatment in which the quality of treated water wasn't changed with 80% reduction of hardness and 35% of water loss.

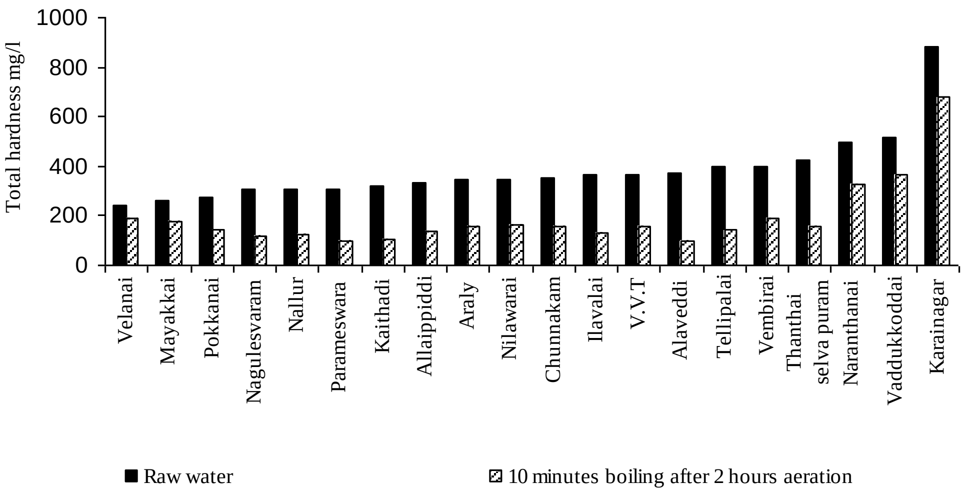

Figure 2 - Total hardness of raw and 10 minutes boiling after 2 hours aerated water

The figure 2 shows the raw and treated water hardness due to ten minutes boiling after two hours aeration as one example. Aeration is a common practice to aerate water to remove CO2, since CO2 is an acidic gas, its removal tends to decrease H+ and raise the pH.Malakootian*et al.*, 2009 stated that with pH increase, the rate of hardness removal increase. Even though the pH changes with aeration and it was less than the recommended SLS maximum permissible level (pH 6.5- 9). Figure 3 shows the percentage reduction of hardness through electrocoagulation and it varies from 15% from 60% for selected wells.

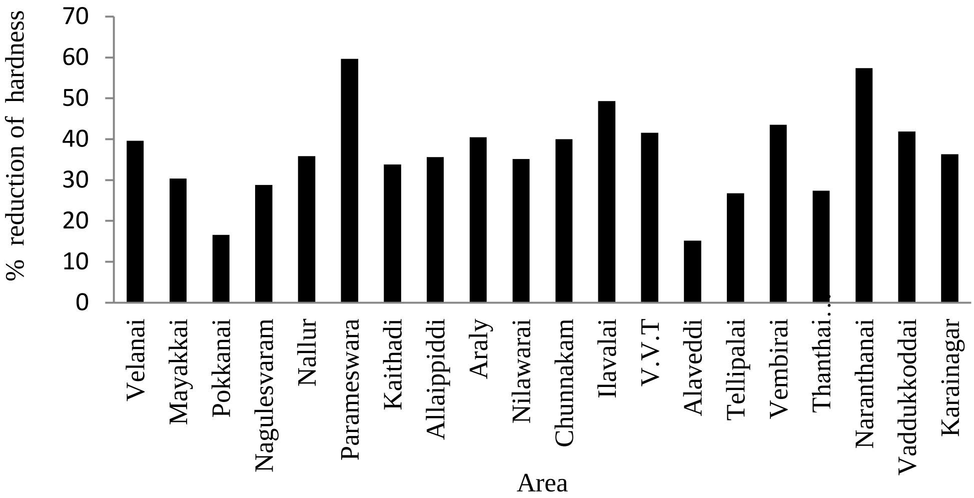

Figure 3 - Percentage reduction of total hardness through electrocoagulation

The hardness reduction range was varied from 10.7 to 68.2% in four hours aeration. The reduction percentage was greater than 40 to 80% of the selected well in overnight aeration. Higher reduction was achieved to Alaveddi water which was 73.4% and lower reduction was achieved to Velanai water as 22.6% for 10 minutes boiling after 2 hours aeration in selected area well water. Mean time higher reduction % was recorded to Alaveddi water which was 89.9% and lower reduction was recorded to Karainagar water (11.4%) in boiling.Reduction pattern was nearly equal to boiling and two hours aeration plus ten minutes boiling.

Significance of the selected treatments

Table 1 shows the mean reduction of the hardness with standard deviation. The percentage reduction of hardness were significantly ($p<0.05$) differed between different treatment. The boiling treatment has highly significant effect followed by 10 minutes boiling after two hours aeration but there was no any significant different between boiling, 10 minutes boiling after two hours aeration and overnight aeration. Usually the peoples are doing the boiling in domestic to remove the hardness but the problem was the duration of the boiling and temperature. Least effect was observed for electrocoagulation and four hours aeration but no any significant variation between electrocoagulation and four hours aeration. Electrocoagulation is the best suited method for hardness removal with cost involvement for high hardness water. But here the low average reduction percentage for electrocoagulation was due to selected water hardness which were medium and low.

Table 2 - Mean reduction of hardness to treatments

Treatments	Mean	SD
Electrocoagulation	36.77^{c}	11.28
Four hours aeration	35.70^{c}	15.47
Overnight aeration	$45.57^{a,b}$	11.15
2 hours aeration plus 10 minutes boiling	$52.12^{a,b}$	15.39
Boiling	56.54^{a}	18.97

Means with the same letters are not significantly different at alpha 0.05 in Duncan's separation.

Hardness reduction

The figures 4, 5 and 6 show the percentage reduction of hardness for different raw water hardness. The figure 4 shows the percentage reduction of hardness for less than 300 mg/l hardness water. The process of removal of hardness is not essential to low hardnesswater however boiling was suitable one.

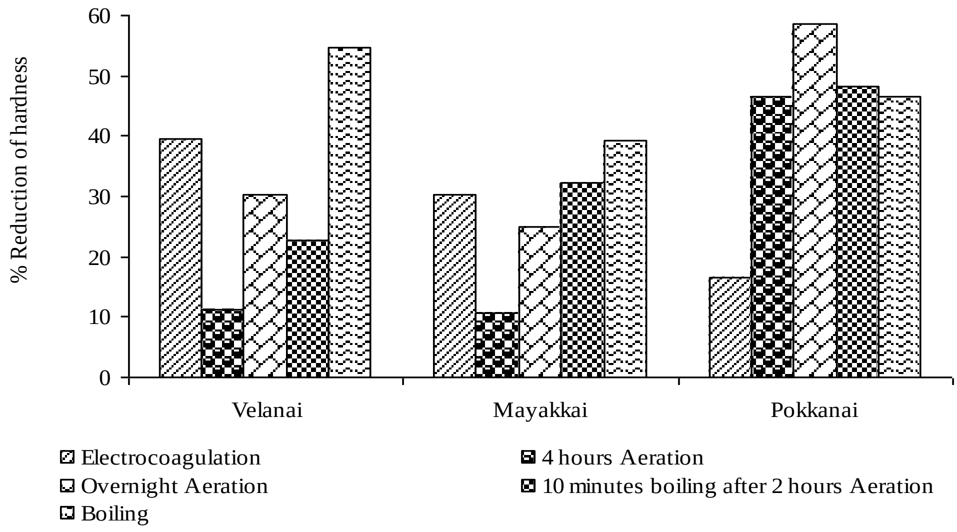

Figure 4 - Percentage reduction of hardness in low hardness area's water

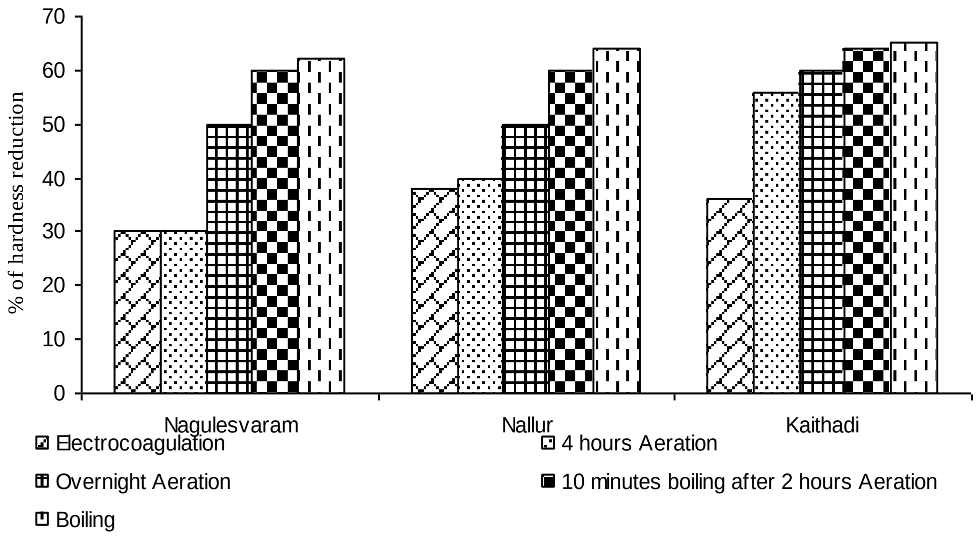

Figure 5 - Percentage reduction of hardness in medium hardness area's water

Overnight aeration, 10 minutes boiling after two hours aeration and 30 minutes boiling was suitable for medium level hard water (300 – 428 mg/l) and shown in figure 5. For high hard water (greater than 428 mg/l) electrocoagulation was suitable method which is a one of the advanced technology however low cost compare to other methods. Residual aluminium also was found in treated water through electrocoagulation but that it was less than SLS maximum permissible level.

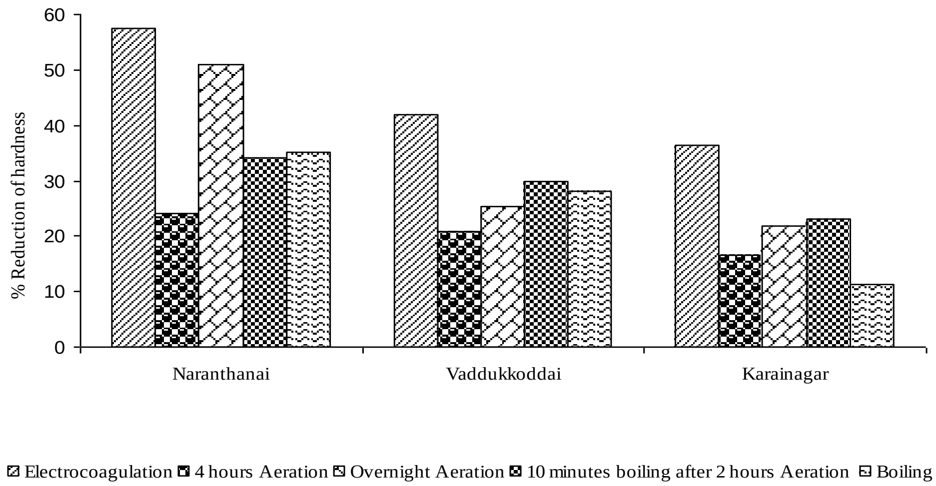

Figure 6 - Percentage reduction of hardness in high hardness area's water

Reduction level wasn't depending on the level of raw water hardness which changes with other chemical parameters. There was no any significant change in chemical parameters of chloride, and alkalinity.Electrical conductivity was reduced and also according to Padmasiri, 2011 in the bench scale model, electrocoagulation reduces the EC of water. But pH was slightly increased by the formation of calcium carbonate but it was less than SLS permissible level. Boiling and aeration were recorded as efficient method for more range of hardness water so this one was selected to design an appropriate filter for local community.

Design Filter

The figure 7 shows the outline of the designed filter with boiling and aeration. Traditional technology of boiling of water in pots was the disadvantage of evaporation loss and boiling duration and temperature. This designed filter will overcome the problem of loss of water. The designed filter could be used as efficient method to remove hardness without any evaporation loss.

CONCLUSION

Raw water hardness was varied from 244 mg/l to 883 mg/l which ensure the problem of hardness in Jaffna Peninsula. The maximum percentage reduction of 56.5% was recorded in boiling. Two hours aeration after 10 minutes boiling and Boiling were selected for suitable method for medium hard water. Removal of hardness not necessary for hardness less than 250 mg/l however boiling is suitable for this water. Electrocoagulation was selected as best treatment for high hardness water. Removal of hardness changes the electrical conductivity, alkalinity and pH, no any effects to the chloride. Also all tested chemical characters were reduced to all treatments except boiling of Karainagar water for electrical conductivity. But pH of all selected wells were increased slightly. Boiler was designed without loss of evaporation water. The designed technology could be used as domestic treatment to get soft water in low cost for households.

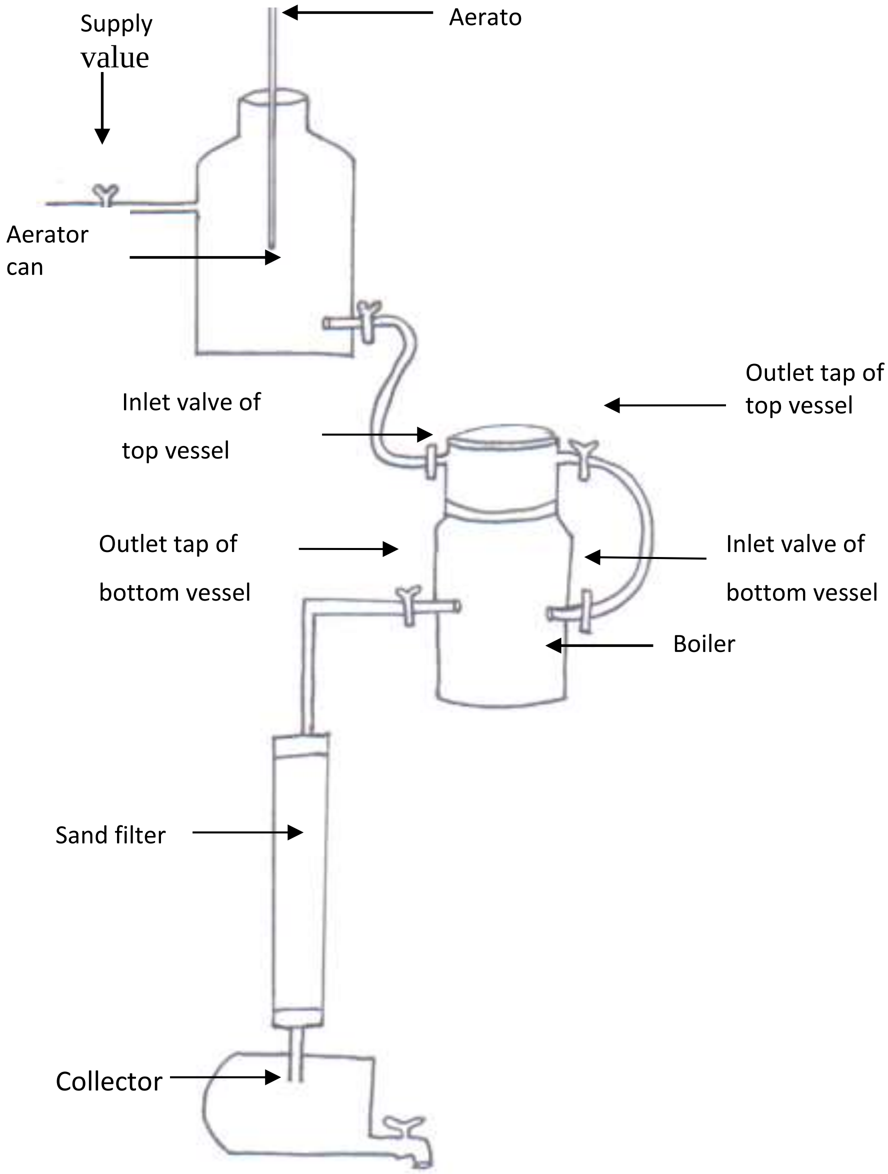

Figure 6 - Diagrammatic view of designed filter

REFERENCES

- Al-zarah, A.I. 2007.Hydrogeochemical processes of Alkhobar aquifer in Eastern region, Saudi Arabia. Journal of Applied Sciences. 7(23): 3669 – 3677.
- Arumugam, S. (1970). Development of groundwater and its exploitation in the Jaffna Peninsula. Paper read at the Annual conference, October 1970. The Institution of Engineers, Ceylon
- Christensen, H. and A.H. Dharmagunawardhane. 1986.Behavior of some chemical parameters in tube well water in Matale and Polonnaruwa districts. Sri Lanka Association for the Advancement of Science, 25-43.
- Cooray, P. G. (1984). An introduction to the geology of Sri Lanka, National museum of Sri Lanka, Colombo. P-225.
- Dissanayake, C.B. 2005.Water quality in the Dryzone of Sri Lanka – Some interesting health aspects, Journal of Science Foundation, Sri Lanka. 33(3): 161 -168.
- Kawamura, S.2000. Integrated design and operation of water treatment facilities, New York, John Wiley & Sons, 510 – 523.
- Malakootian, M., Mansoorian, H.J. and M.Moosazadeh, 2010. Performance evaluvation of electrocoagulation process using iron – rod electrodes for removing hardness from drinking water. Desalination, 255: 67-71.
- Mameri ,N . 1998. De fluoridation of septentrional Sahara water of north Africa by electro coagulation process using bipolar aluminum electrodes, Water Research, 32 (5) : 1604 – 1612.
- Navaratnarajah, V. (1994). Water problems in the Jaffna peninsula, 20th WEDC International Conference in Affordable water supply and sanitation. 1994, Colombo, Sri Lanka. pp.191- 193.
- Padmasiri, J.P. and W.M. Jayawardene. 2011. Water purification using electrocoagulation as a viable solution for upgrading rural water supply schemes. Water professional day symposium. pp 63-68.
- Panabokke, C.R. and A.P.G.R.L. Perera. (2005). Groundwater resources of Sri Lanka. Water resources Board. Colombo. pp-1-3.
- Saurina, J. 2002. Determination of calcium and total hardness in natural water a potentiometric sensor array, AnalyticaChimicaActa 464: 89–98
- Sharma, G., Gupta, N., Gupta,V.,Gupta,S.,Singh,R.P.and S.K. Upadhyay. 2007. Environmental aspects of groundwater resources deterioration in the city of Taj, GQ07 securing groundwater quality in Urban and Industrial Environment, Proceeding of 6th International quality conference held in Fremantle, Western Australia, 2-7 December 2007.
- Sivarajah, N. 2003. Health related problems of water pollution in Jaffna. International workshop on environmental management in north – east Sri Lanka. 1st – 4th December, 2003. Jaffna, Sri Lanka. pp.89-94
- Sri Lanka Standard 614: part 1 1983. Specification for portable water physical and chemical requirements. pp 5-10.
- Viero, A.F., Mazzarollo, A.C.R., Wada, K. and I.C.Tessaro. 2002. Removal of hardness and COD from retuning treated effluent by membrane process.149:145-149.