ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 03, pp. 28053-28057, March, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

pH STABILIZATION OF POTABLE WATER USING SELECTED PLANT METABOLITES

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ARTICLE INFO

Article History:
Received 20th December, 2015
Received in revised form
16th January, 2016
Accepted 28th February, 2016
Published online 31st March, 2016

Key words:

Plant materials,
pH stabilization.

ABSTRACT

An attempt has been carried out to access the changes in pH of water samples brought about by selected plant materials from 24 species belonging to 17 families. Batch treatment was carried out with varying dosages of plant materials (0.5g, 1g, 2g, and 4g) and retention time (1.5HAT, 3HAT, 6HAT, 12HAT and 24HAT). Of 24 plants / parts selected, dried fruits of Phyllanthus emblica were able to neutralize both acidic (46% at 24HAT) and alkaline (55% at 6HAT) range of pH. Likewise, neutralization of acidic pH was observed with dry fruits of Terminalia chebula (42.62% at 24 HAT) and seed kernels of Mangifera indica (35.47% at 12 HAT). Dried fruits of Terminalia bellirica and Terminalia chebula were able to neutralize the alkaline pH with a removal percentage of 46.15% and 44.09% at 12 HAT respectively. On correlation ($p<0.01$) and regression analysis, pH neutralization capacity was found to have link with dosage and retention time. The plants screened in the present study can be utilized for pH stabilization in household water treatment systems.

Citation: Snisha, S.and Dr. C.C. Harilal, 2016. "pH stabilization of potable water using selected plant metabolites", International Journal of Current Research, 8, (03), 28053-28057.

INTRODUCTION

Water resources are getting contaminated beyond the level which we can expect. Most developed nations invested much on water treatment facilities, which provide safe water to their population. The situation is different in developing nations, where the quantity / quality provided in most cases is substantially poor (Choy *et al.,* 2015). Consumption of such untidy water can result in a variety of life-threatening diseases like cholera, diarrhea, etc. According to UNICEF and WHO (2009), worldwide about 1.5billion children die every year from water-borne diseases. India has a vast stretch of remote villages with less extent of water resources for drinking and sanitation purposes. Apart from using local water resources, about 22.17% of rural households draw water from faraway places (Ministry of Drinking Water and Sanitation, 2013). The quality of water thus available is also poor due to inadequate treatment facilities. Considering these aspects, there can have cheap and innovative approaches to water treatment in household or community levels using locally available materials. One of the most important parameters that account for the credibility of drinking water is pH. pH is the measure of acid-base equilibrium and in most natural waters, is controlled by carbon dioxide-bicarbonate-carbonate equilibrium (WHO, 1996).

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It plays an important role in sustaining life in water and various biochemical reactions in living systems. Likewise, pH of water also influence water treatment processes like coagulation and flocculation (Othman, *et al.,* 2008) and the speciation of the conventional chemical coagulants (Ca˜nizares *et al.,* 2009). The practice of using plant materials like seeds of *Moringa oleifera*, *Strychnos potatorum* etc. as natural coagulants to clarify turbid water was common since ancient times (Folkard, 1986). As of now, plant materials like seeds of *Moringa oleifera* (Ndabigengesere, and Narasiah 1998), phylloclade of Cactus (Zhang *et al.,* 2006) and bio-compounds like Chitin (Debora *et al.,* 2013), Tannin (Özacar and Şengil, 2003) etc. have been worked out for their coagulation properties. The influence of pH on bio-coagulation was also mentioned in several literature (Unnisa *et al.,* 2010; Khodapanah, *et al.,* 2013; Prodanović *et al.,* 2011). As an extension to the earlier work, the present study has been carried out to assess the capability of two dozen plant materials in neutralizing the pH of the water to an appreciable level of potability, as being carried out by conventional chemical substances.

MATERIALS AND METHODS

Approximately 30 liters of raw water was collected each time from a natural pond adjoining the Botanical Garden of the University of Calicut. The initial pH was estimated immediately using digital pH meter (Systronics, MK VI).

Table 1. Details of plants / parts selected for the study

S.No	Scientific name	Family	Parts used	Mode of Processing
1	*Abelmoschus esculentus*	Malvaceae	Fruits	The fruits were chopped along with seeds and weighed. The weighed pieces are crushed using a mortar and pestle. Washed off and transferred to respective jars.
2	*Aloe vera*	Liliaceae	Leaves	Thick mucilaginous portion was chopped and weighed. The weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
3	*Azadirachta indica*	Meliaceae	Leaves	Leaves were chopped and weighed. Weighed leaves are crushed using mortar and pestle. Washed off and transferred to respective jars.
4	*Bacopa monnieri*	Scrophulariaceae	Whole plant without root	Plant material was chopped and weighed. Weighed plants are crushed using mortar and pestle. Washed off and transferred to respective jars.
5	*Cyamopsis tetragonoloba*	Leguminosae	Fruit	Fruit was chopped and weighed. Weighed fruits are crushed using mortar and pestle. Washed off and transferred to respective jars.
6	*Euphorbia antiquorum*	Euphorbiaceae	Phylloclade	Central thick mucilaginous portion of phylloclade was chopped into small pieces and weighed, after removing the thorns. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
7	*Hemidesmus indicus*	Asclepiadaceae	Dried Stem cutting	Chopped into small pieces and weighed. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
8	*Lagenandra toxicaria*	Araceae	Rhizome	Rhizome was chopped into small pieces and weighed. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
9	*Mangifera indica*	Anacardiaceae	Seed kernels	Seeds were cut open to obtain the kernels. Soft kernels were weighed and were crushed using mortar and pestle. Washed off and transferred to respective jars.
10	*Mentha arvensis*	Lamiaceae	Leaves	Leaves were chopped into small pieces and weighed. Weighed leaves were crushed using mortar and pestle. Washed off and transferred to respective jars.
11	*Momordica charantia*	Cucurbitaceae	Fruits	Fruits were chopped into small pieces and weighed. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
12	*Musa X paradisiaca*	Musaceae	Scape (Peduncle)	Scape (Peduncle) was chopped into small pieces and weighed. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
13	*Opuntia dillenii*	Cactaceae	Phylloclade	Central mucilaginous thick portion was chopped into small pieces after removal of thorns and crushed using mortar and pestle. Washed off and transferred to respective jars.
14	*Phyllanthus emblica*	Euphorbiaceae	Dried fruits	Dried fruits were weighed and weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
15	*Plectranthus amboinicus*	Lamiaceae	Leaves	Leaves were chopped into small pieces and weighed. Weighed leaves were crushed using mortar and pestle. Washed off and transferred to respective jars.
16	*Ricinus communis*	Euphorbiaceae	Seeds	Seeds were removed from the hard seed coat and weighed. Weighed seeds were crushed using a mortar and pestle. Washed off and transferred to respective jars.
17	*Strychnos potatorum*	Loganiaceae	Seeds	Seeds were broken into pieces using a kitchen blender (stone). Uniform pieces were weighed and transferred to respective jars.
18	*Tamarindus indica*	Leguminosae	Seeds	Seeds were crushed using a mortar and pestle and weighed. Weighed pieces were transferred to respective jars.
19	*Terminalia bellirica*	Combretaceae	Dried fruits	Dried fruits were weighed and weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
20	*Terminalia chebula*	Combretaceae	Dried fruits	Dried fruits were weighed and weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
21	*Theobromo cacoa*	Malvaceae	Seeds	Seeds were removed from the flesh and crushed using a mortar and pestle. Weighed, washed off and transferred to respective jars.
22	*Trigonella foenum-graecum*	Leguminosae	Seeds	Seeds were crushed using a mortar and pestle and weighed. Weighed pieces were transferred to respective jars.
23	*Vetiveria zizanioides*	Poaceae	Roots	Roots were chopped into small pieces and weighed. Weighed pieces were crushed using mortar and pestle. Washed off and transferred to respective jars.
24	*Zea mays*	Poaceae	Seeds	Seeds were weighed and crushed using a mortar and pestle. Washed off and transferred to respective jars.

Plants belonging to 24 species representing 17 families were selected for the present study. They were obtained from various localities, free from pollution. Details of plants selected and parts collected for the study are depicted in Table 1.

Experimental layout

Jar test was performed for each plant material screened. As the pH of the raw water collected was within the drinking standards, it was spiked with 1N HCl to acidify and 1N NaOH to make it alkaline.

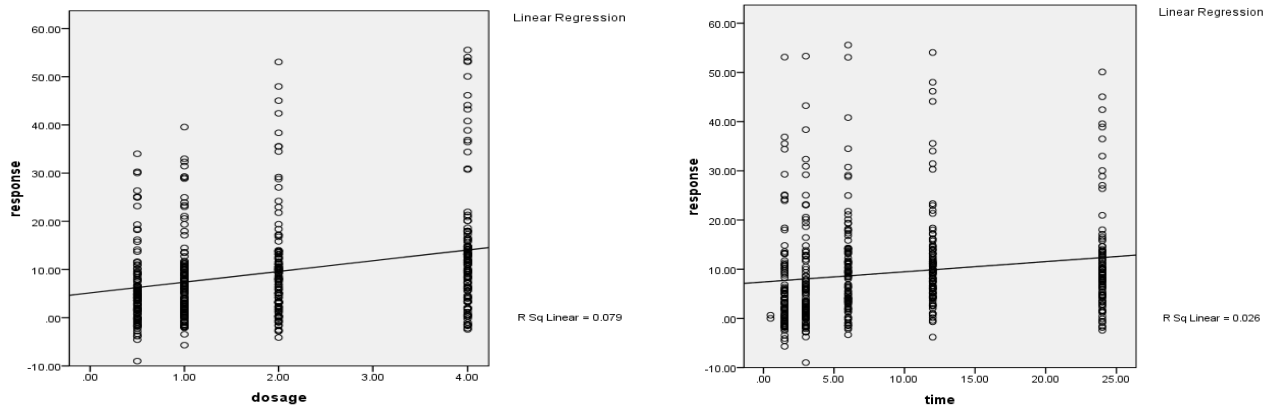
One liter each of the pH spiked raw water was dispensed to glass jars (capacity of 2L) containing the plant material in specific quantity (0.5g, 1g, 2g, and 4g). Altogether 5 set of glass jars were arranged in the same manner (including control) and are retained for specific time period (1.5, 3, 6, 12 and 24 Hours after treatment (HAT)). At the end of stipulated retention time, a sample volume of 60-80 ml was drawn out from the corresponding set using a siphon, without disturbing rest of the water column. This sample was taken for further analysis. pH of the sample drawn out after each retention time was determined using a pH meter (Systronics MK VI).

Table 2. Dosages and retention time of plants/parts at which highest percentage change in the neutralization of acidic pH was noticed

S.No	Plant	Percentage change with respect to control (%)	Quantity (in grams)	Retention time (in hours)
1	*Phyllanthus embilica*	45.84	1g	24HAT
2.	*Terminalia chebula*	42.62	4g	24HAT
3	*Mangifera indica*	35.47	4g	12HAT
4	*Terminalia bellirica*	34.90	4g	24HAT
5	*Euphorbia antiauorum*	31.89	2g	6HAT
6	*Aloe vera*	21.13	0.5g	1.5HAT

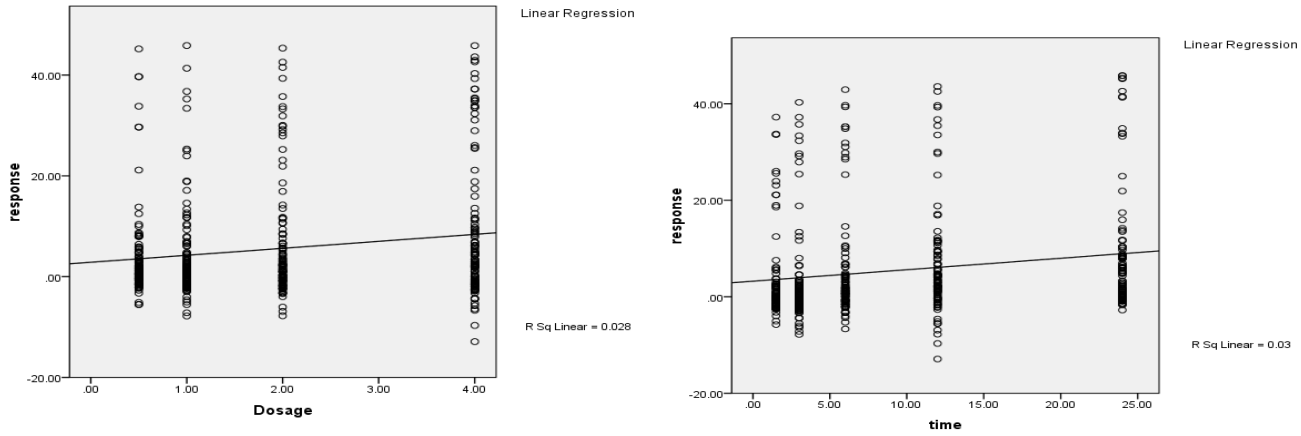
Table 3. Dosages and retention time of plants/parts at which highest percentage change in the neutralization of alkaline pH was noticed

S.No	Plant	Percentage change with respect to control (%)	Quantity (in grams)	Retention time (in hours)
1	*Phyllanthus emblica*	55.55	4g	6HAT
2.	*Terminalia bellirica*	46.15	4g	12HAT
3	*Terminalia chebula*	44.09	4g	12HAT
4	*Momordica charantia*	21.94	4g	12HAT
5	*Azadirachta indica*	21.34	4g	12HAT
6	*Strychnos potatorum*	20.94	4g	24HAT



(a) **(b)**

Figure 1. Linear regression plot showing the positive correlation of (a) dosage and (b) time on the response of the plant material in reducing "acidity" of the water



(a) **(b)**

Figure 2. Linear Regression plot showing the positive correlation of (a) dosage and (b) time on the response of the plantmaterial in reducing alkalinity of water

The percentage change in pH brought about by the plant material was calculated using the formula:

$$\text{Percentage change} = \frac{\text{Initial pH} - \text{Final pH}}{\text{Initial pH}} \times 100$$

The results were subjected to correlation and regression analysis using SPSS (V 16.0) software.

RESULTS AND DISCUSSION

The results of plants/parts which were effective in neutralizing acidic pH are given in table 2 and those which are effective in alkaline pH are given in table 3. In general,most of the plants selected were able to counteract to both augmented acidic and alkaline pH. A gradual increase in the pace of neutralization of

pH (both acidic and alkaline) was observed with an increase in dosage when compared to the control. Almost all the plants selected responded well in neutralizing alkaline pH to neutral level than bringing the acidic pH to normal. At acidic pH, the plants/parts showed varying responses. Highest percentage change brought about by the plants in bringing acidity to neutral levels was 45.84% (dried fruits of *Phyllanthus emblica*) at 24 HAT. In the case of alkalinity neutralization, highest efficiency of 55.55% was observed with *Phyllanthus emblica* at 6 HAT. With *Phyllanthus emblica* fruits, dosages of 1g and 4g were found to be optimum in treating acidity and alkalinity respectively. Likewise, for neutralizing acidic pH, a higher dosage (4g) of *Terminalia chebula, Mangifera indica,* and *Terminalia bellirica* were found to be optimum and exhibited a percentage removal of 42.62%, 35.47%, and 34.90% respectively. Plant materials like *Phyllanthus emblica, Terminalia bellirica* and *Terminalia chebula* were able to neutralize the alkaline pH at a higher dosage of 4g. Usually, lower coagulant dosages are preferred over higher (Šćiban, *et al.,* 2009), however in the present study percentage removal was observed with higher dosages. An increase in dosage and retention time of plant material was found to be statistically significant at a level of $p<0.01$. Upon regression analysis, a positive relationship was also found between the activity of plant material and dosage, as well as with retention time (Fig 1 (a) and (b) and Fig 2(a) and(b)). The optimum time required to achieve the normal pH of water from alkaline range varied from plant to plant. All plant materials, except *Aloe vera*, attained higher percentage removal only after 6HAT. The dosage and retention time required by those plant parts which neutralized the alkaline pH was higher when compared with the dosage and retention time required to neutralize acidic pH (Table 3). Gunaratna, *et al.,* (2007) and Madhukar and Yogesh (2013) have stated that like chemical coagulants, bio-coagulants do not alter the pH of water. But the results obtained in the present study clearly state that plant material does have an innate capability to alter the pH of the water. The reason behind the pH neutralization capacity of plant materials might be due to low molecular weight proteins present in plants / parts that can act as polyelectrolyte which attracts the negatively charged particles as a magnet and thereby converting it into flocs which can be easily removed (Rao N, 2014; Nkhata, 2001).Change in pH was also linked to the varying dosages of the plant material and retention time.

Conclusion

Preliminary screening of 24 plant species belonging to 17 families was carried out for their pH neutralizing capacity. Dried fruits of *Phyllanthus emblica* showed excellent result in neutralizing the augmented acidic and alkaline pH, followed by *Terminalia chebula*(dried fruits) and *Terminalia bellirica* (dried fruits). The percentage removal of pH was linked to the dosage of the plant material and the retention time. Several literatures support the presence of low molecular weight compounds which bring about the coagulation of components in water. The neutralizing capacity of pH by the plant/parts used can be attributed to this reason. The plants screened out in the present study can be utilized in household or community level for water treatment. Further, they can be utilized in pH neutralization either alone or in conjunction with other chemical / biological coagulants. However, it is recommended to check the toxicity of the compounds contained in plant materials, if any, prior to the consumption of such treated water samples.

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