Physics and Chemistry of the Earth 34 (2009) 799–805

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Potential of using plant extracts for purification of shallow well water in Malawi

M. Pritchard [a,*], T. Mkandawire [b], A. Edmondson [a], J.G. O'Neill [c], G. Kululanga [b]

[a] Leeds Metropolitan University, School of the Built Environment, Leeds LS2 8AJ, United Kingdom
[b] University of Malawi, The Polytechnic, Department of Civil Engineering, Private Bag 303, Chichiri, Blantyre 3, Malawi
[c] Centre for Research in Environment and Health, 6 Abbotsway, York YO31 9LD, United Kingdom

ARTICLE INFO

Article history:
Received 22 January 2009
Received in revised form 12 June 2009
Accepted 1 July 2009
Available online 9 July 2009

Keywords:
Drinking water
Guar gum
Jatropha curcas
Moringa oleifera
Water treatment

ABSTRACT

There has been very little scientific research work into the use of plant extracts to purify groundwater. Research studies on the purification of groundwater have mainly been carried out in developed countries and have focused on water purification systems using aluminium sulphate (a coagulant) and chlorine (a disinfectant). Such systems are expensive and not viable for rural communities due to abject poverty. Shallow well water, which is commonly available throughout Africa, is often grossly contaminated and usually consumed untreated. As a result, water-related diseases kill more than 5 million people every year worldwide. This research was aimed at examining natural plant extracts in order to develop inexpensive ways for rural communities to purify their groundwater.

The study involved creating an inventory of plant extracts that have been used for water and wastewater purification. A prioritisation system was derived to select the most suitable extracts, which took into account criteria such as availability, purification potential, yield and cost of extraction. Laboratory trials were undertaken on the most promising plant extracts, namely: *Moringa oleifera*, *Jatropha curcas* and Guar gum. The extracts were added to water samples obtained from five shallow wells in Malawi. The trials consisted of jar tests to assess the coagulation potential and the resulting effect on physico-chemical and microbiological parameters such as temperature, pH, turbidity and coliforms. The results showed that the addition of *M. oleifera*, *J. curcas* and Guar gum can considerably improve the quality of shallow well water. Turbidity reduction was higher for more turbid water. A reduction efficiency exceeding 90% was achieved by all three extracts on shallow well water that had a turbidity of 49 NTU. A reduction in coliforms was about 80% for all extracts. The pH of the water samples increased with dosage, but remained within acceptable levels for drinking water for all the extracts. Overall, *M. oleifera* powder produced superior results, followed by Guar gum and lastly *J. curcas*. There is a need to carry out further more detailed tests, which include toxicity to guarantee the safety of using plant extracts as a coagulant in the purification of drinking water for human consumption.

1. Introduction

About 1 billion people (15% of the world population) are without safe drinking water worldwide (UNICEF, 2009). The vast majority of these people are located in sub-Saharan Africa, South Asia and East Asia (Dungumaro, 2007 and UNICEF, 2009). Around 5 million lives are lost annually due to drinking and using contaminated water (WHO, 2006). The people at greatest risk are children, people living under unsanitary conditions and the elderly (WHO, 2006). Globally, 4 billion cases of diarrhoea are reported every year causing 1.8 million deaths, out of which about 90% are children under five (UNESCO, 2007). In Malawi, diarrhoea morbidity is around 17% (Masangwi et al., 2008).

Groundwater is the main source of drinking water for nearly 60% of the population in southern Africa (UNEP, 2002). The most common source of drinking water for the rural people in Malawi is from boreholes (deep wells), shallow wells, springs and rivers. About 37% of Malawians use boreholes as their main source of drinking water and about 26% draw their water from unprotected wells (Staines, 2002). In Malawi groundwater is usually consumed without any form of treatment (Pritchard et al., 2007; 2008). Water is a medium for thousands of microorganisms, some of which are disease-causing. Pathogens (e.g. bacteria, viruses, protozoa and helminths) in water cause a variety of diarrhoea-related diseases such as cholera, typhoid and dysentery. These pathogens are commonly derived from human faecal material. Around 2.5 billion people are without adequate sanitation in the world (UNICEF, 2009). In the rainy season, many pit latrines in the developing world collapse under their own weight due to poor workmanship which further reduces the sanitation coverage. Open defecation

* Corresponding author. Tel.: +44 7825010371; fax: +44 1138121958.
E-mail address: m.pritchard@leedsmet.ac.uk (M. Pritchard).

1474-7065/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pce.2009.07.001

in the bush and water bodies is still a popular means of human excreta disposal for rural villagers without access to pit latrines (Lungu et al., 2008). In the rainy season, faecal matter from pit latrines and open sources is washed into water bodies, thereby contaminating the water (Dzwairo et al., 2006). Microbiological water quality from shallow wells in Malawi (with depths, typically, not exceeding 15 m) has been found to be more inferior in the wet season compared to the dry season (Pritchard et al., 2007, 2008).

Conventional water purification systems using imported chemicals are prohibitively expensive for many developing countries in Africa. For example, Malawi has 52.4% of its population that live below the poverty line (GOM, 2005). Such expensive conventional methods of assuring potable water quality are unsustainable. The mortality rate arising from the use of unsafe water is a major concern for both government and international institutions throughout the world. If the Millennium Development Goals and the targets set by the World Summit on Sustainable Development are to be met, there is a vital need to develop sustainable technologies to treat groundwater for rural livelihoods. The search for locally available low cost materials therefore is inevitable.

1.1. Plant extracts for water purification

Natural plant extracts have been used for water purification for many centuries. Most of these extracts are derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees and plants. For example, *Strychnos potatorum* was used as a clarifier between the 14th and 15th centuries BC. Shultz and Okun (1984) together with Sanghi et al. (2006) reported that seeds of the nirmali tree (*S. potatorum*) were used to clarify turbid river water about 4000 years ago in India. It is further reported that in Peru water has been traditionally clarified with the mucilaginous sap of tuna leaves obtained from certain species of cacti. *Zea mays* was used as a settling agent by sailors in the 16th and 17th centuries.

Laboratory, pilot-plant and full-scale studies on the performance of plant extracts such as nirmali tree (*S. potatorum*), tamarind tree (*Tamerindous indica*), guar plant (*Cyamopsis psoraloides*), red sorella plant (*Hibisicus sabdariffa*), fenugreek (*Trigonella foenum*) and lentils (*Lens esculenta*) have been conducted using raw water with turbidity that ranged from 50 to 7500 NTU (Shultz and Okun, 1984). The optimum dosage for the nirmali extract was 50 mg/l, which produced a 76% reduction in turbidity at 30 °C. The effective dose for the other extracts ranged from 2 mg/l to 20 mg/l at pH levels from 4 to 9, and proved to be more economical for turbidity values greater than 300 NTU (Shultz and Okun, 1984).

Moringa oleifera powder has been reported in literature to have the capability of reducing low and high turbidity values in surface water (Madsen et al., 1987; Muyibi and Evison, 1995; Muyibi and Okuofu, 1995). Bacterial removal in the range of 90–99% has also been reported (Madsen et al., 1987). *M. oleifera* was used as a natural coagulant in a full-scale treatment trial at the Thyolo treatment works in Malawi during the wet season of 1992. Turbidity values as high as 270–380 NTU were reduced to around four NTU, which are within the WHO (2006) guideline value with the addition of the powder (Sutherland et al., 1994).

Yongabi (2004) tested the coagulative and disinfective capabilities of *M. oleifera*, *J. curcas*, *Pleurotus tuberregium sclerotium* and *H. sabdariffa* against alum on wastewater samples. *M. oleifera* coagulated about 90% of the particles in the samples. The number of total bacterial counts reduced from ‘too numerous to count’ to 2700 colony forming units per ml with *M. oleifera* powder, which accounted for a 66% greater reduction than alum. *J. curcas*, *Pleurotus tuberregium sclerotium* and *H. sabdariffa* demonstrated between 60% and 90% effectiveness in purifying water samples. In particular, Yongabi (2004, p. 12) claimed that *J. curcas* seeds and calyx of *H. sabdariffa* possessed both a coagulative and a disinfective ability.

Natural coagulants have been reported to have several other advantages compared to synthetic coagulants such as alum, in that, they produce much lower sludge volume and are safe to humans. Ghebremichael (2004) reported that the sludge produced from *M. oleifera* coagulated turbid water is only 20–30% that of alum. Litherland (1995), Sanghi et al. (2006) and Katayon et al. (2006) reported that the residue of alum in water may be carcinogenic. Natural coagulants are biodegradable and cost effective for developing countries since they can be locally grown and have a wider effective dosage range for flocculation of various colloidal suspensions (Sanghi et al., 2006).

Most previous studies on the use of plant extracts have focused on surface water (e.g. Jahn, 1986; Muyibi and Evison, 1995; Sanghi et al., 2006). Also, past studies have been undertaken on *M. oleifera* and *S. potatorum*, but there are no real data on the performance of other plant extracts like *J. curcas* and Guar gum. This research therefore was aimed at establishing an inventory of the plant extracts that have been used for water purification and also to carry out preliminary tests on the performance of plant extracts available in Malawi for purification of shallow well water.

2. Materials and methods

2.1. Plant extracts

A plant extracts inventory was produced by examining the literature. The review provided the means to identify the most suitable plant extracts that have been used to treat water. The information on plant extracts included plant names, species, harvesting characteristics, where the plant is cultivated, climatic requirements, uses, estimated cost and other general information.

2.2. Sampling

Water samples were collected in 2008 from five shallow wells from Blantyre (Kumponda and Kumazale) and Chiradzulu (Nlukla, Chelewani and Mtembo) as shown in Table 1. These wells were chosen because of the high average faecal coliform counts from the previous water quality analysis by Pritchard et al. (2007) as shown in Table 2. From this previous analysis Kumponda open well registered an average faecal coliform count of 10,438 colony form-

Table 1
Well characteristics.

Well	District	Constructed/rehabilitated	Depth (m)	Approx. population served	Pump type	Coordinates[a]	
						Easting	Northing
Kumponda	Blantyre	(>20 years)	1.5	(Not used for drinking)	Open	714,378	82,70,075
Kumazale	Blantyre	2001/2004	4	200	Elephant	717,721	82,70,574
Nlukla	Chiradzulu	2004	6	700	Elephant	733,813	82,81,442
Chelewani	Chiradzulu	1998/2003	4	100	MALDA	732,869	82,80,559
Mtembo	Chiradzulu	2004	8	100	Elephant	727,946	82,73,457

[a] 1950 30th ARC DATUM.