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General Research Paper

Indigenous Materials for Improving Water Quality

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ABSTRACT

In rural areas, most people rely on private water supplies such as wells and dugouts. Quality water is vital to the social, health, and economic well-being of people. It sustains ecological processes that support native fish population, vegetation, wetlands and bird life. Water quality is commonly defined by its physical, chemical, biological and aesthetic characteristics. Presently, there are no appropriate low-cost technologies available for removal of several contaminants present in groundwater. Microbial degradation, chemical oxidation, photolysis and adsorption are used for the treatment of wastewater. Although aluminium is the most commonly used coagulant in the developing countries, studies have linked it to the development of neurological diseases. There are several methods used for the purification of water. Activated carbons are the most common adsorbent, and they are made from different plants, animal residues and bituminous coal. *Moringa oleifera* seeds are also used as a primary coagulant in drinking water clarification and wastewater treatment due to the presence of a water-soluble cationic coagulant protein, which is able to reduce turbidity of the treated water. There are many other species like *Vigna unguiculata*, *Voandzeia subterranea*, *Arachis hypogaea*, *Vicia faba* and *Parkinsonia aculeata,* which are also used for purification of water for drinking and cooking purposes while wood ashes are mainly used for clarifying water for activities such as laundry, bathing, washing utensils but very rarely for drinking. Hence, there is an urgent need for development of alternative, cost effective and also environmental friendly coagulants to address the issue.

INTRODUCTION

Water is one of the fundamental requirements of life and any undesired addition of chemical substances lead to its contamination and make it unfit for human utility. The frequency of life threatening infections caused by consumption of untreated water has increased worldwide and is becoming an important cause of mortality in developing countries (Al-Bari et al. 2006, Verma & Rakshit 2010, 2011). In many developing countries, access to clean and safe water is a major problem (Verma & Rakshit 2010, Kumar & Rakshit 2014). According to the UN, 1.1 billion people still do not have access to an adequate supply of drinking water and these people are among the worlds poorest.

Water quality: Water has two dimensions that are closely linked: quantity and quality. Water quality is commonly defined by its physical, chemical, biological and aesthetic characteristics. A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health. Fundamental water quality objectives recognize the environmental values and uses for different waterways that the communities want to see protected. These include fishing and recreational use, healthy aquatic ecosystems to meet cultural and spiritual needs, wetlands and bird life and water for drinking and irrigation. Basically, these objectives have been established after rigorous and continuous consultation with communities for surface waters ensuring sustenance of ecological processes.

The presence of contaminants and the characteristics of water are used to indicate the quality of water. These water quality indicators can be broadly categorized as biological (bacteria, algae); physical (temperature, turbidity and clarity, colour, salinity, suspended solids, dissolved solids), chemical (pH, dissolved oxygen, biological oxygen demand, nutrients, organic and inorganic toxic compounds), aesthetic (odours, taints, colour, floating matter) and radioactive (alpha, beta and gamma radiation emitters). Measurements of these indicators can be used to monitor changes in water quality, and determine whether it is suitable for the health of the natural environment and the uses for which the water is required. The design of water quality monitoring programs is a complex and specialized field. The range of indicators that can be measured is wide and other indicators may be adopted and included in the future as per the need and relevance. The cost of a monitoring program to assess them all would be prohibitive, so resources are usually directed towards assessing contaminants that are important for the local environment or for a specific use of the water. This water quality information can then be used to develop management programs and action plans to ensure that water quality is protected. The different physical, chemical and biological parameters determining water quality are listed in Table 1.

Possible amelioration strategies: Throughout the centuries, every culture has had an intimate and vital connection to water. It is one of the most important elements necessary to sustain life. Civilizations have based their communities in close proximity to water systems for sustenance, cleansing, sacred ceremony and prayer, healing, play and recreation, transport, economics, irrigation of crops and livestock, and unfortunately diluting wastes and contaminants. Each culture has a different way of representing how sacred water is and assigning a unique and intimate value to it. Cultural traditions, indigenous practices, and societal values are all interconnected in the ways people perceive and manage water throughout the world.

In rural and undeveloped countries, people living in extreme poverty are presently drinking highly turbid and microbiologically contaminated water, because they lack knowledge of proper drinking water treatment and they cannot afford costly chemical coagulants. Hence, as a result of this and to overcome chemical coagulant problems, there is a need to develop alternative, cost effective and also environmental friendly coagulants.

Additionally, water that has been disinfected by UV treatment, boiling, chlorination, micro-filtration, ozone, etc. may still be polluted with other contaminants that are not affected by the disinfection treatment. There are several disadvantages associated with conventional water treatment methods; either a heavy cost is incurred or unskilled labour to handle the chemicals.

Presently, there are no appropriate low-cost technologies available for removal of several commonly present groundwater contaminants. Microbial degradation, chemical oxidation, photolysis and adsorption, are used for the treatment of water. Activated carbons are the most common adsorbent, and they are made from different plants, animal residues and bituminous coal. Although aluminium is the most commonly used coagulant in the developing countries, studies have linked it to the development of neurological diseases due to the presence of aluminium ions in the drinking water.

Naturally occurring coagulants are usually presumed safe for human health. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants. In the recent years, the use of various natural products has been widely investigated as an alternative to the current expensive methods of water treatment. Some of the natural products can be effectively used as a low cost absorbent.

Natural plant extracts have been used for water purification for many centuries and Egyptians inscription afforded the earliest recorded knowledge of plant materials used for water treatment, dating back perhaps to 2000BC in addition to boiling and filtration. In recent years, there has been considerable interest in the development of usage of natural coagulants which can be produced or extracted from microorganisms, animal or plant tissues. These coagulants should be biodegradable and are presumed to be safe for human health (Sciban et al. 2009). In addition, natural coagulants produce readily biodegradable and less voluminous sludge that amounts only 20-30% that of alum treated counterpart (Narasiah et al., 2002). Nowadays, a number of effective coagulants have been identified of plant origin. Some of the common ones include *Moringa olifiera, Solanum incunum, Ocimum sanctum, Azadirachta indica, Triticum aestivum, Phyllanthus emblica* and *Strychnos potatorum* and others (Table 2) . Of the large number of plant materials that have been used over the years, the seeds of *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment, especially in rural communities (Ndabigengesere & Narasiah 1998, Ali et al. 2010, Sotheeswaran et al. 2011, Yahya et al. 2011).

Indigenous local knowledge is far more than a collection of facts. It is an understanding of the world and of humanity's place in the world. From observations, people everywhere find patterns, similarities, and associations, from which they develop, a view of how the world works, a view that explains the mysteries surrounding them and gives them a sense of place (Brody 2000). Studies of indigenous knowledge often make comparisons with scientific knowledge in an effort to determine the "accuracy" of indigenous knowledge as measured on a scale that is intended to be objective. Indigenous peoples have achieved harmonious integration with the environment and have sustained this relationship over the centuries. Women of Tanzania, clarify turbid waters using powdered seeds from locally grown plants, *Parkinsonia aculeata* trees and wood ashes and this has become a regular practice of about 98% of households who apply traditional methods for purification of turbid water. Other seeds apart from being used as natural coagulants and their performance in terms of turbidity reduction are from *Vigna unguiculata*, *Voandzeia subterranea*, *Arachis hypogaea*, *Vicia faba* and *Parkinsonia aculeata,* which are used mainly for purification of water for drinking and cooking purposes while wood ashes are mainly used for clarifying water for activities such as laundry, bathing, washing utensils but very rarely for drinking. It was further noticed that the seeds that are used in water clarification are also used as local foodstuff and as such are assumed to be non-toxic to humans. However, *P. aculeata* trees are not very commonly grown by people, a considerable number of people use *P. aculeata* as a shade tree and for demarcating farms. Also, the green or flesh pods are chewed by people because of the sugary taste. Moreover, the different types of seeds that are used traditionally for purifying turbid water belong to the family Fabaceae and are also referred to as legumes. Legumes are used extensively as a substitute for meat protein by people in Sub-Saharan Africa and in countries where animal proteins are scarce and expensive or are not consumed for religious or cultural reasons.

The procedure involved in purification consists of the following steps. The seeds are ground on a special grinding stone to fine powder and kept in plastic bags in dry places for 1 to 2 months for daily use. The 20 litre bucket of drinking water is dosed with 2 to 5 teaspoons (about 20 to 50 grams) of seed powder, while 500 grams to 1 kilogram of wood ashes are used to clarify the same quantity of water for washing and bathing purposes. The water is subjected to rapid mixing speed of about 100-150 revolutions per minute and allowed to swirl itself for about 5 to 10 minutes after which the formed flocs are allowed to settle for 20 to 25 minutes. The clarified water is decanted and stored in a clean, usually clay pot and stored in a cool place for drinking and cooking purposes. The rapid and slow mixing followed by settling (sedimentation) of treated water done by the villagers is analogous to conventional surface water treatment processes that are commonly practiced by many countries and during the performance jar tests to determine optimum dosage of chemical coagulants. The turbidity reduction by different plant species has been presented in Table 3.

Actually, the treated water appeared milky and no longer muddy, but it contained very fine suspended particles that are possibly responsible for the observed high level of residual turbidity. The performance of local coagulant could however be improved by regulating some of the parameters that have been used to influence water coagulation, reported by many researchers. Such parameters include raw water pH, coagulant dosage, mixing speed and duration and settling time (Schultz & Okun 1984, Muyibi & Evisen 1995). The knowledge of purification of polluted domestic water supply sources using locally available seeds has got both direct and indirect ways of improving the quality of life and enhancing sustainable development in rural communities. These developments however, cannot be realized unless local knowledge is recognized, promoted and adopted for providing a holistic framework for enhancing social, economic and ecological developments. Sustainable rural development is also a function of interaction of mechanisms that operate at grass root levels, water sector, economic sector and other key sectors. Moreover, scientific and technological community and other phenomena should all work together and provide a platform of knowledge from which future water and other development projects might explore new development options for the rural people.

In the process of developing a plant based substitute for economical safe approach for water purification against conventional chemical constituents, in vitro antibacterial studies were carried out on the alcoholic and aqueous leaf extracts on *E. coli*. The choice of *E. coli* was done since it is an important indicator organism, indicating faecal pollution of water. Phyto-chemical screening was also performed to check the active antimicrobial components present in the leaf extracts. *Ocimum sanctum* is effective against *E. coli* and shows increase in antibacterial activity with increase in concentration and specified contact time. The aqueous leaf extract showed antibacterial activity with a hundred times more concentration and increased exposure time as compared to the alcoholic leaf extract. The alcoholic leaf extract showed better reduction of microbial load in contaminated water during the coliform reduction test (MP test) as compared to the aqueous leaf extract. In these systems of natural healing, the wood of amla (*Phyllanthus emblica*) is used to clear small rain ponds in the Indian peninsula. Tulsi (*Oscimum sanctum*) is a water purifier with antibacterial and insecticidal properties. Drumstick tree (*Moringa oliefera*), which in Sudan is called the clarifier tree, produces seeds, which are used for water purification. Seeds of honge (*Pongamia glabra*) and nuts of nirmali tree (*Strychnos potatorum*) are used as water clarifiers. This is virtually costless way to render contaminated water fit for human consumption.

Calotropis procera leaves have also been used as a potential wastewater treatment with particular reference to the eradication of coliforms and non-coliforms population. Natural coagulants such as *Moringa stenopetala, Moringa oleifera* (Oluwalana et al. 1997), *Hypoestes verticillaris* has been tested as a substitute for domestic water treatment. Locally, the coagulation attributes *Moringa oleifera* have been found effective in clarifying turbidity of raw water (Oluwalana et a1. 1997). Seeds of *Moringa* spp. in particular are important as a primary coagulant which have been used to effectively clarify highly turbid muddy waters and waters of medium and low turbidity which may appear milky and opaque or sometimes yellow or greyish. Often, the action of *Moringa* seeds as a flocculant is almost as fast as that of alum. Since the bacteria in water are generally attached to solid particles, treatment with moringa seed powder can leave the water clear with 90-99% of the bacteria removed.

Table1: Parameters measuring water quality.

	Parameters	Occurrence/Origin	Health/Sanitary significance
Physical	Temperature	Climatologically influenced	-
	Turbidity	Clay particles, sewage solids, silt and sand washings, organic and biological sludge etc.	-
	Colour	Peat, leaves, branches and vegetables	Objections to high colour
Chemical	Salinity	Natural property of seawater	Organoleptic considerations only
	Solids suspended	Natural deposition in or discharges to water	No direct significance
	pH	Physical characteristic of all waters/solutions	None - except that extreme values will show excessiveAcidity/alkalinity, with organoleptic consequences
	Biological oxygen demand	Natural or introduced organic matter in water	No direct health implications, but an important indicator ofoverall water quality.
	Dissolved oxygen	Natural characteristic of clean waters	Slight organoleptic significance only, but critical for survival of fish.
	Nitrogen	Principally from organic matter naturally present (e.g. from peat, falling leaves etc.) or added in discharges	No direct significance but parameter is an indi cation of the overall purity of a water.
	Phosphorus	Natural or added organic matter (wastes, vegetation etc.)	Indirect - indicates overall water quality
	Silicon/toxic/ persistent organic compounds	Industrial wastes, tip-head leachates	Toxic materials
Biological	Protista (Enterococci, fungi, algae, BGA)	Sewage and similar wastes	Some members of the group have pathogenic properties.
	Plants (ferns, mosses)	Rooted aquatic plants	-
	Animals (worms, rotifers)	Sewage and similar wastes	-

Table 2: Common plant species used for water purification.

Scientific name	Family	Genera	Plant parts	Habit	Reference	Uses
Moringa oleifera Lam.	Moringaceae	Moringa	Seed	Tree	Ndabigengesere et al. (1995)	Coagulation and disinfection
Phaseolus vulgaris L.	Fabaceae	Phaseolus	Seed	Herb	Sciban et al. (2006)	Coagulation
Opuntia ficus indica (L.) Mill.	Cactaceae	Opuntia	Leaves	Shrub	Shilpa et al. (2012)	Coagulation
Dolichos Lablab L.	Fabaceae	Lablab	Fruit	Herb	*Zhang* et al. (2006)	Disinfection
Senna alata (L.) Roxb.	Fabaceae	Senna	Leaves	Shrub	*Aweng* et al. (2012)	Coagulation
Castanea sativa Mill.	Fagaceae	Castanea	Seeds	Tree	*Sciban* et al. (2009)	Coagulation
Aesculus hyppocastanum L.	Sapindaceae	Aesculus	Seeds	Tree	Ramamurthy et al. (2012)	Coagulation
Quercus robur L.	Fagaceae	Quercus	Seeds	Tree	Ramamurthy et al. (2012)	Coagulation
Q. rubra L.	Fagaceae	Quercus	Seeds	Tree	Ramamurthy et al. (2012)	Coagulation
Quercus cerris L.	Fagaceae	Quercus	Seeds	Tree	Sowmeyan et al. (2011)	Coagulation
Coccinia indica (L.) Voight	Cucurbitaceae	Coccinia	Fruits	Vine	Patale & Pandya (2012)	Coagulation
Cicer arietinum L.	Fabaceae	Cicer	Seeds	Herb	Choubey et al. (2012)	Coagulation and disinfection
Phoenix spp.	Arecaceae	Phoenix	Seeds	Tree	Al-Semirey (2012)	Coagulation
Azadirachta indica A. Juss	Meliaceae	Azadirachta	Fruit	Tree	Sowmeyan et al. (2011)	Coagulation
Luffa cylinderca M. Roem	Cucurbitaceae	Luffa	Fruit	Vine	Sowmeyan et al. (2011)	Coagulation
Aloe barbadensis Mill	Alloaceae	Aloe	Seeds	Herb	Yongabi et al. (2011)	Coagulation and disinfection
Jatropha curcas L.	Euphorbiaceae	Jatropha	Seeds	Tree	Ramamurthy et al. (2012)	Coagulation and disinfection
Citrus aurantifolia (Chrism.)	Rutaceae	Citrus	Fruit	Tree	Ramamurthy et al. (2012)	Coagulation and disinfection
Hibiscus sabdarifa L.	Malvaceae	Hibiscus	Calyx	Herb	Sowmeyan et al. (2011)	Coagulation and disinfection
Garcinia kola Heckel	Guttiferae	Garcinia	Seeds	Herb	Ramamurthy et al. (2012)	Coagulation and disinfection
Carica papaya L.	Caricaceae	Carica	Seeds	Tree	Sowmeyan et al. (2011)	Coagulation and disinfection
Mangifera Indica L.	Anacardaceae	Mangifera	Fruit	Tree	Qureshi et al. (2011)	Coagulation
Parkinsonia aculeata L.	Fabaceae	Parkinsonia	Seed	Tree	Marobhe & Gunaratna (2012)	Coagulation
Vigna unguiculata (L.) Verdc	Fabaceae	Vigna	Seed	Herb	Choubey et al. (2012)	Disinfection
Trigonella foenum-graecum L.	Fabaceae	Trigonella	Seed	Tree	Ramamurthy et al. (2012)	Coagulation
Strychnos potatorum	Loganiaceae	Strychnos	Seed	Tree	Ramamurthy et al. (2012)	Coagulation

Table3: Turbitity reduction by different plant species.

Common name	Botanical name	Family name	Uses	Average dosage of powder used (teaspoon/kg)	Average residual turbidity (NTU)
Field bean	*Vicia faba*	Fabaceae	-Common Food stuff -Vegetable soup and stew -Cash crop -Drinking and cooking water purification	3	382(83%)
Bambaranuts	*Voandzeia subterranean*	Fabaceae	-Occational vegetable stuff (vegetable soup & stew) -Drinking and cooking water purification	3	270(88%)
Green gram/Cow peas	*Vigna unguiculata*	Fabaceae	-Rarely grown cash crop -Drinking and cooking water purification	4	225(90%)
Groundnuts	*Arachis hypogaea*	Fabaceae	-Used extensively as food seasoning -Cash crop-Drinking and cooking water purification	2	247(89%)
Jerry bean tree 'wonder tree' Jerusalem thorn	*Parkinsonia aculeate*	Fabaceae	-Drinking and cooking water purification-Green pods -Fuel wood-Shade tree	4	295(87%)
Wood ashes	From any tree species and charcoal	-	-Clarification of water for washing and very rarely for drinking	0.5-1	247(89%)

Leaf extracts, chopped leaves and latex of the giant milk weed or sodom apple (*Calotropis procera*) have shown great promise as a nematicide *in vitro* and *in vivo* (Anvar 1992). The plant has also been reported to contain an active non-toxic proteolytic enzyme which is used in the curdling of milk protein in traditional cheese making in Nigeria.

Submerged macrophytes i.e., *Ceratophyllum demersum*, *Elodea canadensis*, *Potamogeton crispus*, *Myriophyllum spicatum* and *Vallisneria spiralis* can be used for phosphorus removal in lake water and release of phosphorus from the sediment.

CONCLUSION

World population is increasing year to year and has reached 7 billion in 2012, whereas an access of getting pure water remains a problem especially for people who live in developing countries. The severity is much observed in rural dwellers whose source of drinking water is surface water, which is not purified, and this results in transmission of waterborne diseases. To reduce such problems and a strong push to meet the drinking water needs of the developing world, has led to the recent growing interest in using plant based natural coagulants and disinfectants, and plant species showed promising results in coagulating and disinfecting raw water. The plant species also showed a very good result in coagulating turbid water, however, few reports are available in disinfecting capability of plant species, therefore studies should focus on disinfecting ability of natural products. Beyond their advantages over alum, natural coagulants have also few limitations. For instance, they increase organic load in the water which tend to the restabilization to occur. In addition, water treated with natural coagulants was reported only to be used for 24 hours and inefficiency of treating low turbid water is another problem. To avoid the above stated problems, researchers are investigating the active component rather than relying on crude extraction, and protein was reported to be the major active component used in coagulation. In general, other plants should be studied in order to tackle the problem of quality water, especially in developing countries. In such cases, plant species can contribute to advancing the goal of sustainable water treatment technologies that are themselves sustainable.

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