Sciencia Acta Xaveriana
ISSN. 0976-1152

Volume 1
No. 1
pp. 35–47

# POU Water Treatment Technology for Developing Countries

**Syeda Azeem Unnisa**[1], **P. Deepthi**[2] **and K. Mukkanti**[3]

[1] Centre for Environment IST, Jawaharlal Nehru Technological University, Kukatpally-Hyderabad–85. E-mail: syeda_30@yahoo.co.in.

[2] Centre for Environment IST, Jawaharlal Nehru TechnologicalUniversity, Kukatpally-Hyderabad-85. E-mail: cindrella.deeps@gmail.com.

[3] Centre for Pharmaceutical Sciences, IST, Jawaharlal Nehru TechnologicalUniversity, Kukatpally-Hyderabad-85. E-mail: kmukkanti@yahoo.com.

**Abstract.** The Point-of-Use (POU) technology deals with investigating the combined applicability of natural coagulants extracted from seeds of seven agrobased plants and inactivation of *E.coli* with solar disinfection to clarify turbid water. In this study, the coagulant properties of natural coagulants like Moringa oleifera, Strychnous potatorum, Zeemays, Pysum sativum, Phaseolus vulgaris, Abelmoschus esculentum and Coccinia grandis are quantitatively evaluated for the first time. These investigations confirmed positive coagulation activities and 100% inactivation of *E.coli* with solar disinfection when used seqentially.Once optimized, application of these readily available plants seeds and solar disinfection as a part of point-of-use water treatment technology may offer a practical, inexpensive, and appropriate solution for producing potable water at household level in developing rural communities for improving water quality and for reducing associated negative health effects, such as diarrhoeal disease, dehydration, and death.

**Key words:** POU, agro based, household, potable water technology, solar energy, rural people.

(Received: 03 December 2009)

# 1 Introduction

The strong push to meet the drinking water needs of the developing world have led to the recent growing interest in using plant-based natural coagulants (NC) and solar disinfection (SD) in both the developed and developing world [1]. There are reports in the literature [2] and anecdotal accounts from diverse geographic regions of plant-based materials that can effectively remove turbidity from water with little processing. If proven technically robust, these natural coagulants, may offer part of an appropriate approach for water treatment at the household level [3]. Because this technology relies on local materials and local labour, renewable resources, and food grade plant materials is relatively inexpensive, it can contribute to advancing the goal of sustainable water treatment technologies that are themselves sustainable [4]. Drinking water treatment typically includes coagulation, sedimentation, filtration, and disinfection. Coagulation is a critical step in water treatment processes not only because it removes particles but because it also removes the micro organisms that are often attached to the particles [5] by removing turbidity, coagulants also have the potential to remove pathogens and to significantly improve water quality and, subsequently, human health. This paper reports on an investigation into the potential of indigenous or natural water treatment methods as alternatives to conventional chemical water treatment methods. The seeds of seven natural plant species: Moringa oleifera (MO), Strychnous potatoram (SP), Abelmoschous esculentum (AE), Coccinia grandis (CG), Pysum sativum (PS), Phaseolus vulgaris (PV) and Zeemays (ZM) were evaluated for the removal of turbidity and their efficiency was compared with that of alum and sequentially the clarified water was exposed to solar disinfection for inactivation of *E.coli*. For these reasons, there is a need to design and develop appropriate point-of-use (POU) treatment technologies for developing communities. One component of this may be alternative coagulants and solar disinfection that are less expensive, renewable, locally available, and readily implementable.

# 2 Experimental setup

## 2.1 Model turbid water

A stock of synthetic turbid water samples was prepared by suspending 10 g of Kaolin in 1 L of tap water. The suspension was stirred for 30 min and left to stand for 24 hr to hydrate particles. The desire turbidity of 20 NTU (low), 40 NTU (medium) and 80 NTU (high) was prepared by mixing a fraction of decanted kaolin suspension with tap water. The pH of synthetic water samples was maintained constant at 7.0. *E.coli* was mixed in stock turbid water from preserve lab culture samples.

## 2.2 Natural coagulant preparation

Seeds were collected from nearby market. Dissections of the seed pods were performed by hand: The seeds were removed from the pods and were dried in the hot sun. Fine powder was made by using mortar and pestle and was stored in air tighten packets for future use. The scientific names and coagulating active agent is presented in Table 1.

## 2.3 Solar exposure time

Poly Ethylene Terephtalate (PET) bottles made of transparent, clear plastic, cylinder shape with a surface area of $23 \times 7.2 \times 6.0$ cm was used for experimental purpose as they are good transmitters of light in the UV and visible range of the solar spectrum. The total exposure time of experiments varied from 1 to 5 h.

# 3 Analytical measurements

Turbidity was measured using a calibrated ELICO CL 52D Turbidity meter to measure the turbidity of the solution in Nephelometric Turbidity Units (NTU). pH, temperature and alkalinity was measured by physico-chemical methods.

Table 1: Scientific names and active component in agro based seeds.

| S.No | Scientific Name | Seeds Photo | Active Agent |
|---|---|---|---|
| 1 | Moringa oleifera |  | Dimeric cationic proteins |
| 2 | Abelmoschus esculentus |  | Cyclo propenoid fatty acid |
| 3 | Pysum sativum |  | Albumin protiens |
| 4 | Coccinia grandis |  | Oligomeric globulins |
| 5 | Phaseolus vulgaris |  | Albumin proteins |
| 6 | Zeemays |  | Legumin like proteins |
| 7 | Strychnos potatorum |  | Alkaloids & polysaccharides |

## 3.1 Microbial analysis

Microbial analysis was done by standard methods. The Escherichia coli counts were enumerated on eosin methylene blue after 0.1 ml of the turbid water samples was aseptically serial diluted up to three fold. Samples were analyzed before and after treatment for its potability using APHA [6], and Cheesbrough [7] method. The colonies are enumerated by using digital colony meter and the log reduction is given by the following formula.

$$\text{Cfu/ml} = \frac{\text{No. of colonies formed}}{\text{Sample plated}} \times \frac{1}{\text{Dilution factor}}$$

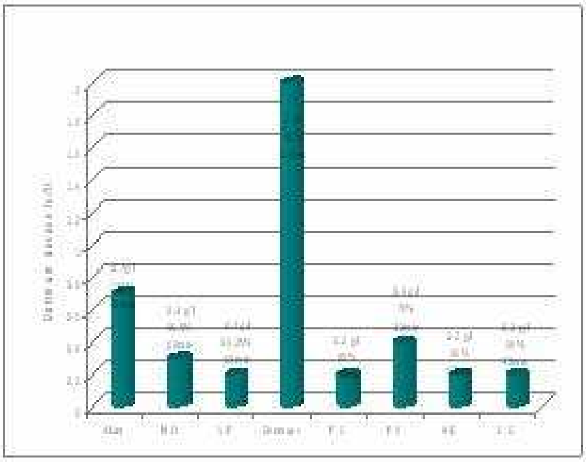

Figure 1: Comparison of turbidity removal, optimum dose and settling time by natural coagulants and alum for 20 NTU.

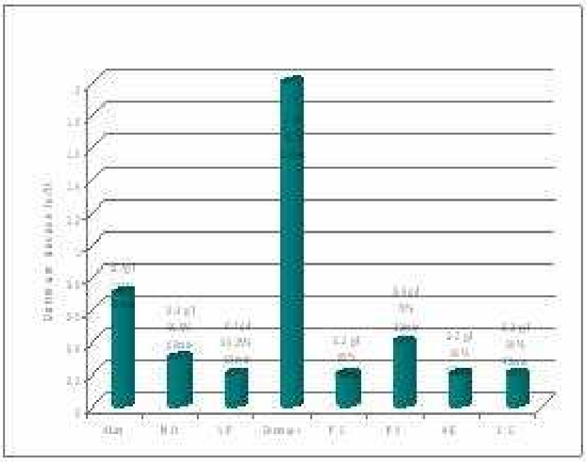

Figure 2: Comparison of turbidity removal, optimum dose and settling time by natural coagulants and alum for 40 NTU.

## 3.2 Methodology

Experimental works evaluate the efficiency and the coagulation effect of the coagulant extract from seven agro based seeds by using jar test method for summer season-2009. This test was performed by measuring turbidity of synthetic turbid water sample after different hour of settling time and dose. The reduction in absorbance relative to the control defines coagulation activity. The results of turbidity reduction with natural coagulant were compared with WHO standards. The clarified water with natural coagulant was exposed to solar radiation for disinfection for 5 hours for inactivation of *E.coli* along with a control. Antimicrobial studies were carried out in agar plate, for untreated and treated samples with natural coagulants and solar disinfection. All of the experiments were performed in duplicates and the average values are presented.

# 4 Results

The results of this study have shown that the seeds of seven natural plant species are powerful polyelectrolyte coagulant whether it is used as a primary or as a coagulant aid in relation to alum. For raw water sample with turbidity of 20 NTU, the analysis of the results show the efficiencies of the natural coagulants are in the order of:

20 NTU: MO>SP>ZM>PS>PV>AE>CG;
40 NTU: MO>SP>PS>ZM>PV>CG>AE;
80 NTU: MO>SP>ZM>CG>PV>PS>AE.

The optimum dosage of natural coagulant that were used in this phase is in the order of,

20 NTU: ZM>PV>MO>CG>PS>AE>SP;
40 NTU: ZM>PV>ST>AE>MO>CG>PS;
80 NTU: ZM>MO>ST>CG>PV>PS>AE

It is worth to say that the turbidity efficiency removal for these synthetic samples at 20 NTU, 40 NTU and 80 NTU were about 96.5–66%, 93–56.25% and 94–59% respectively shown in the Figs. 1, 2 and 3. Moringa oleifera and Nirmali seeds resulted in producing treated water with turbidity less than 5 and remaining none of the seeds resulted in producing treated water with turbidity less than 5 NTU as per WHO guidelines. Therefore either they can be used as primary coagulant (or) coagulant aid in relation to alum. pH was retained at 7.0 before and after treatment with natural coagulant and alum. Initial alkalinity was found to be 230-300mg/l. These coagulants

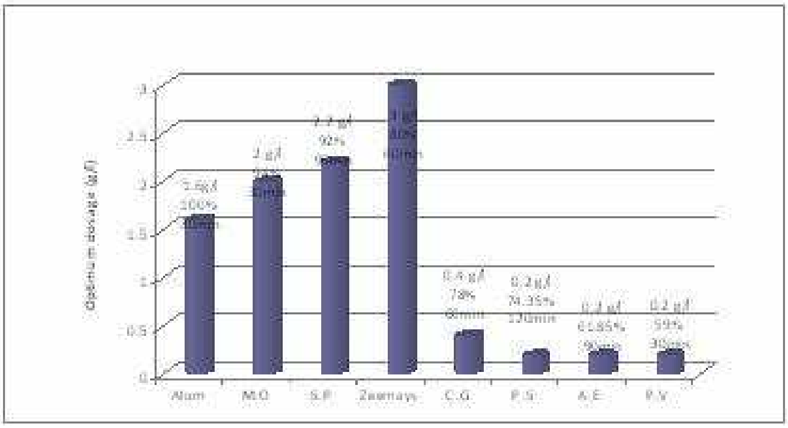


Figure 3: Comparison of turbidity removal, optimum dose and settling time by natural coagulants and alum for 80 NTU.

are from agro based seeds if when mixed with the water does not release any constituents that are harmful to health and no objectionable taste and odour nor increase in the concentration of TDS was observed. Water clarified with natural coagulant were immediately exposed to solar disinfection for 5 h (11 am to 4 pm), the microbial load was reduced drastically which shows no colonies in the plates where the UV rays had inactivated the *E.coli*. For the present experiments the normal plastic bottles with 0.1 percent UV transmittance (at the wavelength of 254 nm) had been used. The average

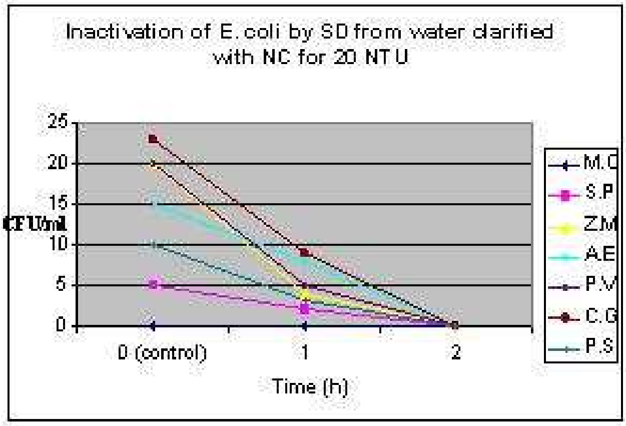


Figure 4: Inactivation of *E.coli* for low turbid sample.

temperature was 28 °C at the beginning of the experiments, and also the average water temperature was obtained to be 39, 40 and 41 and 5 °C after 1-5 hour's radiation time, respectively. As Fig. 4, 5 and 6 illustrates, solar disinfection efficiency of *E.coli* reduction was determined to be 100 percent for all types of turbidity at 2 h radiation time, respectively. The present 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 compared to individual treatment.

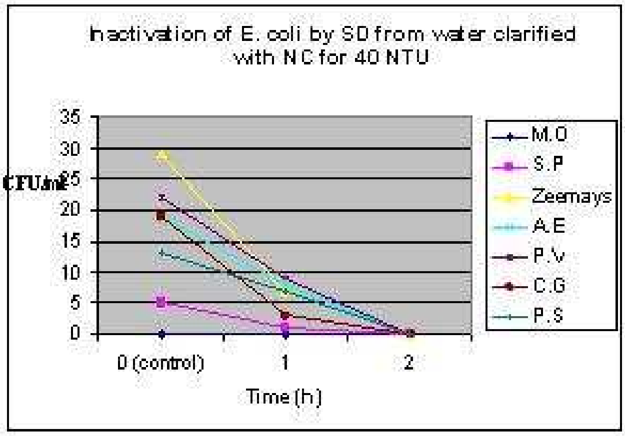


Figure 5: Inactivation of *E.coli* for medium turbid sample.

## 5 Discussion

The treatment of water with the common inorganic coagulants have a number of disadvantages such as cost of chemicals (especially for developing nations), concern for human health, sludge management among others. However there are constraints encountered in the use of chemical coagulants, such as scarcity of foreign currency for importation and inadequate supply of chemicals [8]. Although aluminium is the most commonly used coagulant in the developing countries, studies have linked it to the development of neurological diseases (e.g. pre-senile dementia or Alzheimer's disease) due to the presence of aluminium ions in the drinking water. More so, large non-biodegradable sludge volumes are produced containing residual aluminium sulphate

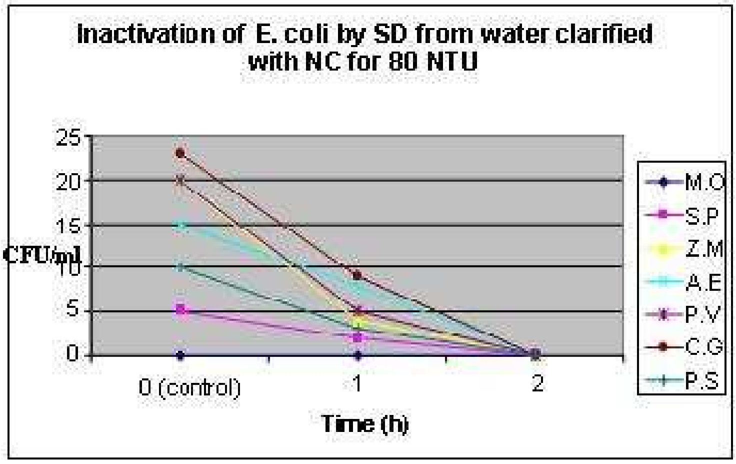


Figure 6: Inactivation of *E.coli* for high turbid sample.

needing treatment facilities to prevent further contamination into the environment [9]. Moreover, researchers observed that the coagulation protein inhibits the growth of enteric and non-enteric bacterial strains. Such dual role of purified proteins in clarification and antimicrobial potential renders this simplified method of extraction and purification of coagulating proteins proper for poor countries where they cannot afford the costly conventional methods for protein purification [10]. Investigated the potential of plant seeds and roots on removal of turbidity and compared it with alum. The researcher used clean water to extract the coagulating agent from seed powder and roots analogous to what is done traditionally by women. It was observed that in terms of turbidity removal, the crude seed suspension compared well with that affected by alum with alum performing only 1% percent better than the natural coagulants. Moreover, they observed that the removal of turbidity was accompanied by bacterial reduction (50%-60%) although upon storing the treated water for 24 hours secondary bacterial growth was noted. Mc Connachie [11] observed that the active agent is a water-soluble cationic protein that harbours very good coagulation properties which is used in extremely low dosages than that used for crude seed extract. Also, water treated by pure proteins is not prone to bacterial re-growth. The researchers thus affirmed that, the isolation and purification of active agents from the seed is relatively easy compared to laborious manipulation of other proteins and thus recommended it for use in water treatment processes. Studies have shown that synergies from the combined application of radiation and thermal treatment have a significant effect on the die-off rate of micro organisms. 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 [12]. More turbid samples, at 300 NTU, also had less inactivation of *E.coli* compared to samples with little or no turbidity. This may be in part due shielding of organisms by particles [13]. Meera and Ahammed [14] 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 [15]. When organisms are exposed to sunlight, photo sensitizers absorb photons of light in the UV-A and early visible wavelength regions of 320 to 450 nm. The photo sensitizers 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 [16]. Most of the published investigation to date has been made using Escherichia 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, pathogencity, types, strains, etc.).The results of the present 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 [17]. The viability of the bacteria Escherichia coli depends to a great extent on its temperature of incubation [18]. 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 [19, 20, 21]. Compared the germicidal effects of different wavelengths of light by measuring the average number of *E.coli* inactivated upon exposure to the varying wavelengths. They found that the most significant decrease in viable bacterial organisms occurred when they were exposed to wavelengths between 260 to 350 nm (compared to inactivation at wavelengths between 550 to 850 nm) because wavelengths below 290 nm do not reach the earth. Reed et al. [22] concluded that the most bactericidal wavelengths were between 315 to 400 nm, which corresponds to the wavelengths of the near-ultraviolet region that are not visible to the eye. The findings of Mofidi [23] are further supported by the research of others. Amir Hossein Mahvi [24] attributed half of the toxic effects of sunlight to wavelengths lower than 370 nm. Tandon et al. [25] concurred, stating that wavelengths between 300 and 370 nm have significant effects on inactivating bacteria and viruses.

# 6 Conclusions

Finally I would like to conclude that, the use of locally available natural coagulants in poor countries has a great potential of improving the economy and health of the people. Extensive studies have been done to know the efficiency of natural coagulant and solar disinfection when used sequentially. It is now up to the governments in poor countries to first recognise and duly support the initiatives of the poor and yet disadvantaged population segments. This will need communities of countries to strengthen the natural water coagulation and solar disinfection as point-of-use (POU) technology in a holistic approach and to support these initiatives including empowering and enabling local scientist and technologists to build up the POU technology that will suit the local requirements and situation based on scientific knowledge available.

## Acknowledgement

We sincerely thank Department of Science and Technology (DST), New Delhi for granting this project under water initiative technology (WTI) programme.

# References


[1] R.M.Conroy et al, *Solar disinfection of drinking water protects against cholera in Children under 6 years of age* Journal of Arch. Dis. Child. Butterworth. Washigton, CRC press, **85** (2001) 295.

[2] M. Mandloi, S. Chaudhari, G.K. Folkard, *Evaluation of natural coagulants for direct filtration*, Environ. Technol. **25** (2004), 481–489.

[3] S.A.A. Jahn, *The tree that purifies water* Journal of Water Research, **38** (1986), 28.

[4] S.A. Muyibi, A.M.S. Alfugara, *Treatment of surface water with Moringa oleifera seed extract and alum—A comparative study using a pilot scale water treatment plant*, Int. J. Environ. Stud. **60** No.6 (2003) 617–626.

[5] R. Babu and M. Chaudhuri, *Home water treatment by direct filtration with natural coagulant*, Journal of Water Health. **3** No.1 (2005) 30.

[6] APHA Standard Methods for the Examination of Water and Wastewater, ($20^{th}$ ed.), AWWA and WEF, Washington. (1983).

[7] M.Cheesbrough, *Medical laboratory manual for Tropical Health Technology* (1984).

[8] WHO, *Water for Life: making it happens* World Health Organisation, Geneva: Switzerland. (2005).

[9] D.J. Lye, *Health risks associated with consumption of untreated water from household roof catchments systems*, Journal of AWR. **38** No.5 (2002), 1306.

[10] M.D. Sobsey, *Drinking water and health research: a look to the future in the United States and globally* Journal of Water Health. **4** No.1 (2006), 21.

[11] H.L. McConnachie, *Field trial of appropriate flocculation processes*, Journal of Water Research, **33** No.6 (1999), 1434.

[12] M.R.Barer, *Batch process solar disinfection is an efficient means of disinfecting drinking water contaminated with Shigella dysenteriae type 1*, Journal of Applied Microbiology. **38** (2004), 414.

[13] S.K. Mani, et al, *Comparative effectiveness of solar disinfection using small scale batch reactors with reflective, absorptive and tranmissive rear surfaces* Journal of Water Research.s **40** (2006), 727.

[14] V. Meera, and M.M. Ahammed, *Water quality of rooftop harvesting systems: a review*, Journal of Water Supply Research Technology-Aqua, **55** No.4 (2006), 268.

[15] S.C. Kehoe, *Effect of agitation, turbidity, aluminum foil reflectors and container volume*

*on the inactivation efficiency of batch process solar disinfection*, Journal of Water Research. **35** No. 4 (2001) 1065.

[16] A. Martin-Dominguez, *Efficiency in the disinfection of water for human consumption in rural communities using solar radiation* Journal of Solar Energy, **78** (2005), 40.

[17] Rob Reed, et al, *Making the most of a scarce resource: Solar disinfection of drinking water in the arid zone of western Rajasthan*, ALN. (2005).

[18] A. Rose, *Solar disinfection of water for diarrhoeal prevention in India* Journal of Arch. Dis. Child, **10** (2006), 141.

[19] M. Berney, *Efficacy of solar disinfection of Escherichia coli Shigella flexneri, Salmonella typhimuriam and Vibrio cholerae*, Journal of Applied Microbiology, **101** (2006) 836.

[20] R.S.Fujioka and B.S.Yoneyama, *Sunlight inactivation of human enteric viruses and fecal bacteria*, Journal of Water Science Technology, **46** (2002) 291–295.

[21] W.J. Masschelein, *UV light in water and waste water sanitation*,Boca Raton, CRC Press, (2002).

[22] R.H. Reed, S.K. Mani and V. Meyer, *Solar photo oxidative disinfection of drinking water: preliminary field observations*, Journal of Applied Microbiology, **30** (2000) 436.

[23] A.A. Mofidi, *Disinfection of Cryptosporidium parvum with polychromatic UV light*, Journal of AWWA, **93** (2001), 109.

[24] M. Amir Hossein, *Feasibility of Solar Energy in Disinfection of Drinking Water in Iran* Journal of American- Eurasian Agric. and Environ. Sci. **2**, No.4 (2007), 410.

[25] P. Tandon, S. Chhibber and R.H. Reed, *Inactivation of Escherichia coli and coliform bacteria in traditional brass and earthenware water storage vessels* Journal of Water Research. **88** (2005), 48.