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Comparative Experimental Investigation on Natural Coagulants & Chemical Coagulants

Smruti Turankar[1], Suhas Sasankar[1], Nikhil Bhosale[1], Pankaj Bedre[1], Prof. Md Shahjada Alam[2]

[1] UG Student, Department Of Civil Engineering, Swaminarayan Siddhanta Institute of Technology, Nagpur, Maharashtra, India

[2] Assistant Professor, Department Of Civil Engineering, Swaminarayan Siddhanta Institute of Technology, Nagpur, Maharashtra, India

ABSTRACT: Lakes in urban expanses are ecologically very important. Those inland water bodies play a major role in sustainable urban development. As a result of the swelling land use and effluent disposal from domestic and industrial activities, water bodies in the urban regions have been suffering in recent times. The present study aims in understanding the physical, chemical and biological conditions of the Futala Lake. This Lake is situated in Nagpur, Maharashtra. This is not being used by the residents due to unknown reasons. This project is based on treating Lake water using organic purification unit which consists of five bio coagulants, which are Tamarind seeds , Velvet Bean seeds , Drumstick seeds , Chickpea seeds , Soyabean seeds which are locally available. Studies conclusively demonstrate that bio coagulants are as efficient alum in purifying water at low cost and also have antimicrobial properties. These were locally available natural coagulants in this study to reduce turbidity and other parameters.

KEYWORDS: Tamarind seeds , Velvet Bean seeds , Drumstick seeds , Chickpea seeds , Soyabean seeds

I. INTRODUCTION

Water is undoubtedly the most vital element among all the natural resources. In many developing countries, access to clean and safe water is a crucial issue. More than 6 million people die because of diarrhea which is caused by polluted water. Due to rapid urbanization and migration from rural areas, there is a tremendous load on water consumption in all major cities. Water condition of surface water of most of the highly populated regions have become highly polluted due to indiscriminate discharge of untreated waste from tannery, textile, municipal waste into water bodies, etc. One of the problems with treatment of surface water is the large seasonal variation in 'Turbidity'.Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand, very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid.

Turbidity in open water may be caused by growth of phytoplankton. Human activities that disturb land, such as construction, mining and agriculture, can lead to high sediment levels entering water bodies during rain storms due to storm water runoff. Areas prone to high bank erosion rates as well as urbanized areas also contribute large amounts of turbidity to nearby waters, through stormwater pollution from paved surfaces such as roads, bridges and parking lots. In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases. This is especially problematic for immuno-compromised people, because contaminants like viruses or bacteria can become attached to the suspended solids. The suspended solids interfere with water disinfection with chlorine because the particles act as shields for the virus and bacteria. Similarly, suspended solids can protect bacteria from ultraviolet sterilization of water.The present study aims at analysis of turbidity parameters of effluent and their reduction in concentrations in low and economical process. Discharging of effluent waste water without treating not only polluting surface water it may also show effect on ground water pollution and soil pollution. So the effluent must be treated in a proper way to meet discharge level requirements. Thus we have opted for Tamarind seeds , Velvet Bean seeds , Drumstick seeds , Chickpea seeds , Soyabean seeds promising bioflocculant whose seeds are plentily available in India which are popular and widely used in rural and tribal areas for the purification of water.

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on the earth need water for their survival and growth. Water is a ubiquitously chemical substance vital to all known forms of life. In nature water exists in liquid, solid and gaseous states. Larger amount of water is present on the earth about three-quarters of the earth surface is covered with water occupying around 97% as seawater and 3% as fresh water. Around two-third of fresh water is icebergs and glaciers. Availability of fresh water for our daily life is only 0.8% of the total amount of water present on earth.Water is a colorless, tasteless and odorless transparent liquid at ambient temperature. Water is a good solvent it is often called as the universal solvent. The polarity of water is an important factor in determining its solvent properties. Water dissolves most of inorganic substances and some organic substances having ionic bonds by dissociating and hydrating them. Uses of water comprise agricultural, industrial, household and environmental activities.Drinking water is a vital resource for all aspects of human beings. Access to safe and clean drinking water is a major concern throughout the world. Ground water surface water and rainwater are often the major sources of water in a community. Ground Water is often the most appropriate source of water for drinking as long as it does not contain high mineral content. Ground water could be extracted through wells or bore holes. Surface Water requires treatment to make it safe for human consumption. Surface water is almost always contaminated by people and animals who defecate in or near the water. Rain water is pure it can be collected in large storage basin or smaller containers. However rain water collected in dirty or unclean containers have to be treated to make it safe for drinking.Natural waters occurring in the environment are not chemically pure waters. While circulating in the environment water contacts with atmosphere, rocks and soil. Due to physical, chemical and biological processes water passing through the ground undergoes purification. Physical processes include dilution, coagulation, precipitation and adsorption. Chemical processes include degradation, oxidation and hydrolysis while biological process includes biodegradation.

II. LITERATURE REVIEW

Research Article 1 (Summary)

Moringa oleifera, Cicer arietinum, and Dolichos lablab were used as locally available natural coagulants in this study to reduce turbidity of synthetic water. The tests were carried out, using artificial turbid water with conventional jar test apparatus. Optimum mixing intensity and duration were determined. After dosing water-soluble extracts of Moringa oleifera, Cicer arietinum, and Dolichos lablab reduced turbidity to 5.9, 3.9, and 11.1 nephelometric turbidity unit (NTU), respectively, from 100 NTU and 5, 3.3, and 9.5, NTU, respectively, after dosing and filtration. Natural coagulants worked better with high, turbid, water compared to medium, or low, turbid, water. Highest turbidity reduction efficiency (95.89%) was found with Cicer arietinum. The jar test operations using different coagulants were carried out in different turbidity ranges namely higher- (90–120) NTU, medium- (40–50) NTU, and lower- (25–35) NTU of synthetic turbid water. The efficiency of the extracts of Moringa oleifera, Cicer arietinum, and Dolichos lablab made them used as natural coagulants for the clarification of water. Doses started from 50 mg/L to 100 mg/L for corresponding six beakers. Turbidity was measured before and after treatment. It was found that the raw water turbidity was 100 NTU. Turbidity reduced to 13.1, 12.7, 10.6, 10, 9.2, and 5.9 NTU corresponding to 50, 60, 70, 80, 90, and 100 mg/L Moringa oleifera doses respectively. After filtration, turbidity reduced to 11.2, 10.9, 9.1, 8.6, 7.9, and 5 NTU, respectively. For medium-turbidity water (turbidity 48 NTU), same doses reduce turbidity to 16.5, 16.1, 15.7, 15.1, 14.9, and 14.7 NTU, respectively, after dosing. And, after filtration, it was 14.1, 13.8, 13.5, 12.9, 12.8, and 12.6 NTU, respectively. Moringa oleifera worked well in higher-turbidity water than lower and medium-turbidity water. Turbidity reduction increases with increasing doses. A similar study conducted showed that the processed Moringa oleifera was improved by isolation of bioactive constituents from the seeds as coagulant/flocculants which gave turbidity removal from 43.9, 91, and 333 NTU to 1.99, 1.40, and 2.20 NTU, respectively, corresponding to the of 0.05, 0.15, 0.30 mg/L. They found that the Moringa oleifera seed is nontoxic and good coagulant in water treatment. It is recommended to be used as a coagulant in developing countries. Encouraged by results of these studies, many developing countries have turned to use this plant as a viable coagulant in water and wastewater treatment on a small scale.

It was found that the raw water turbidity was 95 NTU. Turbidity reduced to 5.9, 5.1, 4.6, 4.5, 4.3, and 3.9 NTU corresponding to 50, 60, 70, 80, 90, and 100 mg/L Cicer arietinum doses. After filtration, turbidity reduced to 5, 4.3, 3.9, 3.8, 3.6, and 3.3 NTU, respectively. For medium-turbidity water (turbidity 49 NTU) same doses reduce turbidity to 12.6, 12.4, 10.2, 9.3, 9.1, and 9 NTU, respectively, after dosing. And, after filtration, it was 10.8, 10.6, 8.7, 7.9, 7.8, and 7.7 NTU, respectively. Most of the results using Cicer arietinum for higher- , medium-, and lower-turbidity-range comply with the Bangladesh drinking standard and the WHO guidelines. Cicer arietinum was found most effective for coagulation when the dose were 100 mg/L for high-, medium-, and lowturbidity water at a 3-min slow mixing time, 12 min slow mixing, and 30 min settling time. Cicer arietinum is cheap, easily cultivable, and available in Bangladesh. On the other hand naturally occurring coagulants are biodegradable and presumed safe for human health.

Different doses were used for different turbidity ranges, and turbidity was measured after dosing. It is found that the raw water turbidity was 100 NTU. Turbidity reduced to 15.5, 14, 13.4, 12.3, 11.6, and 11.1 NTU corresponding to 50, 60, 70, 80, 90, and 100 mg/L Dolichos lablab doses. After filtration, turbidity reduced to 13.3, 12, 11.5, 10.5, 9.9, and 9.5 NTU, respectively. For medium-turbidity water (turbidity 49 NTU), same doses reduce turbidity to 17.1, 16.7, 16.3, 15.9, 15.8, and 15.6 NTU, respectively after, dosing. After filtration it was 14.7, 14.3, 14, 13.6, 13.5, and 13.4 NTU, respectively. A study was conducted using Dolichos lablab as natural coagulant for reduction of turbidity by Unnisa et al, and the study showed that initial turbidities of 20 (low), 40 (medium), and 80 (high) NTUs mainly considerably decreased when the coagulant doses increased. Coagulation was the most effective at a dose of 200 mg/500 mL, when the coagulation activity of the Dolichos lablab seed extract was 65, 62, and 68% at a 60 min settling time. So the use of locally available materials like beans provides a better option for clean, safe water accessible to rural people.Using some locally available natural coagulants, for example, Moringa oleifera, Cicer arietinum, Dolichos lablab, significant improvement in removing turbidity and total coliforms from synthetic raw water was found. Maximum turbidity reduction was found for highly turbid waters. After dosing, watersoluble extract of Moringa oleifera, Cicer arietinum, and Dolichos lablab reduced turbidity to 5.9, 3.9, and 11.1 NTU, respectively, from 100 NTU and 5, 3.3, and 9.5 NTU, respectively after dosing and filtration. It was also found that these natural coagulants reduced about 89–96% of total coliforms. Among the natural coagulants used in this study for turbidity reduction, Cicer arietinum was found most effective. It reduced up to 95.89% turbidity from the raw turbid water.

Research Article 2 (Summary)

In the present study experiments were conducted in the lab to investigate the efficiency of stock solutions obtained from the herbs of Moringa Oleifera (Drum sticks) , Okra gum , and the mucilage isolated from the dry flowers of C.Procera as flocculent for the treatment of turbid water samples containing synthetic turbidity caused by clay materials. Jar test experiments were carried out for high (250NTU and 500NTU), low levels (15NTU, 30NTU and 50 NTU) and medium level(100NTU) of turbidity with the flocculent dosages of 0mg/l 2.5mg/l ,5.0mg/l ,7.5mg/l ,10.0mg/l ,12.5mg/l ,15.0mg/l for Moringa Oleifera , Okra and C.Procera. The results have been compared with the results of alum. The supernatant turbidities obtained from this phase of the study were > 5 NTU. In the next phase again jar tests results were obtained from adding nearly 50% optimum dose of the natural coagulant was kept as constant and dosage of alum was varied. The supernatant turbidities obtained from this study were nearly equal to 5 NTU. (Guide line value recommended by WHO).
From the first phase (Batch Coagulation Test) of the study , it was found that the optimum dosages of Alum, Moringa Oliefera, Okra and C.procera were 10 mg/l , 7.5 mg/l , 10 mg/l and 15 mg/l with the maximum turbidity removal efficiencies of 96% , 76% , 54 % and 64 % for low turbid waters and 92% , 87% , 68% and 73% for medium turbid waters and 98% , 92% , 74% and 86.8% for high turbid water respectively. The supernatant turbidities obtained at the end of this phase for medium turbid water were 8NTU, 13 NTU, 32 NTU and 27 NTU when Alum, S.Potatorum, Cactus and C.Indica were applied as a coagulant respectively. These values are greater than 5 NTU (value recommended by WHO). From the second phase of the study, it was found that when nearly and equal to 50% optimum dose of each coagulants (5 mg/l in the case of Moringa Oliefera, 5 mg/l in the case of Okra and 7.5 mg/l in the case of C.Procera) were applied with varying dosages of alum (2.5 mg/l , 5 mg/l , 7.5 mg/l , 10 mg/l , 12.5 mg/l , 15 mg/l 17.5 mg/l and 20mg/l) it was found that alum of 5 mg/l gave the maximum turbidity removal efficiencies.

The supernatant turbidities obtained at the end of this test were 5 NTU, 2 NTU and 3 NTU for Moringa Oliefera, Okra and C.Procera respectively which are equal to and less than 5NTU. From the observations taken it was also concluded that when natural coagulants were used as a coagulant aid, the dosage of alum can be reduced to almost 50% which can help to reduce the detrimental effects caused by chemical based coagulants. Natural coagulant is sustainable and economical way of water treatment process. In this research the conventional coagulant alum has been mixed with nearly 50% of optimal dosages of each coagulant.

Research Article 3 (Summary)

The main advantages of using natural plant-based coagulants as POU water treatment material are apparent; they are cost-effective, unlikely to produce treated water with extreme pH and highly biodegradable. These advantages are especially augmented if the plant from which the coagulant is extracted is indigenous to a rural community. In the age of climate change, depletion of earth's natural resources and widespread environmental degradation, application of these coagulants is a vital effort in line with the global sustainable development initiatives. Usage of plant-based coagulants for turbid water treatment dates back to over several millennia ago and thus far, environmental scientists have been able to identify several plant types for this purpose. While it is understandable that the coagulants are meant as simple domestic POU technology, there have also been numerous studies focused on their usage for treatment of industrial wastewaters. The mechanisms associated with different natural coagulants are varied as well. It is imperative for relevant stakeholders to fully comprehend the technicalities involved when considering the coagulants for rural, domestic or industrial water treatment. To address this, this paper provides an overview of the natural coagulant sources, processes and mechanisms involved so that environmental specialists can tailor its usage for a myriad of water contaminants. To provide a more focused discussion, natural coagulants derived from non-plant sources such as chitosan (widely produced from exoskeleton of crustaceans) and isinglass (produced from fish swim bladders) are excluded from this review. This exclusion is based on practicability, since non-plant sources are less likely to have the potential for mass production compared to plant sources [10]. It is surprising to note that a comprehensive critical analysis of available plant-based coagulants is still non-existent given the importance of sustainable environmental technology in the 21st century and hopefully this review can provide an immediate platform for environmental scientists to intensify their research on these natural materials.The usage of natural coagulants derived from plant based sources represents a vital development in ‘grassroots’ sustainable environmental technology since it focuses on the improvement of quality of life for underdeveloped communities. Fortunately, it is surprised that usage of these coagulants is far more receptive by environmentalists worldwide since it avoids the common problem faced by biofuels usage where skeptics feel that their benefits are outweighed by global food shortage and deforestation caused by mass plantation of biofuel plants. Nonetheless, there are many pressing issues that are hindering process development of these coagulants, namely, absence of mass plantation of the plants that affords bulk processing, perceived low-volume market and virtually non-existent supportive regulation that stipulates the quality of the processed coagulant extracts. The cost-effectiveness of using the natural coagulant as simple POU technology. The last factor is especially vital since it is normally difficult for regulatory authorities to endorse a product for sale to the general public. In view of this, it is felt that application is currently restricted to smallscale usage and academic research but it can benefit from fervent promotion and endorsement from relevant stakeholders, particularly the from the authorities. In technical terms, these natural coagulants are highly effectual for treatment of waters with low turbidity but may not be feasible in the case of wastewaters with extreme pH. As such, it is always prudent for water treatment practitioners to circumspectly select the most suitable natural coagulants and tailor them for specific proposes. Quite clearly, M. oleifera is the most researched plantbased coagulants but it is felt that further research can be conducted by using the information described in this review as a platform to discover other plant species which are non-toxic and can be mass produced. As a starting point, researchers should pay close attention to other plants with parts that have high active coagulation extract yields which contain recognized active coagulant agents including galacturonic acid.Researchers have identified the coagulant component from M. oleifera seed extract as a cationic protein. It is thought to consist of dimeric proteins with a molecular weight in the range of 6.5–14 kDa. Using the crude extract as coagulant presented problems of residual dissolved organic carbon (DOC) which makes its use in drinking water not feasible. It is therefore necessary to purify the coagulant. However, the direct application of this isolated agent is not possible under the hypothesis of sustainable and appropriate technology. Consequently, the search for simple and low cost purifications procedures as well as the use of the coagulant in combination with other coagulants and treatment processes needs to be adopted.

Moringa oleifera (horseradish or drumstick tree), a nontoxic (at low concentrations) tropical plant found throughout India, Asia, sub Saharan Africa and Latin America whose seeds contain an edible oil and water soluble substance , is arguably the most studied natural coagulant within the environmental scientific community. It is widely acknowledged as a plant with numerous uses with almost every part of its plant system can be utilized for beneficial purposes. Moringa is most frequently used as food and medicinal sources within less-developed communities. It has been reported that rural communities in African countries utilize its crude seed extracts to clear turbid river water. Moringa oleifera is a tropical multipurpose tree that is commonly known as the miracle tree. Among many other properties, M. oleifera seeds contain a coagulant protein that can be used either in drinking water clarification or wastewater treatment.

Hence an analysis and review of available literature reveals that biocoagulant activity of studied plants has been little explored. Review of literature indicate that there are lot of work done on effect of plant based coagulants on water quality.

III. PROPOSED METHODOLOGY

All coagulation experiments were carried out using synthetic artificial turbid water. A conventional jar test apparatus was used in the experiments to coagulate sample of synthetic turbid water using coagulants.

3.1 MATERIALS USED

The powdered form of 5 seeds, namely 'Moringa oleifera' (Drumstick), 'Cicer Arietinum' (Chick pea), 'Dolichos lablab' (Velvet Bean), 'Glycine max' (Soyabean), 'Tamarindus indica' (Tamarind) were used as locally available natural coagulants in this study to reduce turbidity of synthetic water. The tests were carried out using artificially prepared turbid water with conventional 'Jar test apparatus'.

1. Moringa oleifera (Drumstick):

(Fig.4.1: Moringa oleifera seed pods)

It is the most widely cultivated species in the genus Moringa, the only genus in the plant family 'Moringaceae'. Common names include moringa, drumstick tree (from the long, slender, triangular seed-pods), horseradish tree (from the taste of the roots, which resembles horseradish), and ben oil tree or benzoil tree (from the oil which is derived from the seeds). It is widely cultivated for its young seed pods and leaves used as vegetables and for traditional herbal medicine. It is also used for water purification.

(Fig.4.2: Drumsticks)

Moringa seed cake, obtained as a byproduct of pressing seeds to obtain oil, is used to filter water using flocculation to produce potable water for animal or human consumption. Moringa seeds contain dimeric cationic proteins which absorb and neutralize colloidal charges in turbid water, causing the colloidal particles to clump together, making the suspended particles easier to remove as sludge by either settling or filtration. Moringa seed cake removes most impurities from water. This use is of particular interest for being nontoxic and sustainable compared to other materials in moringa-growing regions where drinking water is affected by pollutants. Only the inner white pods of the dried seeds, in a powdered form are used as Coagulants.

2. Cicer arietinum (Chickpea):

Chickpea (Cicer arietinum) seeds are high in protein. Cicer arietinum or chick pea has been widely consumed as a food source which has high contents of carbohydrate and protein. Of late, this plant extract has also been found to exhibit coagulation activity in the treatment of synthetic water. The chemical compositions in C. arietinum was found to be largely carbohydrate followed by crude protein which are the two most attributed constituents responsible for the coagulation of colloidal particles. For every 100 grams of Chickpea, 19 grams of protein is present which assists in coagulation process.

(Fig.4.3: White Chickpea)

3. Dolichos lablab (Velvet Bean):

On a dry matter basis, the percentage of crude protein varies from 22·4 to 31·3, crude fibre, 7·62 to 9·63 and total carbohydrate, 54·2 to 63·3. The amounts (mg/100 g) of calcium, phosphorus, phytate phosphorus and iron ranges from 36·0 to 53·5, 388 to 483, 282 to 380 and 5·95 to 6·90, respectively. The proteins in it bear a positive charge and tend to bind with the negatively charged particulates in turbid water thereby forming flocs.

(Fig.4.4: Velvet Beans)

(Fig.4.5: Dried seeds of Velvet Beans)

4. Glycine max (Soyabean):

Widely known as soybean, the G. max plant is the most important source of vegetable oil, accounting for more than 50 % of the world's oilseeds. Its genus name 'Glycine' has been derived with reference to the Greek word 'glykys' which means sweet. Like most legumes, the seed extracts were reported to exhibit water clarification properties when tested in synthetic water.The soybeans contained relatively large fraction of lipid and is the second highest legume trailing behind A. hypogaea. This contributes to coagulation activities, and de-lipidation of the seeds will be useful if enhancement in its turbidity removal is required. In addition to turbidity removal, de-lipidated or De-oiled soybeans have also been recently found out to be lowcostbioadsorbents in the treatment of various dye-contaminated waters. Palmitic and stearic acids which contributed to the bactericidal activities in H. esculentus are also present in G. max. Hence, this plant extract could also exhibit potency against some of the bacteria present in raw surface water.

(Fig.4.6: Soyabean)

For every 100 grams of Soyabean, 36.49 grams of Protein is present which plays a crucial role in the process of coagulation and flocculation. Recently, a product called 'PolyGlu' was made using fermented Soyabean. It could clear muddy water within a few seconds. Higher protein content could be one of the reasons for its effective coagulant and flocculating properties.

5. Tamarindus indica (Tamarind):

(Fig.4.7: Tamarind seeds)

Table 4.1 Composition of tamarind seed kernels

Composition	Original	De-oiled
Oil	7.6%	0.6%
Protein	7.6%	19.0%
Polysaccharide	51.0%	55.0%
Crude fiber	1.2%	1.1%
Total ash	3.9%	3.4%
Acid insoluble ash	0.4%	0.3%
Moisture	7.1%	

The Protein and Polysaccharide composition is mainly responsible for the Coagulation properties found in powdered form of dried Tamarind seeds. Proteins bear a positive charge which end up binding with the negatively charged colloidal particles when an optimum quantity is added to turbid water.

JAR TEST APPARATUS

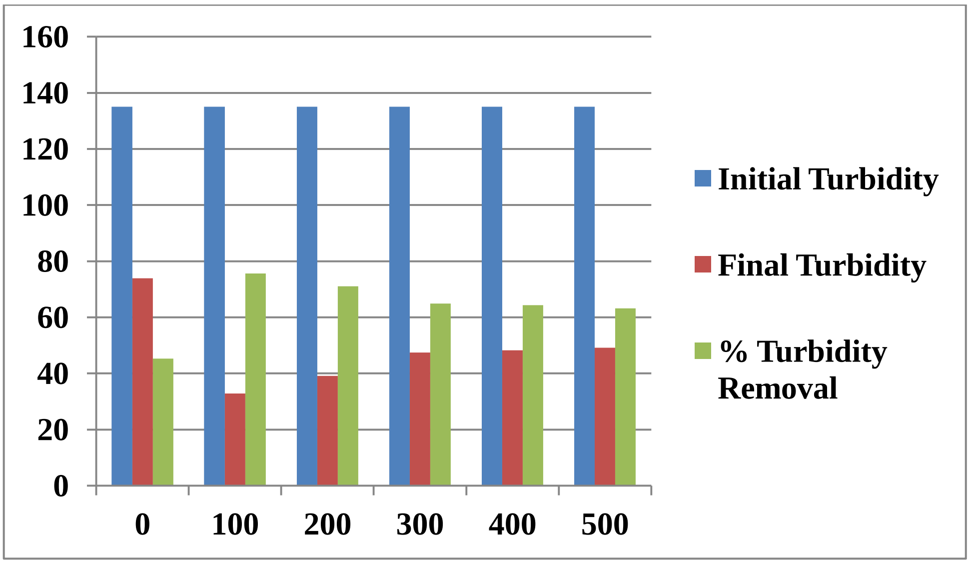
Jar test is the most widely used experimental methods for coagulation-flocculation. A conventional jar test apparatus was used in the experiments to coagulate sample of synthetic turbid water using some coagulants . It was carried out as a batch test, accommodating a series of six beakers together with sixspindle steel paddles. Before operating the jar test, the sample was mixed homogenously. Then, the samples ought to be measured for turbidity, coliform count for representing an initial concentration. Coagulants of varying concentrations were added in the beakers. The whole procedures in the jar test were conducted in different rotating speed.

IV. RESULTS & DISCUSSION

The following Bar charts indicate the values of Coagulant dose (mg/L), Initial Turbidity (NTU), Final Turbidity (NTU), Turbidity removal (%). 'NTU' refers to Nephelometric Turbidity units.

1. Tamarindus indica (Tamarind):

Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant dose (mg/L)

Dried Tamarind seeds were made into a fine powder and used as coagulant. Varying doses were used as shown in the Bar chart above. Since the nature and effectiveness of this natural coagulant was unknown, dosages of 100, 200, 300, 400, and 500 mg/L respectively were used in each of the 5 jars. The Initial Turbidity of synthetic water sample was found to be 135 NTU. Once the Jar test experiment was completed, Final (Supernatant) Turbidity of all samples was measured using a Nephelometer. As per the observations and Bar chart plotted above, maximum percentage Turbidity removal in this case was found at a dosage of 100 mg/L. But this is not the optimum coagulant dose as the Turbidity values kept increasing. So, doses were changed and the Jar test experiment was conducted once again in order to obtain the optimum dosage.

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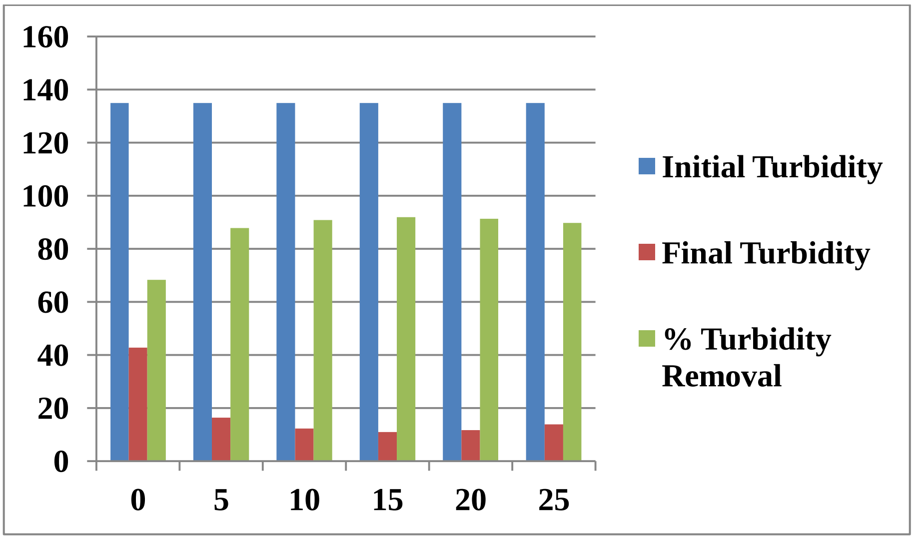
Turbidity removal (%) versus Coagulant dose (mg/L)



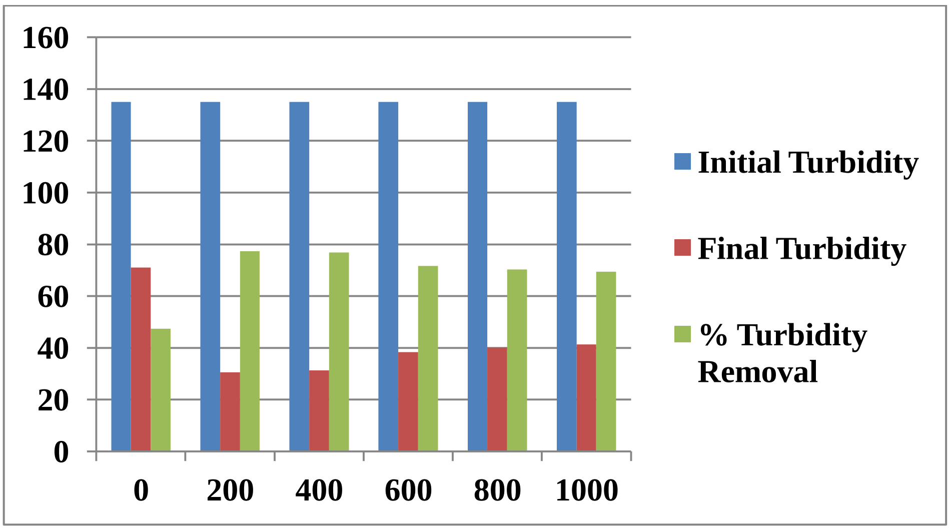
Coagulant dose (mg/L)

As per the new measured values, maximum percentage Turbidity removal of 91.92% was obtained at an optimum dose (Tamarind seeds powder) of 15 mg/L.

2. Dolichos lablab (Velvet Bean):

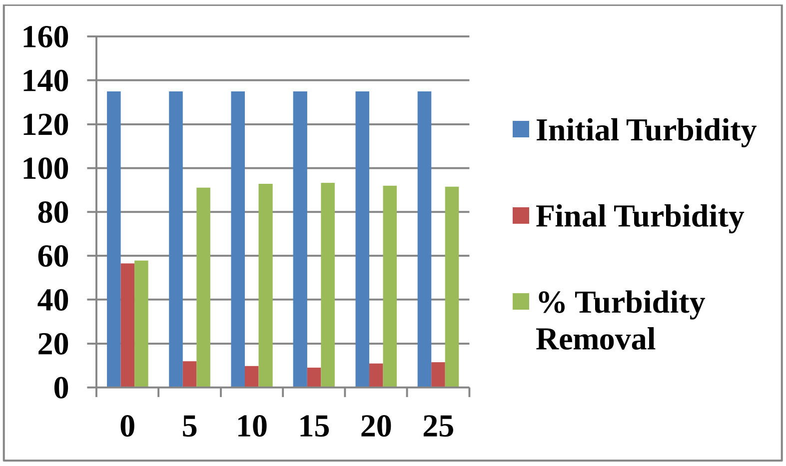
Dried Velvet Bean seeds were made into a fine powder and used as coagulant. Varying doses were used as shown in the Bar chart. Since the nature and effectiveness of this natural coagulant was unknown, dosages of 200, 400, 600, 800, and 1000 mg/L respectively were used in each of the 5 jars. The Initial Turbidity of synthetic water sample was found to be 135 NTU. Once the Jar test experiment was completed, Final Turbidity of all samples was measured using a Nephelometer. As per the observations and Bar chart plotted, maximum percentage Turbidity removal in this case was found at a dosage of 200 mg/L. But this is not the optimum coagulant dose as the Turbidity values kept increasing.

Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant dose (mg/L)

Turbidity removal (%) versus Coagulant dose (mg/L)

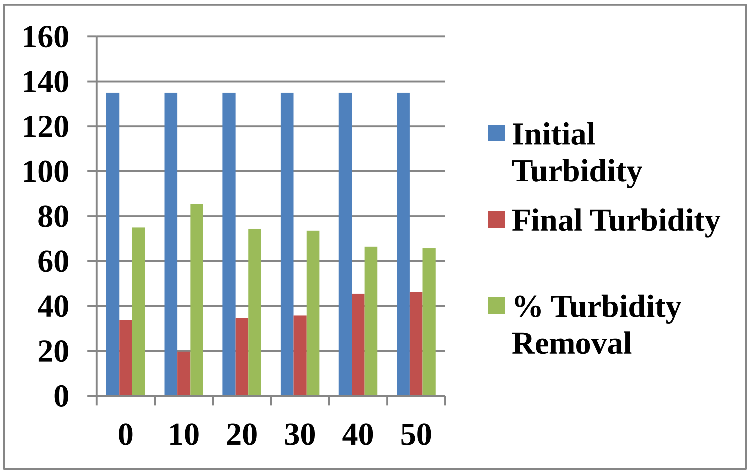


Coagulant dose (mg/L)

As per the new measured values, maximum percentage Turbidity removal of 93.31% was obtained at an optimum dose (Velvet bean seeds powder) of 15 mg/L.

3. Moringa oleifera (Drumstick):

Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant dose (mg/L)

Dried Drumstick seeds (only the white pods) were made into a fine powder and used as coagulant. Varying doses were used as shown in the Bar chart. Since the nature and effectiveness of this natural coagulant was unknown, dosages of 10, 20, 30, 40, and 50 mg/L respectively were used in each of the 5 jars. The Initial Turbidity of synthetic water sample was found to be 135 NTU. Once the Jar test experiment was completed, Final Turbidity of all samples was measured using a Nephelometer. As per the observations and Bar chart plotted, maximum percentage Turbidity removal in this case was found at a dosage of 10 mg/L. But this is not the optimum coagulant dose as the Turbidity values kept increasing. So, doses were changed and the Jar test experiment was conducted once again in order to obtain the optimum dosage.

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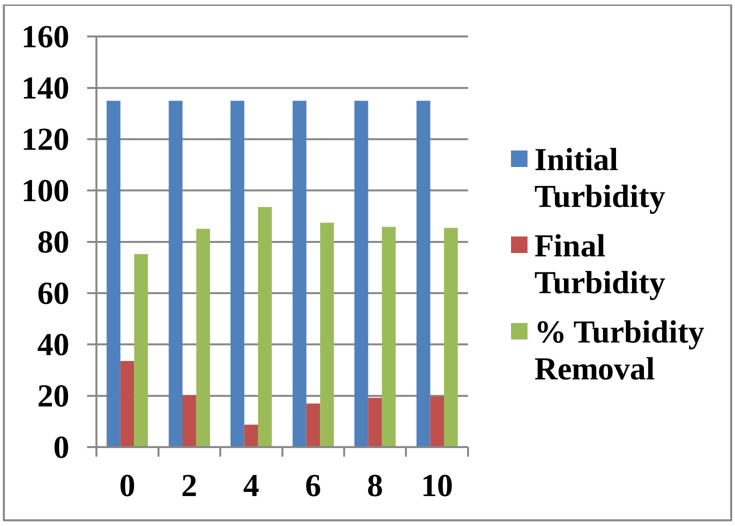
Turbidity removal (%) versus Coagulant dose (mg/L)



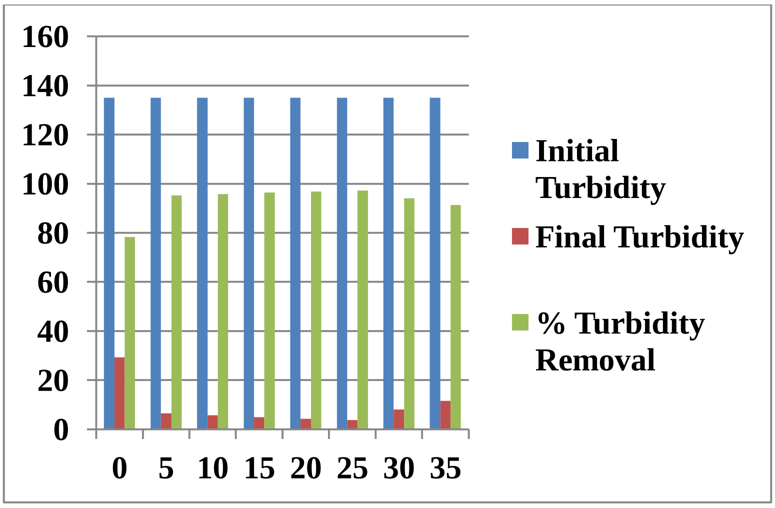
Coagulant dose (mg/L)

As per the new measured values, maximum percentage Turbidity removal of 93.51% was obtained at an optimum dose (Drumstick seeds powder) of 4 mg/L.

4. Cicer arietinum (Chickpea):

Dried Chickpea seeds were made into a fine powder and used as coagulant. Varying doses were used as shown in the Bar chart. Since the nature and effectiveness of this natural coagulant was unknown, dosages of 5, 10, 15, 20, 25, 30, and 35 mg/L respectively were used in each of the jars. The Initial Turbidity of synthetic water sample was found to be 135 NTU. Once the Jar test experiment was completed, Final Turbidity of all samples was measured using a Nephelometer. As per the observations and Bar chart plotted, maximum percentage Turbidity removal of 97.25 % in this case was found at an optimum dosage of 25 mg/L. Since optimum dosage is obtained, Jar test experiment using Chickpea as a coagulant was not conducted once again.

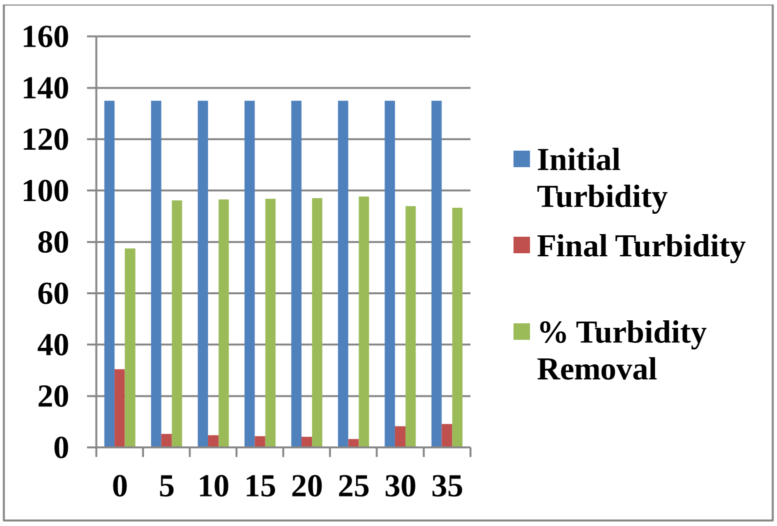
Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant dose (mg/L)

5. Glycine max (Soyabean)

Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant dose (mg/L)

Dried Soyabean seeds were made into a fine powder and used as coagulant. Varying doses were used as shown in the Bar chart. Since the nature and effectiveness of this natural coagulant was unknown, dosages of 5, 10, 15, 20, 25, 30, and 35 mg/L respectively were used in each of the jars.

The Initial Turbidity of synthetic water sample was found to be 135 NTU. Once the Jar test experiment was completed, Final Turbidity of all samples was measured using a Nephelometer. As per the observations and Bar chart plotted, maximum percentage Turbidity removal of 97.6 % in this case was found at an optimum dosage of 25 mg/L.

Table 5.1 Efficiency of Bio-Coagulants

NAME OF COAGULANT	FINAL TURBIDITY (NTU)	TURBIDITY REMOVAL (%)
Tamarind seeds	10.9	91.92
Velvet Bean seeds	9.02	93.31
Drumstick seeds	8.76	93.51
Chickpea seeds	3.7	97.25
Soyabean seeds	3.24	97.6

The Final Turbidity values and the Percentage Turbidity removal values are tabulated . So, out of all the seeds considered, 'Soyabean seeds' have been found to be the most suitable and effective natural coagulants.

V.CONCLUSION

After dosing water-soluble extracts of Tamarind seeds, Velvet Bean seeds, Drumstick seeds, Chickpea seeds, and Soyabean seeds, Turbidity reduced from 135 NTU to 10.9, 9.02, 8.76, 3.7, and 3.24 Nephelometric turbidity unit (NTU), respectively. Highest turbidity reduction efficiency (97.6%) was found with 'Glycine max' (Soyabean) at an optimum dosage of 25 mg/L.Chickpea seeds were the next most effective natural coagulant as a Turbidity reduction efficiency of 97.25% was observed. Then comes Drumstick seeds, Velvet Bean seeds, and Tamarind seeds respectively in the order of effectiveness as far as Turbidity reduction is considered. Therefore, by using locally available natural coagulants, suitable, easier, and environment friendly options for water treatment were observed.Hence, there is a need to search for the native materials which can be used for water purification as these can provide technology near to the point of use that can be adapted by communities. In these lines, the present study has been focused on reviewing natural coagulants for water treatment owing to the disadvantages of chemical coagulants. Present technologies of water treatment have been created on the foundation of traditional practices/ methods, which have been ignored off late.This

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study will not only throw light on the traditional knowledge but also provide an insight of the available natural coagulants. In this review, we have presented natural coagulants whose availability is innate, their efficiency is also presented so that they can be considered for further study. It can be concluded that natural coagulants bring with them advantages of being low cost, copious, native and efficient for treatment. Further studies in optimizing working parameter of the coagulants along with increasing shelf life will benefit research in this area.

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