THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Design and Study of Low Cost Household Drinking Water Treatment Process for Rural Areas

Atish Kumar
MSc.II (Environmental Science)
Bharati Vidyapeeth Institute of Environmental Education & Research, Pune, India
Milind R. Gidde
Professor, Department of Civil Engineering
Bharati Vidyapeeth University College of Engineering, Pune, India

Abstract
As we know that, surface water and ground water are polluted because of anthropogenic activity. So, to address the widespread need of safe water for drinking purpose, a low cost water treatment process can serve as a subsidy such that every family can take advantage of this luxury. In this paper, literature review of existing water treatment processes have been completed and design of a low cost water treatment process is developed. Water flow rate tests are carried out to optimize water treatment plant design. The processes are based on simple and natural techniques which consist of Screening, Natural aeration, Sedimentation, Filtration media- Gravel, Sand, charcoal) and Disinfection by SODIS method that empowers people anywhere in the world to create affordable and effective water treated out of locally available materials. The cost of manufacturing a unit is calculated to be Rs.245, which is an affordable price for people in rural areas. With a low cost water treatment process, residents in the rural areas could enjoy having safe drinking water and improve quality of life.
Experimental investigation was carried out to study the removal efficiency of turbidity, TSS, TDS, and bacterial population (MPN) in drinking water, and got 89.53% removal efficiency for turbidity, 91.56% for TSS, 62.19% for TDS, 100% bacterial removal and the dissolve oxygen level was increased by 20-25%.
So, after treatment of water through the designed model, it shows a greater efficiency in removing all these above mentioned water parameters and it will serve clean and pathogen free water to rural areas.

***Key words**: Filtration, Natural aeration, Screening, Sedimentation, SODIS*

1. Introduction

"Water is the driver of life'' exists in many forms in the nature .however chemically pure water does not exist for any appreciable length of time in nature, rain water is the purest form of naturally occurring water, but due presence of different pollutants in atmosphere it become contaminated.

A considerable amount of water is frozen to form ice. About 97% of the Earth's water is in the oceans which is unfit for human consumption. The mass balance of rainfall shows that about 70% has lost by direct evaporation and transpiration by plants while the remaining 30% goes in to streams. About 1.6 million people die every year from diarrheal diseases (including cholera) attributable to lack of access to safe drinking water and basic sanitation and 90% of these are children under 5, mostly in developing countries. Approximately 150 million people are infected with schistosomiasis causing tens of thousands of deaths yearly; approximately 500 million people are at risk of trachoma from which 146 million are threatened by blindness and 6 million are visually impaired. Intestinal helminthes (ascariasis, trichuriasis and hookworm infection) are plaguing the developing Countries due to inadequate drinking water with 133 million suffering from high intensity intestinal helminthes infections, there are around 1.5 million cases of clinical hepatitis every year (World health Organization 2009).

To provide safe and pathogen free drinking water, a low cost drinking water treatment model is designed. It may helpful for rural areas because of this is a low cost drinking water treatment process through natural and simple techniques and which is made up of locally available materials. It will provide safe drinking water and free from pathogens, the basic processes are followed in this process are Screening, Natural aeration, Sedimentation, Filtration (consist of sand, gravel, charcoal), and Disinfection by SODIS method.

2. Objectives

- To Design low cost water treatment process for rural households.
- To determine the efficiency designed unit.

3. Materials and Methods

3.1. Materials required
For designing of model following materials are required:

Items	Description	Quantity
Plastic bottle	2 liter	4
Plastic bottle	1.5 liter	3
Plastic bottle	1 liter	1
Wire mesh	1mm x 1mm	2
Sand	1mm - 1.5mm	1 kg
PVC pipe	15 mm	1 ft.
Fine Gravels	5-10 mm	500 gm
Coarse gravels	20-25 mm	1 kg
Charcoal pieces	20-25 mm	250 gm

Table 1: Description of materials required for construction of model

3.2. Construction of Model

Figure 1: Construction of model

First of all designing of the processing unit should be done which involves following processes

3.3. Screening
It is the first stage of treatment process in which the large floating particles (Such as piece of wood, leafs, plastics etc.) can be removed.

A cold drink bottle of 2 lit was cut horizontally to remove a quarter upper portions of that, a wire mesh was provided at the opening of bottle to provide screening.

3.4. Natural Aeration System
The bottles which were used for screening are arranged horizontally and the bottom side was provided by the small holes. Other same sized bottles are cut horizontally and arranged linearly vertical. The middle bottle also having holes at the bottom and other one is intact, as shown in fig

The liner assay was done for providing natural aeration to the water. The water falls from one bottle to another by the gravitational force allowing interaction of gases with atmosphere.

3.5. Sedimentation
The assembly was connected to the sedimentation unit by the PVC pipes from the last bottle. Sedimentation unit consist of 3 bottles of 1.5 lit. The 3 bottles are kept inverted and are arranged one besides one (vertically linear). Bottles are attached by the pipe at the upper portion.

The water pass through sedimentation unit at slow flow rate and the suspended and large colloidal particles tends to settle down at the bottom of bottle due to gravity

In this process finer particles are removed which can no be removed by sedimentation process. Sedimentation is followed by the filtration unit. A bottle was cut with its bottom portion and set inverted. The filter media consists of coarse gravels, fine gravels, charcoal, coarse sand and fine sand and known as sand bed filter through which water is allowed to pass.

3.6. Filtration

This process removes the turbidity as well as TSS and TDS also get removed, because charcoal granules are used in the filter media which is a good absorbent, this filtration method is called as sand filtration.

3.7. Preparation of media

Following step were followed for preparation of filter media:

Steps		Image
1.	A 2 liter bottle was taken and the base of bottle was cut off, then a wire mesh (1mm x 1mm) placed at the top side for preventing the gravel from falling through the opening.	
2.	Coarse Gravels (20-25 mm) were added up to 6 cm Quantity- 850 gm	
3.	Charcoal granules (20-25mm) were added about 3 cm Quantity- 100 gm	
4.	Then fine gravels(10-12 mm) were added about 2 cm and on the top layer of filter sand(1-1.5mm) were added about 7 cm Quantity of fine gravels – 200gm Quantity of sand - 500 gm	

Table 2: Preparation of filtration media

3.8. Disinfection

One of the most promising methods of removing microbiological organisms associated with waterborne diseases is solar water disinfection, more commonly known as SODIS. This particular application of solar UV radiation and solar heat has been developed by the Swiss Federal Agency for Environmental Science and Technology (EAWAG)

The premise of the SODIS system is simple: it functions by inactivating waterborne microbes as a result of exposure to UV-A radiation and heat (pasteurization). Water of low turbidity (<30 NTU) is placed in clear PET plastic or glass bottles (clear plastic bags may also be used). The water is then aerated by vigorous shaking in contact with air, as the deactivation of bacteria has shown to be more effective in oxygenated water than in anaerobic conditions. This water is then exposed to direct sunlight for several hours (the official SODIS website recommends 6 hours) so that it becomes sufficiently heated and exposed to UV radiation for 6-8 hours, both of which inactivate microbes in the water. If there is extensive cloud coverage, as many as 2 days will be needed for sufficient exposure to UV radiation. The system is suitable for treating small volumes of water (<10L), and water that is relatively clear (corresponding to a turbidity of <30 NTU)

Figure 2: Half painted bottle which is used for Disinfection process
Figure 3: Exposed horizontaly to the sunlight

3.9. Collection of Water Samples

Site of sample collection- Samples are taken from three different sites during the month of August, September, October, for the efficient checking of the removal of the different concentrations of different parameters, for better interpretation of output.

- Site a – Katraj lake (Sample 1)
- Site b – Ambegaon lake (Sample 2)
- Site c – Fish tank (BVIEER) (Sample 3)

"Grab Sampling" technique was used for sampling

3.10. Pretreatment Analysis

All the collected samples were analyzed by six parameters to evaluate the initial characteristics before the treatment is given and the procedure for each parameter are as follow:

- pH
- Turbidity
- Total dissolve solids
- Total suspended solids
- Dissolve oxygen
- MPN

3.11. Treatment of Water Through Model

Pass the water from the designed model at constant flow rate0.5 liter/minute

3.12. Post-Treatment Analysis

The same parameters which were analyzed before the treatment of raw water were analyzed for treated water after the treatment. e.g. - Turbidity, Total Dissolved Solids, Total suspended solids, MPN, Dissolved oxygen, pH…

3.13. Determining the Efficiency

The results of pre and post treatment were analyzed and following equation was used to evaluate the efficiency of designed model.

$$\text{Efficiency (\%)} = \frac{c_i - c_f}{c_i} * 100$$

Where,

- Ci = Initial Concentration
- C_f= Final Concentration

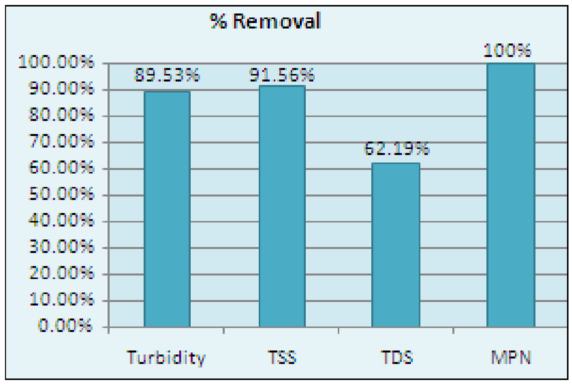
4. Results

- **Total Turbidity Removed**
  Maximum turbidity from all the samples were noticed 171.4 NTU and removed up to 9.8 NTU, and the according to Indian standard permissible limit for turbidity is 10 NTU
  So, the average efficiency of total turbidity removal is 89.53%
- **Total Suspended Solids Removed**
  Maximum TSS amongst all the samples were noticed 2822 mg/l and removed up to 160 mg/l,
  So, the average efficiency of TSS removal is 91.56 %

- **Total Dissolve Solids Removed**
  Maximum TDS amongst all the samples were noticed 1330 mg/l and removed up to 480 mg/l, and the desirable limit for TDS is 500. So, the average efficiency of TDS removal is 62.19 %.
- **Increase in Dissolved oxygen**
  The Dissolved oxygen level was increased by 20-25%
- **Most Probable Number of bacteria (MPN)**
  The highest initial bacterial number found in samples was 155 organisms per 100 ml, after treatment the sample was showing nil results. So, the efficiency of bacterial removal by SODIS method is 100 %.

5. Removal Efficiency

The efficiency of model is determined by determining the removal efficiency of each parameter.



Graph 1: Removal efficiency of different parameters of different samples

6. Discussion

In rural areas high rate of water born diseases are due to contamination of water from different sources. This tentative finding of study shows that the sand filter media which consist of charcoal granules are more capable of removing Total Dissolved Solids. Natural Aeration provides efficient disinfection by SODIS method.

7. Is the Project Sustainable..?

Many appropriate technologies and many water supply or treatment projects in the developing world failed due to high operation cost. I think this project might be sustainable because the used technology is natural, simple, and uses local materials.

8. Conclusion

The study focuses mainly on designing a low cost drinking water treatment process and to determine its efficiency and the designed treatment model can be adopt to treat the drinking water (source- Lake, Ground water, Streams). The results were obtained after designing and treatment. The average removal efficiency of Turbidity was 89.53 %, and the average efficiency for TDS was calculated 62.19%, where the TSS was removed up to 91.56% and the MPN average efficiency was 100%.
The materials used for preparation of this model are locally available and cost effective, this model can be used as a low cost water treatment technology.
Overall, conclusion can be derived that this model can be utilized to treat water for domestic purpose.

8.1. Advantages

- Low cost treatment.
- It is manufactured by local materials available in rural areas.
- The operation and maintenance is easy.
- No skill operation is require
- Natural process is used, no chemicals were required.

8.2. Drawback

- Disinfection process requires abundant solar radiation.

9. Acknowledgements

This gives me enormous pleasure to express my heartfelt gratitude to my admirable guide Dr. Milind Gidde (Professor, Dept. of civil engineering, BVDU, Pune) who has been guiding me consistently and encouraging me during the project. I would like to extend my sincere gratitude to BVIEER for allowing me to carry out my dissertation work and providing all the necessaries.

10. References

1. APHA, 2002, Standard methods for the examination of water and wastewater, 20thEdition. “American Public Health Association”, Washington, DC.
2. Ashok Gadgil (2008),”Safe and Affordable Drinking Water for Developing Countries” Mailstop 90R3058, Lawrence Berkeley National Laboratory 1 Cyclotron Road, Berkeley, CA 94720, pp. 176-191.
3. B. Dawney (2010), “Appropriate technology project: Optimization of SODIS water treatment method by decreasing turbidity” Engineering for Sustainable Development, Queen's University.
4. G.K. Rijal, R.S. Fujioka (2001), “Synergistic effect of solar radiation and solar heating to disinfect drinking water sources.” Water Science Technology, 43 (12):155-162,
5. Morris ElyaDemitry(2011)., “Simple and Appropriate Methods for Household Water Treatment” Utah State University, pp.15-21.
6. Sachin.S.Pandey (2010), “BSF-Low cost water treatment technology”, Institute of environment education and research bharatividyapeeth university katraj, Dhanakwadi, pune-43
7. Louis Chan, Marcus Chan, Jingwen Wang, “Design of Water Filter for Third World Countries”, Department of Mechanical and Industrial Engineering, 2009
8. R.H. Reed, "Solar inactivation of faecal bacteria in water: the critical role of oxygen." Letters of Applied Microbiology, (24) 276-280, 1997.
9. Lenntech Water Treatment Solutions, "Waterborne Diseases", 2010