International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 3 Issue: 11 | Nov-2016 www.irjet.net p-ISSN: 2395-0072

Emanating Trends in the Usage of Bio-coagulants in Potable Water Treatment: a Review

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Abstract - *In this review, understanding the role of recently discovered new natural coagulants plays a significant role. Though Moringa olifera has maintained its role in water treatment, it cannot be depended whole heartedly because of the followings drawbacks: i) Large amount of seeds required for small water treatment, and ii) Increased settling time. Here, some of the new materials such as Plantago ovata, Rambutan, Cocinia indica, Cyamopsis tetragonobola and others are discussed for under-standing its role in treatment of water and wastewater. For instance, as per the research conducted, the Rambutan seed, results in more than 90% turbidity removal. FCE (FeCl3 induced crude extract) as an eco-friendly biocoagulant was revealed to be a very efficient coagulant for removing turbidity from waters; and the conventional extraction method of the active coagulant agent by blending the seeds in solvents for 2 min alone sufficiently extracts most of the coagulant component from the Jatropha seed and provides up to 99.4% turbidity removal. Likewise, the active components from other natural materials have also been extracted to overcome the difficulties posed by chemical coagulants.*

Key Words: Rambutan, *Jatropha curcas*, Guar gum, FCE, Blending time, Humic acid concentration

1. INTRODUCTION

The ultimate need in today's uprising world is to provide access to clean drinking water by cost effective means, particularly to the rural population who are not capable to afford an effective water treatment [8]. Chemical coagulants are widely used for turbidity removal in water and wastewater treatment resulting in dangerous health problems. Additionally they are uneconomical to use in developing countries. The Recent work aimed at comparative study of turbidity removal efficiency with various types of natural coagulants available. Natural coagulants produce readily biodegradable and less voluminous sludge that amounts only 20 – 30% that of alum treated counterpart. Among the numerous inorganic and organic chemicals, aluminum salts are most widely used because of their effectiveness and competitive cost. Due to the problems caused by conventional coagulants used in water treatment plants, the use of coagulant preferably extracted from natural and renewable sources plays a predominant role. Therefore, use of plants as water purifiers is simple and effective. It is common practice from ancient times and this can be used to treat water while retaining its natural benefits [22]. These coagulants must be safe for human health and their surrounding environment. In recent years, numerous studies on a variety of plant materials which can be used as natural coagulants have been reported [1].

1. Various Natural Species Used As Coagulants

Since the evolution of mankind, Plants have been used for water treatment. Therefore, natural coagulants play a vital role in water sector that is facing challenges today on how to give people more access to clean drinking water by cost effective means, especially the rural poor who are incapable to afford any water treatment chemicals [11]. At present times, a large number of plant based materials such as *Nephelium lappaceum, Jatropha curcas, Plantago ovato, Guar* gum and others, are used as effective coagulants and also agro based materials are being used as coagulant aid[18].Nowadays various types of natural polyelectrolytes such as Chitosan [7] are also used in potable water treatment.

For instance, Rambutan (*Nephelium lappaceum*) is one of the seasonal fruits grown in Malaysia. It also grows in some parts of Tamilnadu, India. The rambutan canning industry is well-established in Thailand and canners in Malaysia are also producing canned rambutans in syrup. The rambutan fruits are deseeded during canning process and the seeds remain as a wasted by-product of the canning industry. The seed contains 34.1-34.6% moisture. The ash, protein, fat (petroleum ether extract) and crude fibre contents of the seeds on a dry weight basis were measured to be 2.6-2.9%, 11.9-14.1%, 37.1-38.9% and 2.8-6.6% respectively[1]. Another abundantly available and low cost material is

the *Plantago ovata*. These seeds contain mucilage, protein, fixed oil, cellulose, and starch. The seed and press cake (waste after oil extraction) are believed to contain an active coagulant agent which can be used in wastewater treatment also. Interestingly, the efficiency of turbidity removal by a natural coagulant is significantly influenced by the characteristics and the origin of the coagulant. Therefore, an extraction method was developed aiming at improving the material's coagulation capability and therefore reducing the rate of coagulant consumption to make water turbidity removal more cost effective [2]. Likewise, many natural coagulants play a tremendous role in Water Treatment. Therefore, this review helps in identifying such type of coagulants.

2. EXTRACTION OF ACTIVE COMPONENTS

In coagulation and disinfection, a substantial number of active compounds have been isolated from various parts of plant species. Researchers have tried to investigate the specific part where the active agent is located. The active components can be extracted from the plant parts and used in pure or semi-pure form, thus reducing the total amount of organic material added to the treatment process which results in the possibility for undesired and increased microbial activity. Extraction process for the seeds can be done by using different types of solvent like water, organic compound or by using salt solution. Water is by far the most popular choice due to its good polarity, availability and cost. Salt is the second most widely used solvent to extract protein. For example, the active coagulant agent in the *J. curcas* seed is treated as the soluble cationic protein[3].The distilled water is used as solvent in the preparation of coagulant. Then the filtrate was filtered through muslin cloth. Other solvents such as, NaCl and NaOH were also used to prepare effective coagulant. The extract was dried and used in the form of powder also.

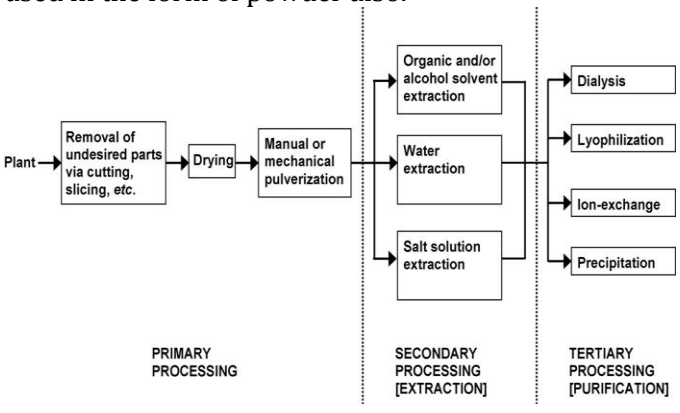

Chart -1: General processing steps in preparation of plant-based coagulants [4].

3. PREPARATION OF WATER SAMPLES

In most of the experiments involving coagulation processes, Kaolin is used to create natural turbid water by artificial means. This mixture is left overnight and the supernatant has been used for testing. Sometimes, turbid water from river or stream is collected to carry out the experiments. Also, sieving the suspension using 75 micron sieve produces faster results. If the water collected from river has initial turbidity exceeding 5NTU, coagulation processes are to be adopted [2, 9, 16, 17, 21, 29].

4. CONTRIBUTION OF NATURAL COAGULANTS TOWARDS TURBIDITY

The contribution of plant materials towards turbidity removal can be detected using Jar test. This test involves three significant stages – Rapid mixing for 1-4 min at 100-120 rpm, slow mixing for 10-25 min at 30-45 rpm and sedimentation for 15-30min [1, 9, 21, 31]. The resulting mixture is passed through the muslin cloth to separate the filtrate and the supernatant, which is used for determining the final turbidity. While carrying out the Jar test, parameters like pH, Dosage, Initial turbidity, Humic acid concentration and blending time for extraction of active ingredients are varied for testing the nature of plant material. The following table represents the percentage of removal turbidity by natural plant species:

Table -1: Different types of Natural Coagulants with their Efficiency

Name of Plant Species	Parts used	Removal efficiency	Reference
Nephelium lappaceum	Seed	99%	[1]
Cassia alata	Leaves	93.33%	[2]
Cocinia indica	Fruit	99.3%	[9]
		94%	[16]
Parkinsonia aculeate	Seeds	99.7%	[10]
Opuntia spp.	Plant	98%	[12]
Phaseolus vulgaris	Seeds	87.3%	[13]

Cyamopsis tetragonobola	Guar gum	99.97%	[15]
Okra	mucilage	98.7%	[17]
Azhadirachta indica	Seeds	99%	[19]
Trigonella foenum-graecum	Seeds	81%	[20]
Plantago ovata	Seeds	95.6%	[21]
		94.5%	[6]
Chestnut	Seeds	80%	[23]
Hyacinth Bean	Bean peels	99.14%	[24]
Opuntia ficus indica	Entire species cut into strips, dried and powdered	99.74%	[24]
Hibiscus sabdariffa	Seeds	99%	[26]
Acacia catechu	Bark	91%	[27]
Dates	seeds	94%	[30]
	Pollen sheath	93%	[30]
Jatropha curcas	Seeds	99.4%	[31]

Though the exact method of coagulation cannot be accomplished, four basic mechanisms occur generally: Ionic layer compression, Adsorption and charge neutralization, entrapment in a flocculent mass, and Adsorption and inter-particle bridging.

As for turbidity this was measured in the form of coagulation activity calculated by the formula:

$$\text{Coagulation activity } (\%) = [(T_s - T_b)/ T_b] \times 100,$$

Where T_s is the turbidity concentration after treatment (mg/L) and T_b is the turbidity concentration of blank (mg/L) [2]. Based on the probable evidence of presence of tannins in Acacia, the major removal mechanism of hydrophobic turbid colloidal particles could be through the binding or chelation with phenolic groups catechu [27, 29].

5. ADVANTAGES OF NATURAL COAGULANT

Owing to the diversified deleterious health effects and economic considerations of use of chemical coagulants (i.e., at least in both developing and under developed countries), several natural coagulants have been either currently researched or actually being used in few WTPs around the world. Numerous natural coagulants (i.e., plant-based materials) like Azhadirachta indica (Sowmeyan et al., 2011); Cassia alata (i.e., a wild legume species) (Aweng et al., 2012); Parkinsonia aculeata seed (Marobhe et al., 2013); Cocinia indica (Jadhav and Mahajan, 2013); Jatropha curcas (Abidin et al., 2013); Moringa olifera (Pise and Halkude, 2013); Mangifera indica (Dange and Lad, 2015); Acacia catechu (Thakur and Choubey, 2014) have been tried to remove turbidity from water. The higher the tannin concentrations, the smaller are the formed flakes and more intense the turbidity of the treated water [14]. Recently, Choy et al (2014) evaluated the scope of utilization of plenty of natural coagulants as future alternatives for sustainable water clarifications and Chart.2 enunciates the significant advantages of natural coagulants over chemical coagulants. As per the analysis carried out by Megersa et al (2014), although, plant species have enormous advantage in water treatment, they also have limitation. The major limitation is the release of organic matter and nutrients to apply at large scale. In concise, from these reviews, it can be concluded that plant species have the potential to serve as a complementary water treatment agent especially in rural areas.

Natural coagulants and disinfectants have enormous advantages in water treatment. They are of great interest for low cost water treatment and help to provide pure water for world population especially for developing countries who hardly get pure water and an additional benefit of using coagulants derived from natural products like Moringa oleifera, is that a number of useful products may be extracted from the seed. Usage of natural products also reduces the formation of disinfectants that deteriorate human health and their byproducts are organic and biodegradable and reduced risk of handling. In terms of action on the physicochemical characteristics of the clarified water, the natural polymers and coagulants show little

variation in pH, alkalinity, conductivity and concentration of cations and anions, and allow more effective removal of BOD and COD and, in some cases microorganisms [28]. The merits of natural coagulant over chemical coagulant are illustrated in the figure given below:

Chart -2: Significant Advantages of Natural Coagulants over Chemical Coagulants [3].

6. FUTURE WORK

However, detailed studies are necessary to completely delineate the appropriate mechanisms like co-precipitation, co-flocculation, and self-agglomeration involved in the turbidity removal by various natural coagulants used, so that it can be applied on a large scale treatment basis. For the determination of appropriate mechanism, SEM and FTIR analysis should be made in all the coagulation processes involving natural coagulant materials.

7. CONCLUSIONS

Increased water scarcity is observed much in rural areas and also to a certain extent in Urban areas. To reduce such problems and the strong push to meet the drinking water needs of the developing world, recently interest has been increased upon the usage of plant based natural coagulants and disinfectants. Since the plant species showed promising result in coagulating and disinfecting raw water with reduced sludge production, disposal problem of sludge in the case of conventional coagulation process has been eradicated. The improper dosage issues caused due to high water treatment cost have been overcome by the natural species. Also, the need of pH adjustment is ruled out on the use of eco-friendly coagulants. Likewise, many significant problems posed by chemical coagulants have been overcome by these coagulants.

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