EXPERIMENTAL STUDY ON TREATMENT OF DOMESTIC WASTE WATER USING NATURAL COAGULANTS

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ABSTRACT

Natural coagulant is a naturally occurred, plants based coagulant that can be used in coagulation-flocculation process of domestic wastewater treatment for reducing turbidity. The objectives of this study were to assess the possibility of using natural coagulants as an alternative to the current commercial synthetic coagulant such as aluminium sulphate and to optimize the coagulation process. Based on the experimental results, it was concluded that natural coagulants which have been obtained from Cicer arietinum(Chickpea), Moringa Oleifera(Drumstick), Hibiscus Rosa Sinensis,Dolichos lablab(Velvet Bean),Glycine max(Soyabean),Tamarindus indica(Tamarind) have showed an merely equalant coagulation comparing to commercial alum. The turbidity removal efficiency for Dolichas lablab, Azadirachta Indica, Moringa Oleifera, Hibiscus Rosa Sinensis respectively were 37.45%, 63.01%, 31.47%, 12.95% against 75.01% obtained from alum.

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 most widely used measurement unit for turbidity is the 'Formazin Turbidity unit' (FTU). ISO refers to its units as FNU (FormazinNephelometric units). ISO 7027 provides the method in water quality for the determination of turbidity. The propensity of particles to scatter a light beam focused on them is now considered a more meaningful measure of turbidity in water. Turbidity measured this way uses an instrument called a**'Nephelometer'**with the detector set up to the side of the light beam. More light reaches the detector if there are lots of small particles scattering the source beam than if there are few. The units of turbidity from a calibrated Nephelometer are called **'Nephelometric Turbidity Units' (NTU)**. To some extent, how much lightreflects for a given amount of particulates is dependent upon properties of particles like their shape, color and reflectivity. Governments have set standards on the allowable turbidity in drinking water. The 'World Health Organization' establishes that the turbidity of drinking water should not be more than **5 NTU**, and should ideally be below **1 NTU**. A per Indian standards **(IS 10500:2012)**, permissible limit of Turbidity is **5 NTU** and maximum limit is **10 NTU**.

Turbidity is commonly treated using either a settling or filtration process. Depending on the application, chemical reagents will be dosed into the wastewater stream to increase the effectiveness of the settling or filtration process. In-situ treatment of turbidity involves the addition of a reagent, generally a flocculant, evenly dispensed over the surface of the body of water. The flocs then settle at the bottom of the water body where they remain or are removed when the water body is drained. There are a number of chemical reagents that are available for treating turbidity, which include 'Aluminium Sulfate'(Alum), 'Ferric chloride', 'Gypsum', 'Poly-aluminium chloride' etc.

Turbid water is objectionable primarily because the physical appearance of dirty water is less appealing than clear sparkling water. The main problem turbidity causes is interference with disinfection processes. Bacteria, which are usually present in turbid water, can be protected from chlorine and other disinfectant techniques. The flow rate of a water body plays a big part in its potential for turbidity. The heavier a rain is, the greater its ability to pick up and carry sand, silt, clay and organic particles. Fast-moving water can carry more and larger particles because the force of the water overcomes the tendency of these particles to settle out of suspension. High velocity water can also stir up bottom sediments that then become resuspended and increase turbidity even further. Some of the environmental conditions that cause turbidity include:

a. **Erosion** due to soil disturbances or lack of ground cover as a result of construction, mining, logging or wildfires.
b. **Urban runoff** of debris from developed areas, where the prevalence of paved surfaces does not allow natural settling of particles to take place from stormwater before it reaches creeks, streams and rivers.
c. **Wastewater** that has been cleaned but still carries some residual particles.
d. **Decay of living organisms**, both plant and animal.
e. **Algae**, especially when environmental conditions make bodies of water especially nutrient-rich and trigger algal blooms.
f. **Bottom-feeding fish** that stir up sediment as they seek out food.

As Turbidity does not directly impose any health risk, it is only considered a secondary water contaminant. However, cloudy water could indicate the possibility that other pollutants, such as 'Cryptosporidium' and 'Giardia' which do pose a health risk, are present.

'Clarification' refers to the sequence of operations used to remove suspended solids (mineral and organic) from the raw water together with a proportion of the dissolved organic matter (flocculating fraction). Depending on the concentrations of the various contaminants present, there may be the need for increasingly complex operations ranging from simple filtration with or without reagents. Clarification process is applied when there is a high degree of turbidity in the water or when solids must be separated from liquids. Clarification is highly effective at reducing turbidity and removing color, solids and colloidal material from water and wastewater when used together with chemical feed, sludge treatment and filtration of clarified elements.

Sedimentation and Decantation are done to get rid of the heavier suspended particles. Clarification which is the next step consists of 4 distinctive processes namely:

a) Coagulation
b) Flash mixing
c) Flocculation
d) Settling

The variables that affect how these processes are carried out are water velocity, time, andpH. Sufficient time and velocity are necessary to maximize the probability that particles will come together. The pH level is an important determinant of how thoroughly colloids are removed.

a) Coagulation:

During this process, as per the conventional method,chemical coagulants are added to water to destabilize colloidal and finely divided materials and to cause them to begin aggregating.

The most commonly employed metal coagulants fall into 2 groups – Aluminium-based, such as Aluminium sulfate, Aluminium chloride and Sodium Aluminate; and Iron- based, such as Ferric sulfate, Ferric chloride, and Ferric chloride sulfate. Other chemicals sometimes used in the water treatment process are Magnesiumcarbonate and Hydrated lime, among others.

Aluminium and Iron coagulants work by forming highly adsorptive multi-charged polynuclear complexes. The pH of the system can be manipulated to control the characteristics of the complexes and their effectiveness.

b) Flash mixing:

After chemical coagulants are introduced, the water is mixed quickly and forcefully by the flash mixer so that the chemicals are evenly distributed throughout the water. This step is very important to create the conditions for efficient, effective water treatment.

Flash mixing must last atleast30 seconds, or else the chemicals will not be properly distributed. When wateris flash mixed for a longer period, the mixer blades will tend to chop or shear the aggregating material back into small particles.

Coagulation actually begins during flash mixing as the coagulants neutralize the electrical charge of the fine particles. This stops the repulsion of like-charged particles and allows the particles to begin bonding and forming larger clumps.

Coagulation affects the performance of other stages of treatment, favoring microbiological quality of the final product thereby increasing the lifetime of Filters and reducing the final cost of treated water.

c) Flocculation:

After flash mixing, flocculation begins with a slower gentler mixing that brings the fine particles produced during the coagulation step into contact with each other. The flocculation phase usually goes on for 30-45 minutes in a flocculation basin that may have multiple compartments.

Each comp This approach allows increasingly large clumps of matter to form without being broken apart by the mixing blades.

At the end of this process, most of the turbidity and particulate matter in the water should be formed into a material called **'floc'**, which consists of relatively large clumps of impurities and bacteria bound together in clusters of about 0.1 to 3.0 mm in size.

A larger floc is more likely to break apart in the flocculation basin.

The coagulation-flocculation process is necessary in water treatment primarily because of non-settleable solids, particles too small to be removed effectively by other treatment processes such as Sedimentation and Filtration.

These non-settleable solids can be changed into larger and heavier settleable solids by physical and chemical changes brought about by adding and mixing chemical coagulants in raw water. Colloidal particles consist of particles with an electric charge, usually negative.

This characteristic prevents the collision and aggregation of particles. Addition of certain chemicals to colloidal suspension can enhance destabilization and segregation of particles, leading to formation of flocs of considerable dimensions. These flocs can then be furtherremoved by Sedimentation and Filtration In general, Coagulant processing involves 4 steps such as:

a) Bridging mechanism
b) Charge neutralization
c) Double layer compression
d) Sweep floc mechanism

artment has a different mixing speed, and these speeds randomly decrease as water flows from top of the basin to its bottom.

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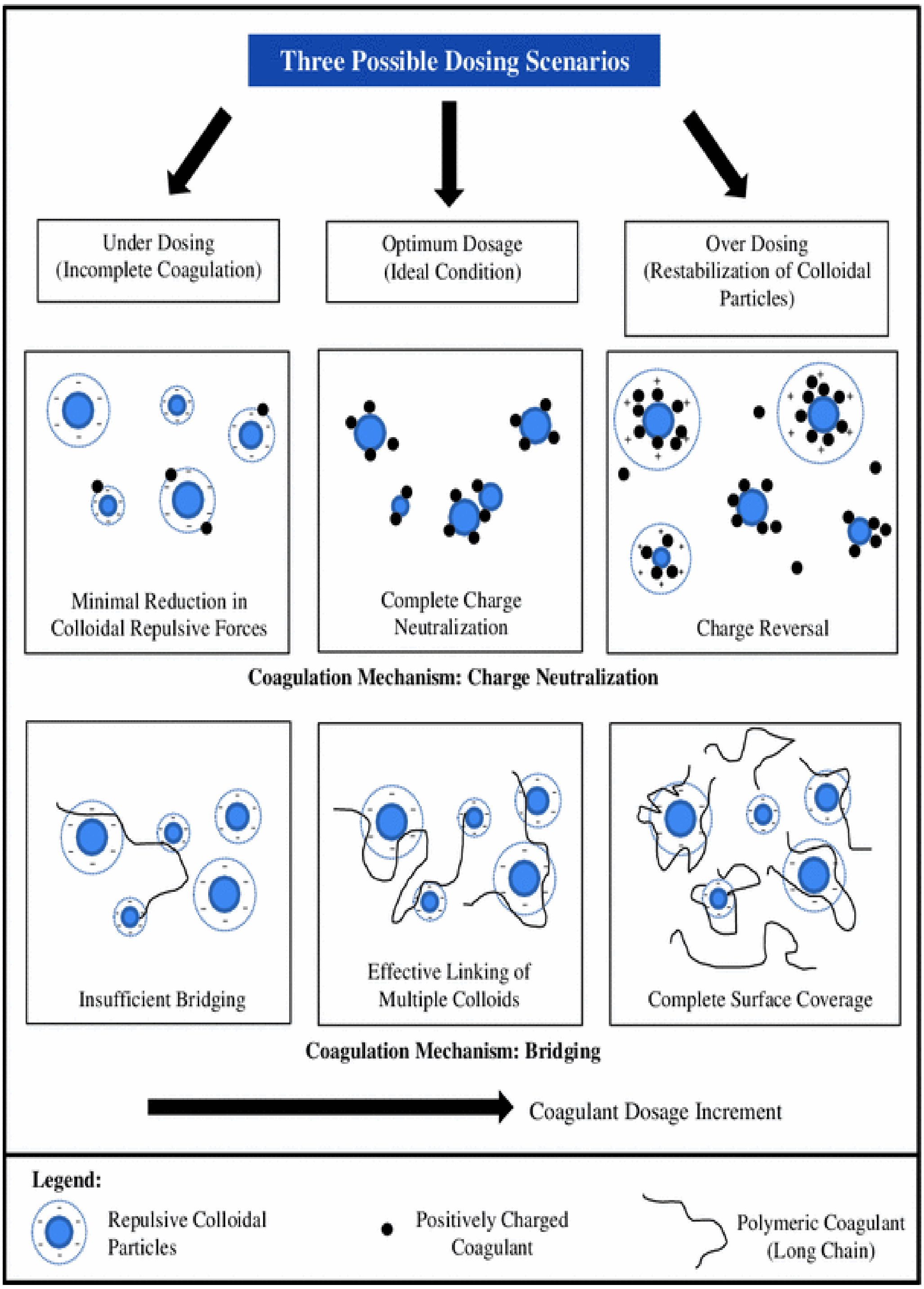


Trivalent coagulants are 50 to 60 times more effective than Bivalent coagulants in terms of forming flocs. Organic polymers such as polyacrylamides are usually used as flocculants in addition to metallic salts to improve floc formation.

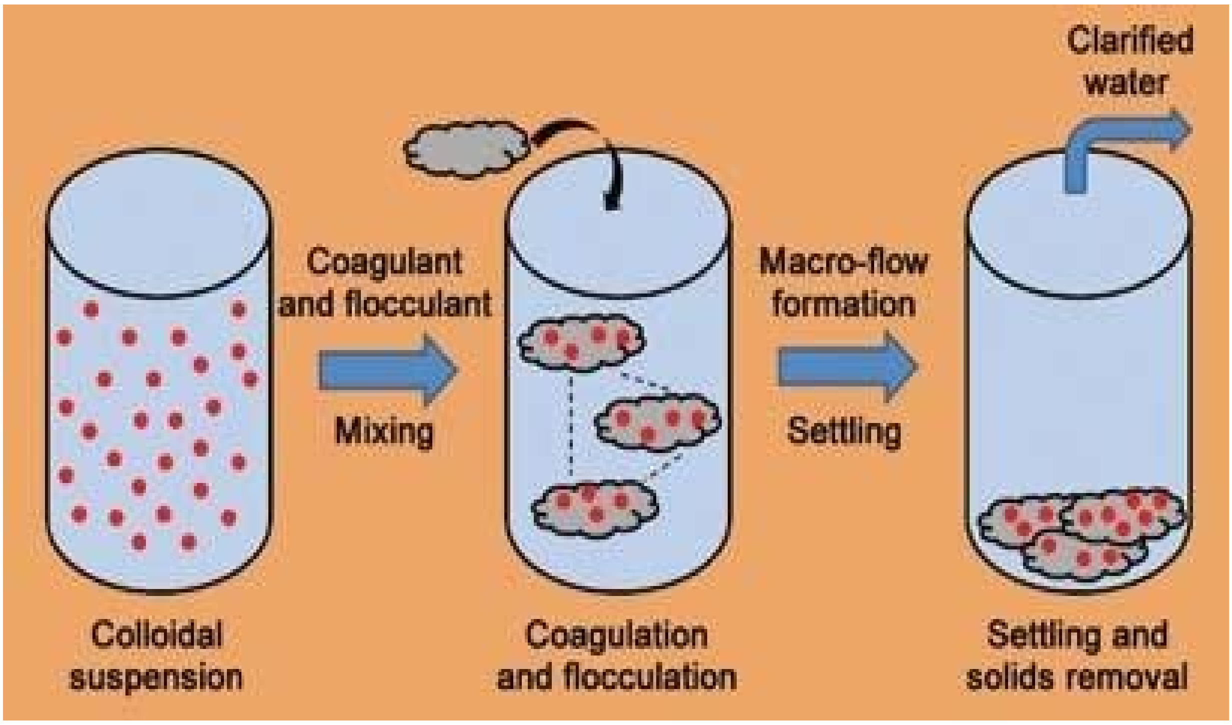
'Zeta potential' is a key indicator of stability of colloidal dispersions. The magnitude of Zeta potential indicates the degree of electrostatic repulsion between adjacent, similarly charged particles in a dispersion.

'**Vanderwaals force**' include attraction and repulsion between atoms, molecules and surfaces as well as other intermolecular forces.

d)Settling:

This process takes place in a 'Clarifier' which consists of tanks or basins which hold water or wastewater for a period sufficient to allow the floc and other suspended materials to settle to the bottom. This process makes the water clear by removing all kinds of particles, sediments, oil, natural organic matter and color.

Floc which collects on the bottom of the basin is called sludge, and is piped to drying lagoons. The purpose of a clarifier is to remove solids, produce a cleaner effluent and concentrate solids. Concentration of solids removed from the wastewater reduces the volume of sludge for dewatering and/or disposal.



OBJECTIVES

The major objectives of this study are:

1. To reduce the level of Turbidity and thereby indirectly microbial contaminants from water using locally available natural coagulants.

2. To make the water treatment process easier, safe, and environment friendly for household applications.

Commonly used chemicals for various treatment units are synthetic organic and inorganic substances. In most of the cases, these are expensive since they are required in higher dose and are not cost effective.

Many of the chemicals are also associated with human health and environmental problems. So, there raised a voice to develop cost-effective, easier, and environmental friendly process of water clarification.

The history of the use of natural coagulants is long. Natural organic polymers have been used for more than 2000 years in India, Africa, and China as effective coagulants and coagulant aids at high water turbidities.

They may be manufactured from plant seeds, leaves, and roots.

These natural organic polymers are interesting because, comparative to the use of synthetic organic polymers containing acrylamide monomers, there is no human health danger and the cost of these natural coagulants would be less expensive than the conventional chemicals.

Natural coagulants have bright future and are concerned by many researchers because of their abundant availability, low price, environment friendly (biodegradable nature), and multi- function capability.

Natural Coagulants contain **positively charged proteins** which combine with **negatively charged colloids** resulting in agglomeration. They are commonly composed of combination of several macromolecules such as Carbohydrates, Proteins and Lipids. In many practical cases, Cationic polyelectrolytes are the most promising flocculants to undermine contaminated particles that are negatively charged. Electrostatic interaction provides strong adsorptions that neutralize the particles' surface and potentially cause charge reversal.

Main mechanisms that govern the coagulation activity are Adsorption and Charge neutralization. Natural polymers contain numerous charged functional groups residing in their polysaccharide chain such as -OH, -COOH, and -NH. In many cases, the major building blocks are the polymers of Polysaccharides and Amino acids.

Plant-based coagulants are ideal for purification of contaminated water in less urbanized aras as they seem to carry less cost in comparison to the chemical coagulants which are far more expensive.

Coagulants of plant origin are mostly useful when Turbidity is in the range of low to medium.

Disadvantages of using chemical coagulants:

1. Existence of Aluminium zest in treated water may provoke Neurological and Pathological diseases.

2. With Aluminium salts, there is always a concern about residuals in treated water. It has strong carcinogenic properties.

3. Consumption of water treated with chemical coagulants on a long run may also lead to Dementia and Alzheimer's disease.

4. Cost of imported chemicals can be a serious financial burden for developing countries.
5. Alum, when reacts with natural alkalinity present in water, leads to reduction of pH and a low efficiency in coagulation of particles in cold water.

6. Sludge produced while using chemical coagulants is voluminous and non-biodegradable after treatment.

7. Poor disposal of sludge after clarification leads to increase in cost of treatment.

8. Inorganic Coagulants add dissolved solids (salts) to water.

9. Aluminium sulfate is effective only over a limited pH range.

10. Sodium Aluminate is ineffective in soft waters.

In India, majority of the population still lives in villages and small towns. These rural/tribal communities do not have access to public water supplies. People living in these regions obtain their water supply from unprotected sources such as open dug wells or small streams and ponds which are polluted. The treatment of water in these areas has a unique problem. Therefore, there is an urgent need for development and widespread promotion of simple treatment techniques for rural/tribal areas. The proteins in natural coagulants are considered to act similar to synthetic, positively charged polymer coagulants of non-plant origin. When added to raw water, proteins which carry a positive charge bind to the negatively charged particulates that make raw water turbid. Under proper agitation, these bound particulates grow in size due to agglomeration thereby forming flocs, which may be left to settle by gravity or be removed by Filtration.

LITERATURE REVIEW

Research Article 1 (Summary):

Moringaoleifera, Cicerarietinum, 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 Moringaoleifera, Cicerarietinum, 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 Cicerarietinum. 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 Moringaoleifera, Cicerarietinum, and Dolichos lablab made them used as natural coagulants for the clarification of water. Doses started from 50 mg/L to100 mg/L for corresponding six beakers. Turbidity was measured before andafter 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 Moringaoleifera 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 to16.5, 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. Moringaoleifera 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 Moringaoleifera was improved by isolation of bioactive constituents from the seeds as coagulant/flocculants which gave turbidity removal from 43.9, 91, and 333NTU 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 Moringaoleifera 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 waste watertreatment on a small scale.

It was found that the raw water turbidity was 95 NTU. Turbidity reduced to5.9, 5.1, 4.6, 4.5, 4.3, and 3.9 NTU corresponding to 50, 60, 70, 80, 90, and100 mg/L Cicerarietinum 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 49NTU) 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 Cicerarietinum for higher-, medium-, and lower-turbidity-range comply with the Bangladesh drinking standard and the WHO guidelines. Cicerarietinum was found most effective for coagulation when the dose were 100 mg/L for high-, medium-, and low-turbidity water at a 3-min slow mixing time, 12 min slow mixing, and 30 min settling time. Cicerarietinum is cheap, easily cultivable, and available inBangladesh. 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 to50, 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 to17.1, 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 studywas 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 of200 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 locallyavailable materials like beans provides a better option for clean, safe water accessible to rural people.

Using some locally available natural coagulants, for example, Moringaoleifera, Cicerarietinum, 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, water- soluble extract of Moringaoleifera, Cicerarietinum, 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, Cicerarietinum 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 MoringaOleifera (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 MoringaOleifera , 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, MoringaOliefera, 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 and27 NTU when Alum, S.Potatorum, Cactus and C.Indica were applied as a coagulant respectively. These values are greater than 5 NTU (valuerecommended 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 MoringaOliefera, 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 MoringaOliefera, 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.

Whileit is understandable that the coagulants are meant as simple domestic

POUtechnology, 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 virtuallnon-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 small-scale 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 wastewaterwith extreme pH. As such, it is always prudent for water treatment practitioners to circumspectly select the most suitable natural coagulants and tailor themfor specific proposes. Quite clearly, M. oleifera is the most researched plant- based 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 coagulantagents 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 resi 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.

Moringaoleifera (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. Moringaoleifera 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.

MATERIALS USED

The powdered form of 5 seeds, namely 'Moringaoleifera' (Drumstick), 'Cicer Arietinum' (Chick pea), 'Dolichos lablab' (Velvet Bean), 'Glycine max' (Soyabean), 'Tamarindusindica' (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 'Jartest apparatus'.

1. Moringaoleifera (Drumstick):

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.

Moringaoleifera seed pods

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. Cicerarietinum (Chickpea):

White Chickpea

Chickpea (Cicerarietinum) seeds are high in protein. Cicerarietinum 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.

3. Dolichos lablab (Velvet Bean):

Velvet Beans

Dried seeds of Velvet Beans

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 ironranges 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 flows.

4. Glycine max (Soyabean):

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 lowcost bio-adsorbents 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.

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. Tamarindusindica (Tamarind):

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Tamarind seeds

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 toturbid water.

APPARATUS USED

Jar Test Apparatus:

Jar testing is a pilot-scale test of the treatment chemicals used in a particular water plant. It simulates the coagulation/flocculation process in a water treatment plant and helps operators determine if they are using the right amount of treatment chemicals, thus, improving the plant's performance.

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Nephelometer:

A Nephelometer is an instrument for measuring concentration of suspended particulates in a liquid or gas colloid. A Nephelometer measures suspended particulates by employing a light beam (source beam) and a light detector set to one side (often 90°) of the source beam.

METHODOLOGY

Preparation of Synthetic water:

Exactly 2 grams of soil (with considerable amount of clay materials) was added to 1 litre of tap water in order to produce a muddy water sample. Suspension was stirred vigorously to uniformly distribute the soil particles. This sample was then allowed to pass through a screen to remove the bigger sized particles. Synthetic water sample was thus prepared and transferred into the beakers which would then be placed in the 'Jar test apparatus'.

Preparation of Stock solution of Natural coagulants:

Seed kernels of all 5 seeds were ground to fine powder whose size was maintained at approximately 600 micrometers in order to achieve solubilisation of active ingredients in the seed. 100 ml Distilled water was added to the powdered form of each seed of known quantity. It was then vigorously mixed to promote water extraction of the coagulant proteins.

Jar test operation:

In order to obtain the value of optimum dosage of each coagulant, different dosages were added in each of the 6 beakers. The first jar containing the synthetic water in every experiment was considered as a 'Control sample'. It contained 900 ml of muddy water and 100 ml of Distilled water without any coagulant. The remaining 5 jars were each filled with varying doses of coagulant (whose weight was carefully measured) in 100 ml distilled water, thoroughly mixed and then added into the beaker containing 900 ml turbid synthetic water sample.

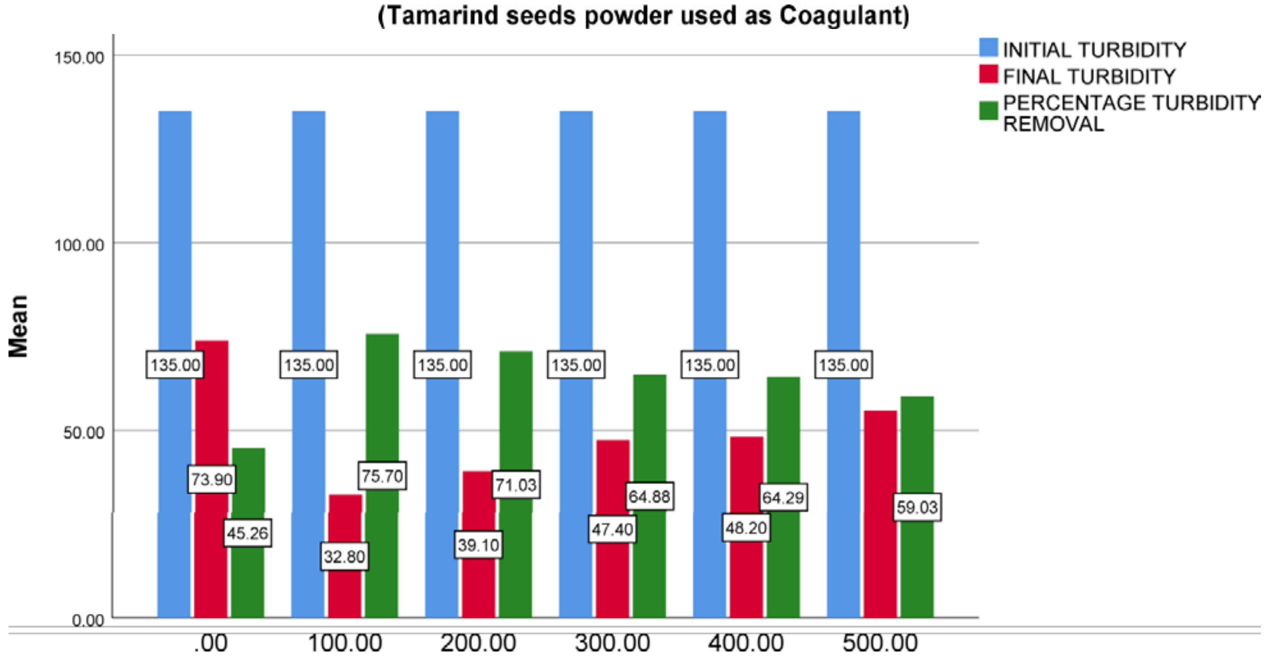
Before starting the apparatus, Initial Turbidity of the sample is to be measured. Calibration of the instrument was done using a buffer solution whose Turbidity value was already known. Initial Turbidity is measured using an instrument called 'Nephelometer'. Then the rotating paddles were lowered into all the 6 jars. The apparatus was switched on and the required mixing speed and duration of mixing was set.

Rapid Mixing	300 rotations per minute	5 mi
Slow Mixing	60 rotations per minute	15 minutes
Settling	-	60 minutes

RESULTS

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.

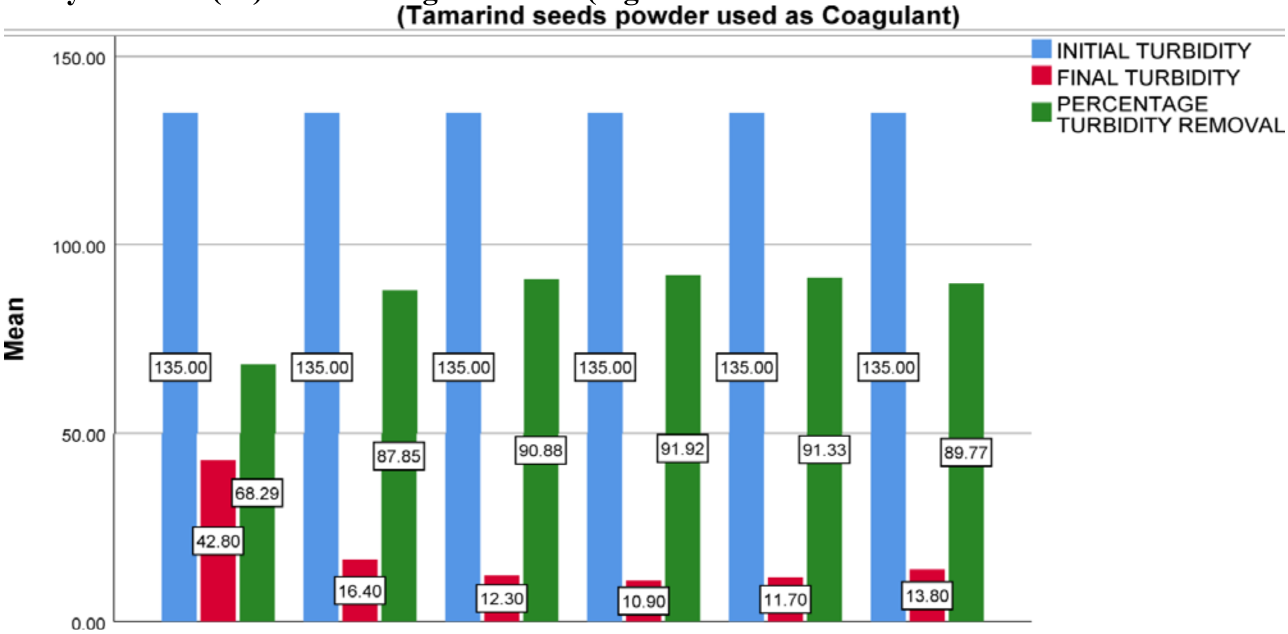
1. Tamarindusindica (Tamarind):



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 sampleswas measured using a Nephelometer. As per the observations and Bar chartplotted 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.

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



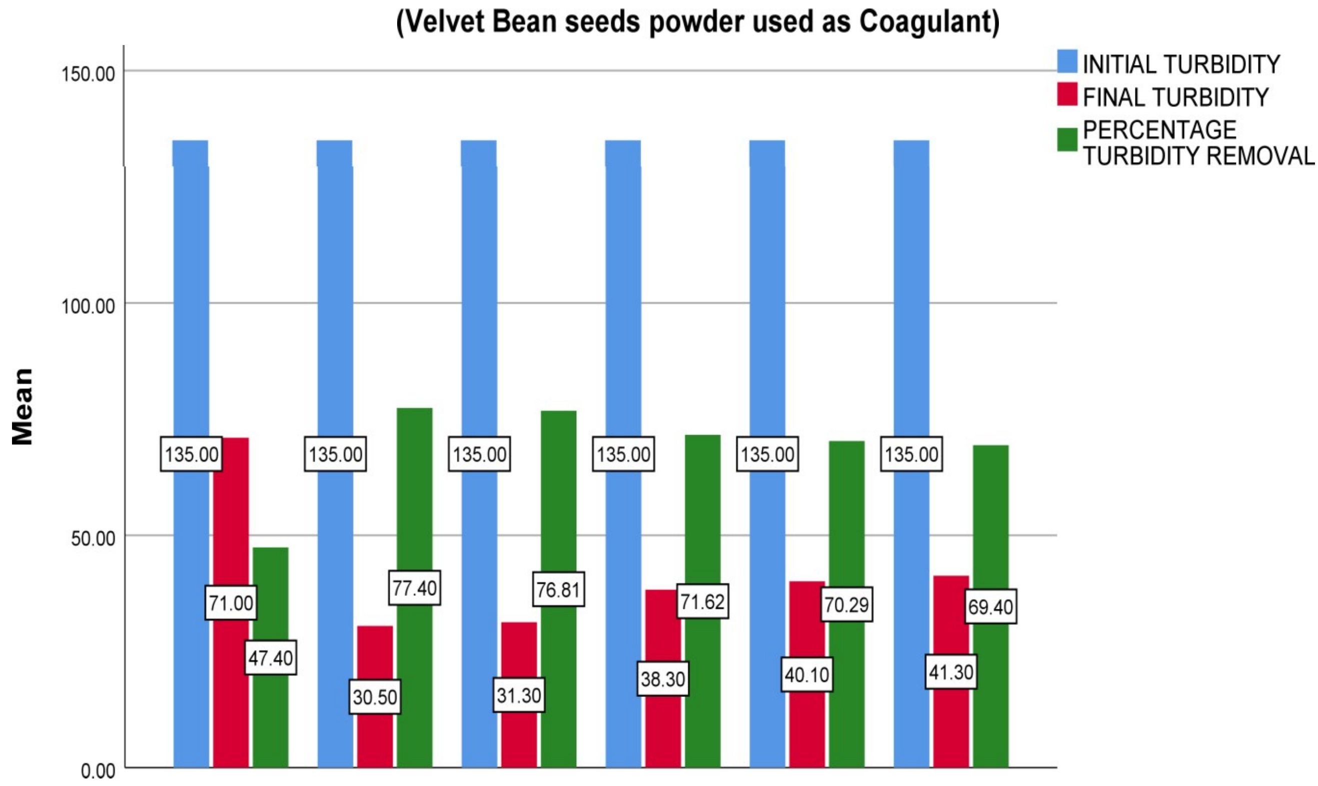
Coagulant dose (mg/L)

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**.

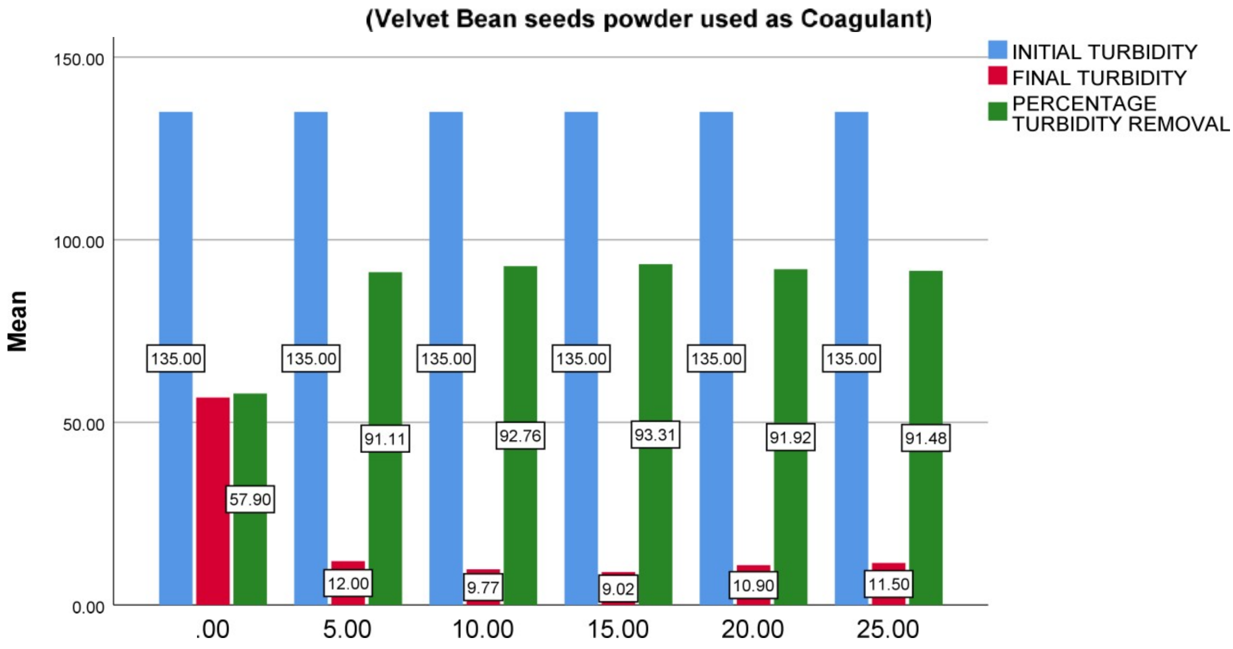
2. Dolichos lablab (Velvet Bean):

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 of200 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)

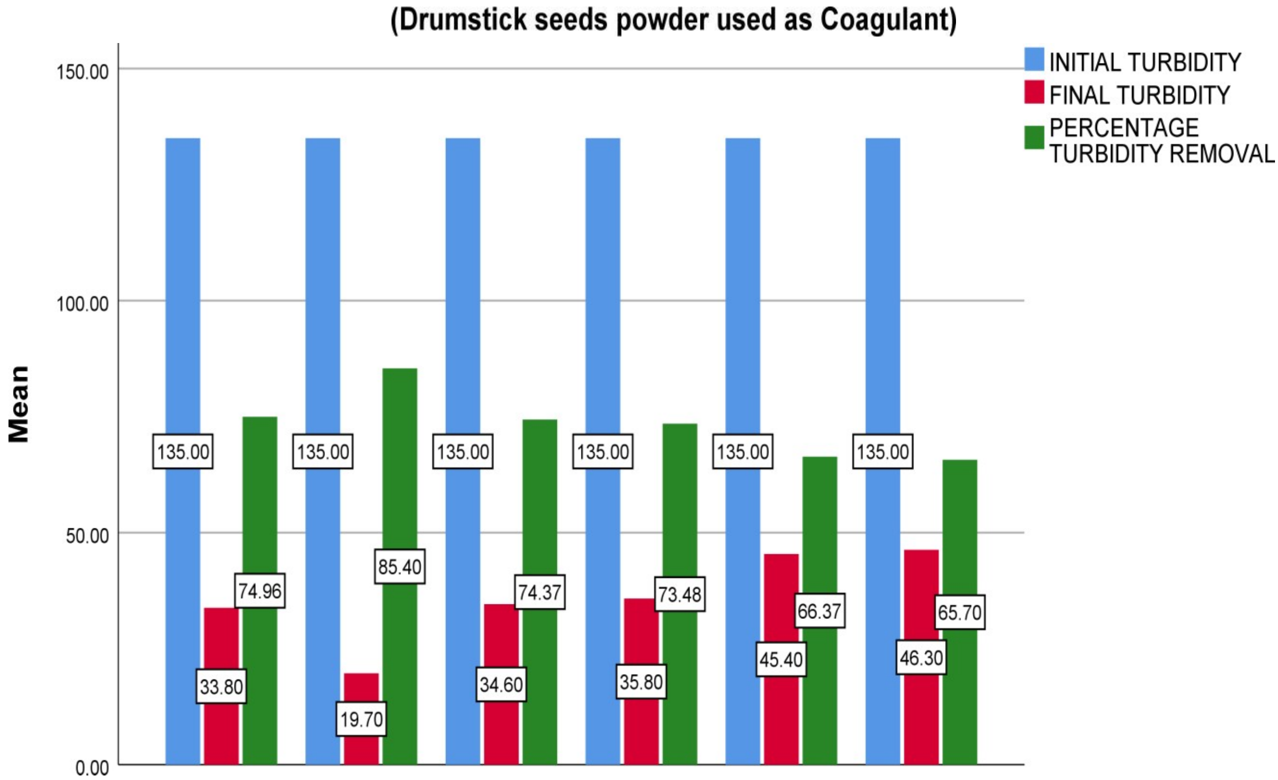


Coagulant dose (mg/L)

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. Moringaoleifera (Drumstick):

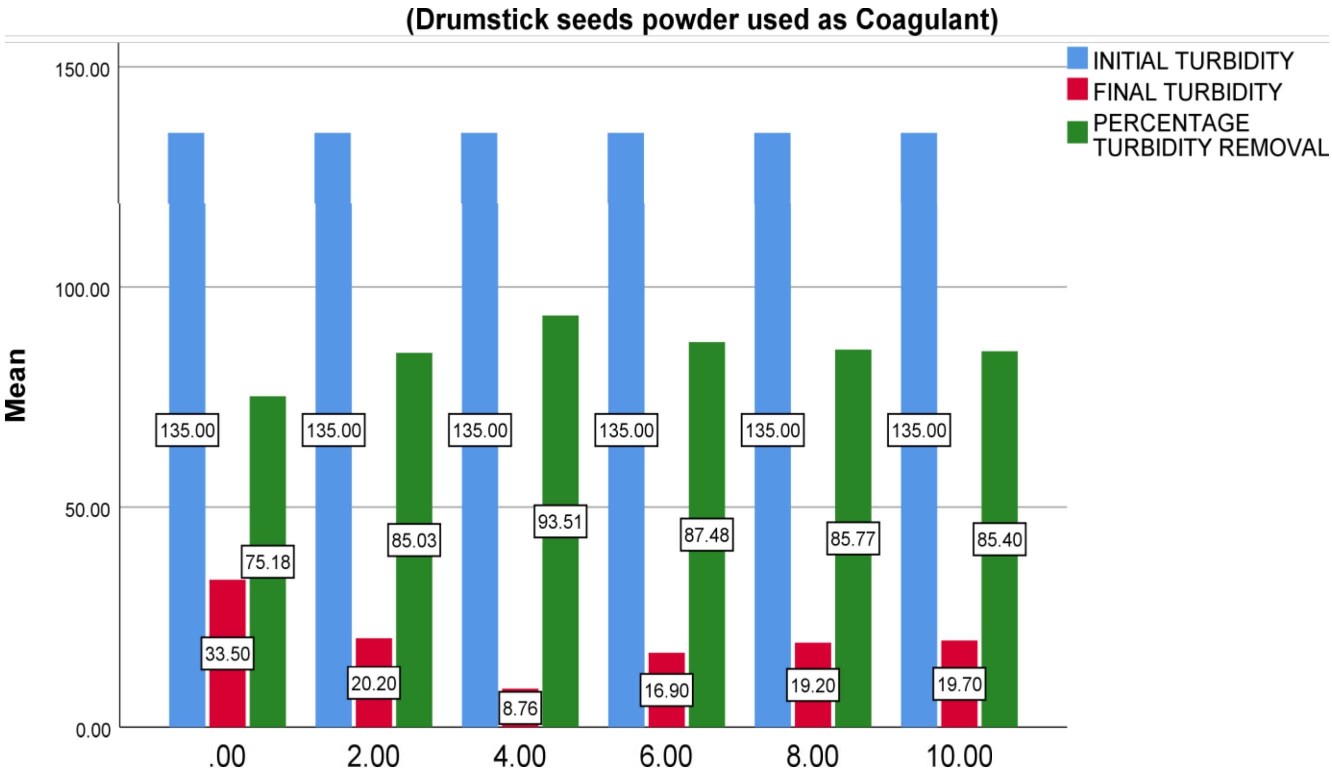
Turbidity removal (%) versus Coagulant dose (mg/L)



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

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**.

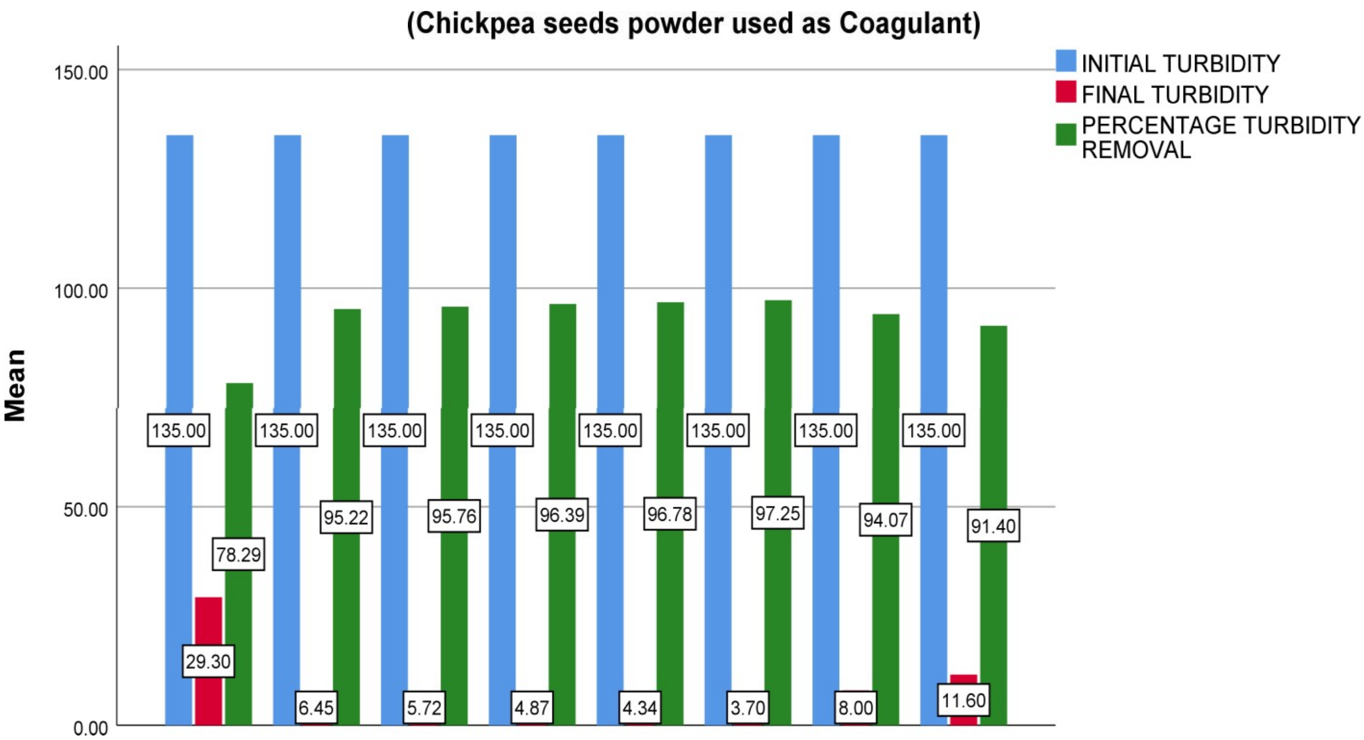
4. Cicerarietinum (Chickpea):

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, 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

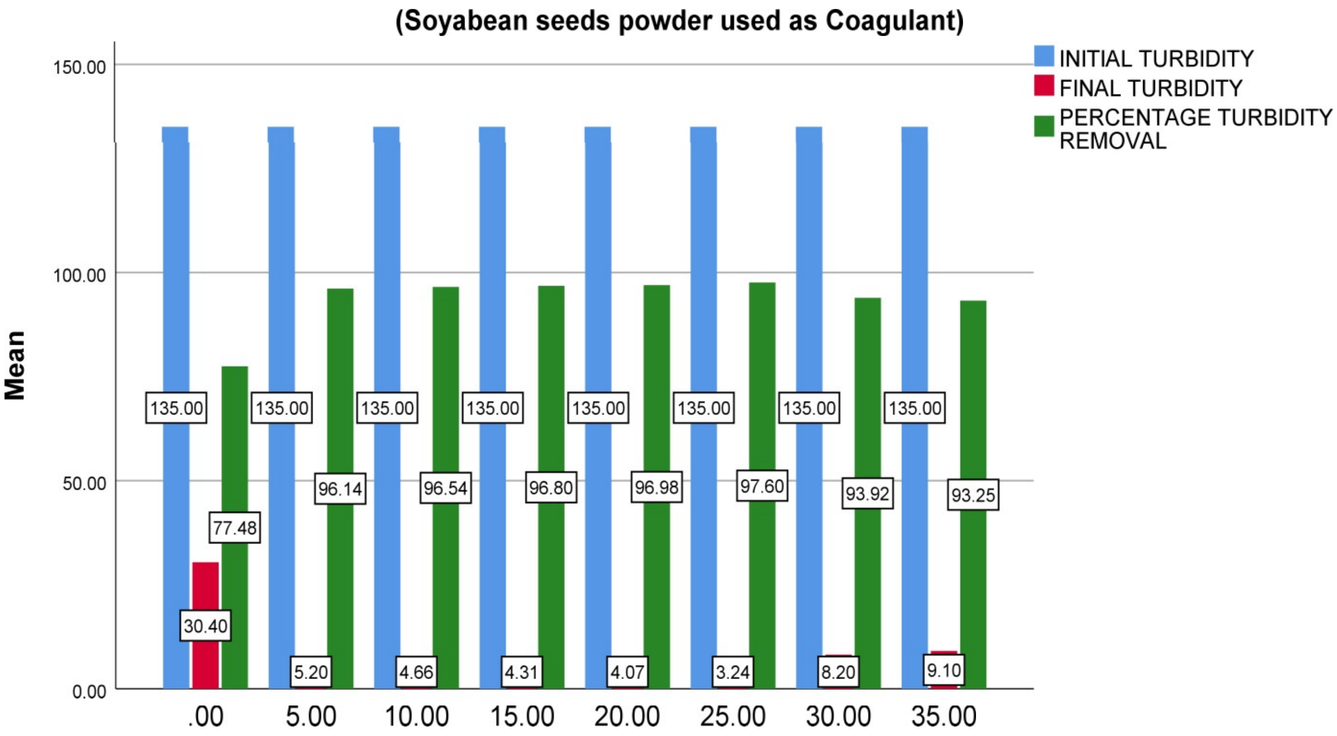
Turbidity removal (%) versus Coagulant dose (mg/L)



Coagulant (mg/L)

5. Glycine max (Soyabean)

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

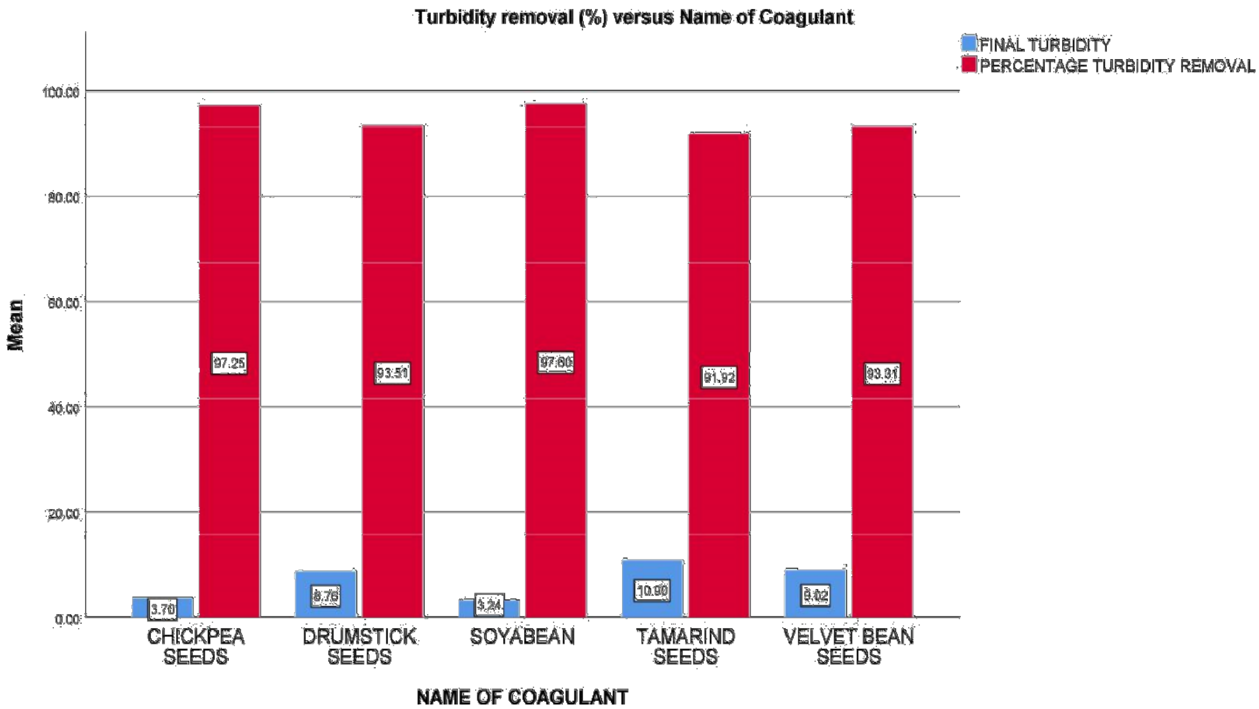


Coagulant (mg/L)

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**.

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 as well as plotted in the table and bar chart respectively as shown above. So, out of all the seeds considered, 'Soyabean seeds' have been found to be the most suitable and effective natural coagulants.

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 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.

However, 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. In-depth studies on the characterizations of the active coagulant compounds would be beneficial to gain the necessary knowledge in understanding their respective coagulation activities. The efficiency of natural coagulants could be heightened with the optimization of both the Ph and coagulant dosage used. Gradual introduction to the existing water treatment technology is possible once the bottlenecks of commercialization and limitations of natural coagulants have been resolved.

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SOFTWARE USED

1. **SPSS** (Statistical Package for the Social Sciences) software for plotting Bar charts indicating Coagulant dose and Percentage Turbidity removal.