Water purification: a sustainable technology for rural development

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Abstract: This study deals with the preliminary investigation on combined treatment with the coagulative ability of *Moringa oleifera* seeds to reduce turbidity and to determine the effectiveness of solar disinfection for the inactivation of *Escherichia coli (E. coli)* and coliforms on various turbid waters. Turbid water samples showed drastic reduction in microbial load and turbidity at time interval of 60 min settling with *Moringa oleifera* seeds at optimum dose of 0.12 gms where as solar disinfection showed drastic reduction in microbial counts (*E. coli* and coliforms) from too many to count to nil.

Keywords: environmental technology; water purification; *Moringa oleifera*.

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1 Introduction

In rural areas of developing countries, a large portion of women's daily work is to secure an adequate amount of potable water for their families. The severe exposure to water pollution has many harmful effects on human health. The toxins cause various water-borne diseases like Diarrhoea, Dysentry, Amoebiasis, Hepatitis, Typhoid fever, Cholera and Jaundice, which are fatal to human being (Sobsey, 2006). In recent years, risk management has attracted a great deal of attention from both researchers and practitioners. Complexity and uncertainty in many practical problems require new methods and tools. Risk management can be used as a tool for greater rewards, not just control against loss (Wu and Olson, 2009).

Unlike cities where fairly large population is using water filters, Aqua guards, UV-ultra filters, the rural population is thriving on the contaminated water supply owing to prohibitive cost and low availability of chemical coagulants and disinfectants and the heavy investment in settling up the conventional water treatment plants at village level is not only a theoretical exercise but practically impossible for several reasons. Such projections have prompted interest in using traditional methods for treating the water. *Moringa oleifera* seeds treat water on two levels, acting both as a coagulative and as antibacterial agent (Babu and Chaudhuri, 2005). It is generally accepted that Moringa works as a coagulant owing to positively charged water-soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxins, etc.) allowing the resultant 'flocs' to settle to the bottom and can be removed by filtration (Lye, 2002).

For many people in rural areas getting enough firewood is a problem. It is a difficult task on which most rural women spend several hours a day for gathering firewood or it must be purchased. This means that even when people know that they should boil all water for drinking, it is often not done. Hence, it is good to promote other simple method that could help people get safe drinking water and, therefore, avoid diseases. A potential alternative to the common disinfection methods mentioned previously is solar disinfection. Solar water disinfection is a process that entails filling a transparent bottle with water and placing it in the sun for several hours (Kehoe et al., 2001).

2 Materials and method

2.1 Sample collection

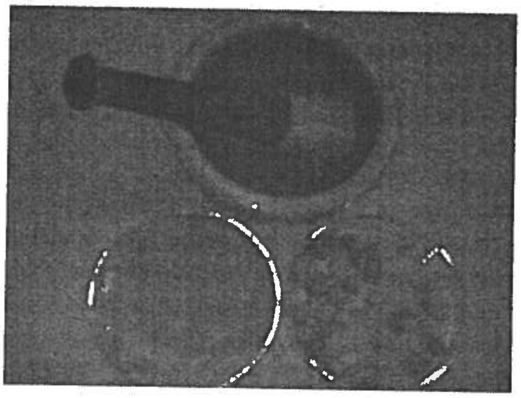
Turbid water samples were collected in plastic bottles of 1.5 l from different lakes i.e., Kukatpally lake, Pragathi Nagar lake and Medchal lake, Hyderabad, AP, India.

The physical appearance of samples was mainly turbid in nature and was contaminated by different sources like industrial sewage, municipal sewage and agricultural runoff.

2.2 Plant material

The Moringaceae is a single genus family with 14 known species. Of these, *Moringa oleifera* is the most widely known and utilised species (Sutherland et al., 1994). Dried pods of *Moringa oleifera* were brought from Horticulture Nursery Training Centre, Khammam district, AP, India. Seeds were separated from the pods and then pulverised using a clean pestle and mortar shown in Figure 1.

Figure 1 Fine powder of *Moringa oleifera* seeds



2.3 Coagulant solution preparation

The pulverised seed material of about 0.12 gms (optimum) was made into paste using little amount of water and mixed into 5 ml of clean water, which was shaked for 1 min to activate the coagulant properties of the seed to form a solution (Jahn, 1986). The solution was filtered through a muslin cloth (to remove insoluble materials) into the 500 ml of turbid water to be treated.

2.4 Disinfection bottles

Polyethylene Terephthalate (PET) bottles made of transparent, clear plastic, cylinder shape with a surface area of $23 \times 7.2 \times 6.0$ cm^3 were used for experimental purpose, as they are good transmitters of light in the UV and visible range of the solar spectrum.

2.5 Exposure time

The total exposure time of experiments varied from 2 h to 8 h. Sunlight is strongest from 10 am to 2 pm so initial experiments were conducted to encompass this time bracket by up to 1.5 h before and up to 3 h after (from 8:30 am to 4:30 pm).

2.6 Physico-chemical and microbial analysis

Samples were analysed before and after treatment for its potability using APHA (1988) (Cheesbrough, 1984) method. The turbidity of water samples was measured using the turbidity meter (ELICO CL 52 D). The *E. coli* and coliforms bacteria counts were enumerated on Eosin Methylene Blue and MacConkey, respectively, after 0.1 ml of the turbid water samples was aseptically serial diluted up to three fold.

2.7 Turbidity test

For estimating turbidity, we have used nephelometer CL 52D ranging 0–200 NTU, accuracy 3% full-scale non-linear, readability 0.1, repeatability 2% full scale based on formazine (hydrazine sulphate and hexamine) standards. Sample was run of known volume, in which the concentration of the particular ion/element to be estimated by nephleometric method, into a volumetric flask of the same volume. Samples were treated with the reagent and allowed it to stand to permit uniform turbidity formed in the flask. Sample was transferred into a separate marked test tube. Sample compartment lid was open and the sample-filled test tube was inserted into the compartment. The value of turbidity of the contents of the test tube was displayed on the readout. Concentration of the ion was deriving in the sample, by reading it off the calibration curve for the measured value of turbidity of the dispersant of the ion in sample.

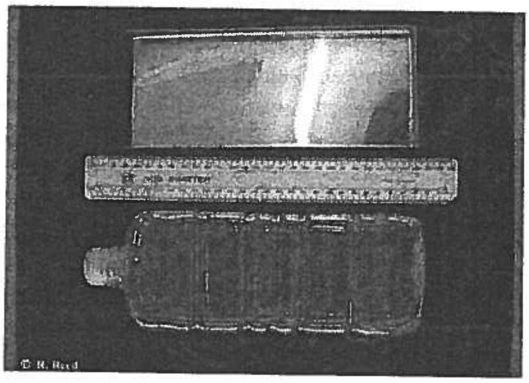
2.8 Methodology

Laboratory trials, carried out at Centre for Environment, IST, JNT University, Hyderabad, India, have compared the effectiveness of combined treatment with natural coagulants and solar disinfection for purifying turbid waters.

The dried seeds of *Moringa oleifera* were pulverised into fine powder. Small amount of clean water was added to the powder to form a paste. Paste was mixed into 5 ml of clean water and was shaked for 1 min to activate the coagulant properties and to form a solution. Solution was filtered through a muslin cloth and then poured into the turbid water. Entire set-up was kept for jar test method, where the sample was stirred rapidly for 1 min and then followed by slow stirring for about 5–10 mins. Then, the samples were kept for 30, 60 and 90 mins of settling time. After the particles and contaminants have settled to the bottom, the clean water was carefully separated. Then, the water was filtered through Watmann filter paper.

The water treated with natural coagulant was then poured into plastic PET bottles and was shaked for few minutes to get air in to the water, as oxygen helps to kill the bacteria. The bottles were placed lying down in a sunny place, to absorb more sunlight the bottles were placed on the black cloth depicted in Figure 2. Transparent bottles containing samples were placed indoors served as control. After 2 h of solar disinfection, bottles were placed in cool place. The water samples were analysed for its potability before and after treatment with combined treatment (natural coagulant treatment followed by solar disinfection). All of the experiments were performed in triplicate and the average values were presented.

Figure 2 Solar disinfection



3 Results

From the visual observation results, the turbidity of water samples was high with terrible odour, which was then decreased after treatment. The physical nature and microbial load of turbid water samples for the study area are given in Table 2. The turbidity reduction was observed in all treated samples when compared with control nevertheless it was high turbid (116 NTU) or low turbid (7.5 NTU) waters, which is shown in Figure 3. The turbidity reduction by *Moringa oleifera* seeds was observed in all samples when compared with WHO standards shown in Table 1.

Figure 3 Comparison of turbidity removal by *Moringa oleifera* seeds

Table 1 Drinking water standards

S. No.	*Parameter*	*WHO standards*
1	Turbidity	0–5 NTU
2	*E. coli*	0–1 Cfu/ml
3	Coliforms	0–10 Cfu/ml

Source: WHO (2005)

Table 2 Turbidity and microbial reduction before and after treatment with *Moringa oleifera* seed [optimum dose – 0.12 gms, settling time – 60 min]

Sample location	*Physical appearance*		*Turbidity (NTU)*		*Coliform counts* (Cfu/ml)		*E. coli counts* (Cfu/ml)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
Medchal	Very dirty, highly turbid with lot of suspended matter	Clear supernatant	116	10.5	TMTC	6000	TMTC	2000
Pragathi Nagar	Foul smell appearing greenish	Clear supernatant	22.5	1.0	TMTC	1000	TMTC	1000
Kukatpally	Rotten foul smell, appearing greenish	Clear Supernatant	7.5	0.75	90,000	500	TMTC	1000

The microbial load (coliforms and *E. coli*) reduction was seen in all samples in 60 min of settling time when compared with the other two 30 min and 90 min. The variance of reduction in different settling times might have occurred due to insufficient time for the reaction to complete in 30 min settling time and due to disassociation of proteins in 90 min settling time. The 60 min settling time can be opted as the optimum settling time for treatment as the drastic reduction of turbidity shown in Figure 4 as well as lowest reduction of microbial load was observed, which is shown in Figure 5.

Figure 4 Turbidity reductions with *Moringa oleifera* at different settling intervals

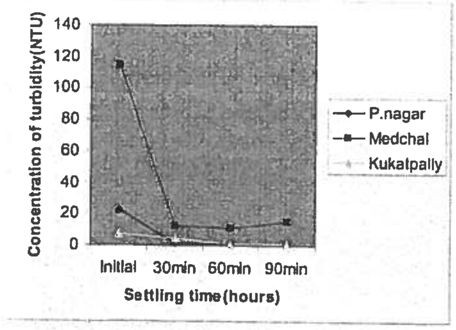
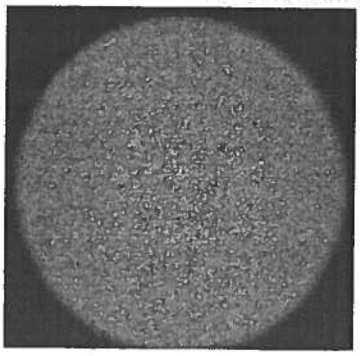
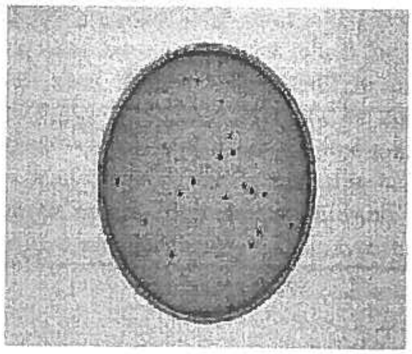


Figure 5 (a) *E. coli* colonies in turbid sample and (b) *E. coli* colonies after treatment with natural coagulant at optimum dose of 0.12 gms and settling time of 60 min



(a)



(b)

Water samples after treatment with natural coagulant were immediately exposed to solar disinfection for 2 h (11 am to 1 pm), the microbial load was reduced drastically, which shows no colonies in the plates where the UV rays had inactivated the micro-organisms shown in Table 3. For the present experiments, the normal plastic bottles with 0.1% UV transmittance (at the wavelength of 254 nm) had been used. The average temperature was 19°C at the beginning of the experiments, and also the average water temperature was obtained to be 39, 40 and 41°C after 2, 4, 6 and 8 h radiation time, respectively. As Table 3 illustrates, solar disinfection efficiency in *E. coli* and coliform reduction was determined to be 99.6, 99.8 and 99.9% at 5 h radiation time, respectively.

Table 3 Inactivation of microbial load of the turbid water samples after combined treatment at optimum dose of 0.12 gms, settling time of 1 h and solar disinfection of 2 h (11 am to 1 pm)

Sample location	*Bacterial species*	*Initial microbial load*	*Microbial load after natural coagulant treatment*	*Microbial load after solar disinfection*
Medchal	*E. coli*	TMTC	2000	Nil
	Coliforms	TMTC	6000	Nil
Pragathi Nagar	*E. coli*	TMTC	700	Nil
	Coliforms	TMTC	1000	Nil
Kukatpally	*E. coli*	TMTC	1000	Nil
	Coliform	TMTC	500	Nil

4 Discussion

The fruit extract can be practical for protection and to avoid risk of contamination by water-borne pathogens and to promote indigenous solutions for disease-control and environmental management (Ahmed et al., 2009).

This study shows that turbidity removed by natural coagulant at first stage of purification has increased the solar disinfection efficiency, and, in fact, it reduces the microbial inactivation when compared with individual treatment, which might have occurred owing to the exact occurrence of the polyelectrolyte mechanism, i.e., the seeds of *Moringa oleifera* contain significant quantity of low molecular weight (water-soluble proteins), which carry positive charge. When the seeds were crushed and added to raw water, the polysaccharides produce positive charge acting like magnets and attract the predominantly negatively charged particles such as clay, silt, bacteria and toxic particles in water (McConnachie et al., 1999).

Turbidity is a significant factor in the disinfection process. The effectiveness of solar disinfection has been tested on samples with turbidities ranging from less than 10 NTU to approximately 300 NTU. Researchers have found that higher turbidity samples exposed to sunlight attained consistently higher water temperatures, which was attributed to absorption of radiation by the particulate matter (Kehoe et al., 2004). More turbid samples, at 300 NTU, also had less inactivation of *E. coli* compared with samples with little or no turbidity. This may be in part due to shielding of organisms by particles (Mani et al., 2006). Meera and Ahammed (2006) reported that less than 1% of the total incident UV light is able to penetrate beyond a water depth of 2 cm from the surface in samples with turbidities greater than 200 NTU. Therefore, it may be necessary to filter turbid waters before sun exposure.

For over 4000 years, sunlight has been used as an effective disinfectant (Conroy et al., 2001). When organisms are exposed to sunlight, photosensitisers absorb photons of light in the UV – A and early visible wavelength regions of 320–450 nm. The photo sensitisers react with oxygen molecules to produce highly reactive oxygen species. In turn, these species react with DNA; this leads to strand breakage, which is fatal, and base changes, which result in mutagenic effects such as blocks to replication. The biocide effect of sunlight is due to optical and thermal processes and a strong synergistic effect occurs for water temperatures exceeding 45°C (Martin-Dominguez et al., 2005). Most of the published investigation to date has been made using *E. coli* as model microorganism, because it is a very well known bacteria from all points of view (DNA, metabolism, structure and composition, morphology, behaviour under different nutrient media, pathogenicity, types, strains, etc.).

The results of this study, namely the complete elimination of indicator bacteria within a few hours, showed that sunlight, given an appropriate intensity and good water transparency, was the most important factor in the reduction of hygienically relevant micro-organisms in surface waters. It has reported that the reduction of indicator bacteria in surface waters depended on physical parameters (e.g., temperature, pH, oxygen saturation and sunlight), chemical parameters (inorganic and organic substances) as well as the activities of macro and micro-organisms (Reed et al., 2005).

The viability of the bacteria *E. coli* depends to a great extent on its temperature of incubation (Rose et al., 2006). In general, the chemical composition of water as well as its content in suspended solid particles, their turbidity, etc., affect in a very important way the disinfection processes (Berney et al., 2006; Fujioka and Yoneyama, 2002).

Masschelein (2002) compared the germicidal effects of different wavelengths of light by measuring the average number of coliforms inactivated upon exposure with the varying wavelengths. They found that the most significant decrease in viable bacterial organisms occurred when they were exposed to wavelengths between 260 nm and 350 nm (compared with inactivation at wavelengths between 550 nm and 850 nm) because wavelengths below 290 nm do not reach the earth. Reed et al. (2000) concluded that the most bactericidal wavelengths were between 315 nm and 400 nm, which corresponds to the wavelengths of the near-ultraviolet region that are not visible to the eye. The findings of Mofidi et al. (2001) are further supported by the research of others. Mahvi (2007) attributed half of the toxic effects of sunlight to wavelengths lower than 370 nm. Tandon et al. (2005) concurred, stating that wavelengths between 300 nm and 370 nm have significant effects on inactivating bacteria and viruses.

From this work, the rural people can be motivated to grow the *Moringa oleifera* plants in their backyards and use for treatment. This can reduce their illness and increase their wages. The combined natural treatment method results contribute towards helping the village people by adopting this simple technology, which will bring health for their children and family. Promoting both economic development and environmental protection is more likely to produce better overall results (Lihua et al., 2009).

5 Conclusion

Our work has shown that combined treatment to purify turbid waters with natural coagulants and solar disinfection showed a measurable reduction in the turbidity and inactivation of bacterial species, demonstrating that natural coagulants and solar disinfection can enable such households to widen their sources of treated drinking water. The historical record of the use of natural coagulants and solar disinfection for the traditional ceremonial purification of drinking water should assist its wider acceptance as a practical approach to water treatment in rural India, where sustainable implementation will be the next challenge.

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