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Using *Strychnos potatorum* Seeds as a Natural Coagulant in Flood Affected Areas of Bangladesh

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Abstract

The aim of this research is to find and show the effectiveness of *Strychnos potatorum* seeds as a natural coagulant for purifying and producing potable water in flood prone rural areas of Bangladesh. *Strychnos potatorum*, locally called 'Nirmali' or 'Nirmala', is a natural coagulant which was used in the Indian Subcontinent during the stone ages but has slowly become forgotten. This research was carried out to reintroduce this ancient coagulant and find its effectiveness during floods, particularly in Bangladesh. As a riverine country prone to flooding and devoid of quality water purification systems, coagulants like alum and ferric sulfates are often used although these synthetic chemicals have been found producing DBPs in water which are associated with certain health hazards. And so, replacing these synthetic chemicals with a natural coagulant such as *Strychnos potatorum* seeds in flood prone rural areas will be a beneficial and cheap water purification system for the populace. To prove the effectiveness, various tests (pH, HCO_3, Cl, Na, K, Na_2CO_3, NTU, TCU, Total Hardness ($CaCO_3$), BOD, COD, CFU) were carried out across flood prone areas around Dhaleshwari River (Nagarpur, Tangail) to find out whether *Strychnos potatorum* seeds will be able to replace the commonly used chemical coagulants and provide drinkable water to the flood affected people or not. Experiments were carried out to find the optimal dosage, flocculation and settling time and reusability of the *Strychnos potatorum* seeds. The reason behind selecting this region for research purpose is that the soil and tree characteristics of this area is perfect for planting and growing *Strychnos potatorum* trees and they can be easily distributed among the populace when disaster hits. The test results proved that the parameters comply with the WHO Drinking Water Standards. So, our test results have shown that the *Strychnos potatorum* seeds are highly effective when it is used to treat water in these flood prone areas. And our initial estimation is *Strychnos potatorum* will provide a remarkably successful and high yield in these targeted areas. According to our calculations and research it will cost only 0.18 dollars or 18 cents *versus* 0.25 dollars for most conventional method (Potash Alum) for per liter of water treatment. As the project will require planting *Strychnos potatorum* trees, the project will improve the environment and distributing them to flood affected populace will increase the peoples' awareness regarding tree plantation and drinking safe water. Also, this project will act as a replacement to the synthetic chemical coagulants used in the flood affected rural areas of Bangladesh and replacing those synthetic chemical coagulants with biodegradable *Strychnos potatorum* will be good for the environment as a whole there will be less chemical waste. This project will strengthen the water security of Bangladesh as well as play an important role in stopping the climate change and its adversities.

Introduction

Bangladesh is a riverine country. Every year due to water related disasters thousands of people faces potable water crisis. And during this crisis, they use coagulants such as aluminum sulfate (referred to as alum), ferric sulfate, and ferric chloride. Although recent studies have revealed that these synthetic chemicals can be behind multiple health hazards. Studies have shown aluminum is strongly neurotoxic and may be involved in Alzheimer's disease development [1]. Most of the chemical disinfectants that are used for antibacterial activity generate unwanted disinfectants by products (DBPs) in water. These are associated with harmful health hazards such as hemolytic anemia, cancer risk, nervous system effect and liver effects [2]. And so, it is imperative to find a replacement for these synthetic chemicals and disinfectants. Natural coagulants such as *Strychnos potatorum* seeds can be a replacement for these traditional yet harmful chemicals.

Coagulants have been used for water purification since ancient times. *Strychnos potatorum* seeds are an example of ancient yet highly effective water purification. They were used for water purification in the Indian subcontinent 4000 years ago. And *Strychnos potatorum* is one of them. *Strychnos potatorum* (Figure 1), locally called 'Nirmali' or 'Nirmala' was used by people during stone ages to produce potable water.

Strychnos potatorum (locally called Nirmali or Nirmala) is a deciduous, much branched small or medium sized tree, or sometimes a shrub, growing from 4-18 meters. Its barks are 1.32 cm thick, black or brownish-black, corky, with very deep and narrow vertical, thin ridges, which easily break off. The Bole of this tree can be up to 100 cm in diameter. Leaves are about 57.5 cm long. The Fruit which contains the seeds is a berry, black when ripe, globose, 12 cm in diameter, whitish, shining, with short addressed yellow silky hairs. Seeds are

Figure 1: *Strychnos potatorum*.

globose in shape. Each berry contains 1-2 seeds in a whitish pulp [3]. It is suitable for: light (sandy), medium (loamy) and heavy (clay) soils and prefers well-drained soil. Suitable pH: acid, neutral and basic (alkaline) soils. It can grow in deciduous forests. It prefers loamy soil and can tolerate drought [4]. Population of Nirmali is depleting fast due to self non generative mechanism in fruits. They are often decayed and are prone to fungal attack as soon as they fall. Flowering occurs in September-October, while fruiting occurs in December [5].

Strychnos potatorum seed extract is an anionic poly-electrolyte which contains carboxyl (COO^-) and hydroxyl (OH^-) as main active groups. It also contains proteins, alkaloids, carbohydrates, and lipids. The seeds of *Strychnos potatorum* also contain strychnine which was supposed to be responsible for the coagulating properties.

During our research we found very little work done on this ancient yet effective natural coagulant. In a history book, 'A history of ancient and early medieval India: from the stone age to the 12th century' by Singh U, et al. [5], we found that *Strychnos potatorum* was used as natural coagulant by the people of Indian Subcontinent about 4000 years ago. We found three research papers that have done significant work on proving the effectiveness of *Strychnos potatorum*. These are 'Use of *Strychnos potatorum* Seed Powder as a Water Purifier: A Sustainable Approach for Rural Development' by Vijay KS, et al. [6], '*Strychnos potatorum*: Phytochemical and pharmacological review' by Yadav KN, et al. [3] and 'Appropriate Technology for Treatment of Potable Water in Developing Countries: Coagulants Derived from Natural Materials by Folkard GK, et al. [7]. Anti-bacterial properties were researched in Vijay KS paper, while the phytochemical properties of *Strychnos potatorum* was researched well in Yadav KN paper. But we did not find any research on the application of these *Strychnos potatorum* seeds as natural coagulants in the flood affected areas of Bangladesh. We prepared and applied the extract following Folkard GK paper. And we used 'Vikaspedia', 'Plants for a Future', 'Useful Tropical Plants Database' and 'Wikipedia' websites for plant details. We studied our study area's soil from the journal 'Yearbook of Agricultural Statistics 2019' by Bangladesh Bureau of Statistics (BBS), Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh and the study area's tree characteristics from the book 'Bangladesh and Global Studies Class 9-10' by NCTB.

For the research, Nagarpur of Tangail district was chosen as the study area. Particularly, regions of Nagarpur that are situated on the bank of Dhaleshwari river was selected as study area. Nagarpur is a heavily flood prone area. We have carried out our research in this area. We have researched on the study area's characteristics of trees, soils to find out whether *Strychnos potatorum* could grow or not. Also we have collected samples from the study area and treated them with *Strychnos potatorum*. Then the treated samples and non-treated samples were analyzed for different physio-chemical parameters to prove the ancient coagulant's effectiveness in replacing the widely used harmful chemical coagulants with *Strychnos potatorum* and ensuring drinkable water during floods in not only our selected study area but also all the flood affected areas of Bangladesh.

Materials and Methods

Mechanism of coagulation

Nirmali seeds (*Strychnos potatorum*) are anionic polyelectrolytes. These particles get faded in water through inter particle bridging. The seed contains -COOH and -OH groups that are able to increase the coagulation competency because lipids, carbohydrates and alkaloids, Galactomannan and Galactan are mixture of polysaccharide division that are extracted from the seeds which is capable of reducing turbidity up to 80%.

The mechanism of coagulation of Nirmali seeds works based on an idea where there may be interaction between polymer and dissolved particles in the water due to the fact that Nirmali seeds' polymer contains numerous charged functional groups residing in their polysaccharide chain such as -OH, -COOH, -NH. The coagulation process involves four main mechanisms:

a) Bridging Mechanism

b) Charge Neutralization

c) Double Layer Compression

d) Sweep-Floc Mechanism

Generally, the other synthetic coagulants like potash alums, work based on charge neutralization. Potash alums have positive charge and the dirt particles in the water generally contain negative charge, which are neutralized by the potash alums and thus it flocculates and due to sedimentation, the dirt particles can be found at the bottom.

The Nirmali seed extracts coagulates using bridging mechanism because these seeds are anionic polyelectrolytes. The microbe extract of Nirmali contains carbohydrate, lipids and alchaloids having -COOH and -OH groups which enhance its coagulating potential. Polysaccharide particles extracted from Nirmali seeds contained galactomannan and galactan which is competent in removing turbidity up to 80%. Abundant absorption sites of -OH beside the chains of galactomannan and galactan that constituted in Nirmali seed extracts lead to inter particle bridging effect. Then the particles can be found sedimented at the bottom which also includes bacteria and other microorganisms. This is how coagulation happens in molecular level while using Nirmali seed extracts [8,9].

Description of study area

For study area, we have chosen flood prone Nagarpur Upazilla of Tangail district which is situated on the bank of Dhaleshwari River. Tangail, according to characteristics of trees is situated in Tropical Deciduous Forest area in Bangladesh [10] (Figure 2). Nagarpur is situated in AEZ-8: Young Brahmaputra-Jamuna Floodplain. It is occupied by permeable silt loam to silty clay loam soils on the ridges and impermeable clays in the basins which are neutral to slightly

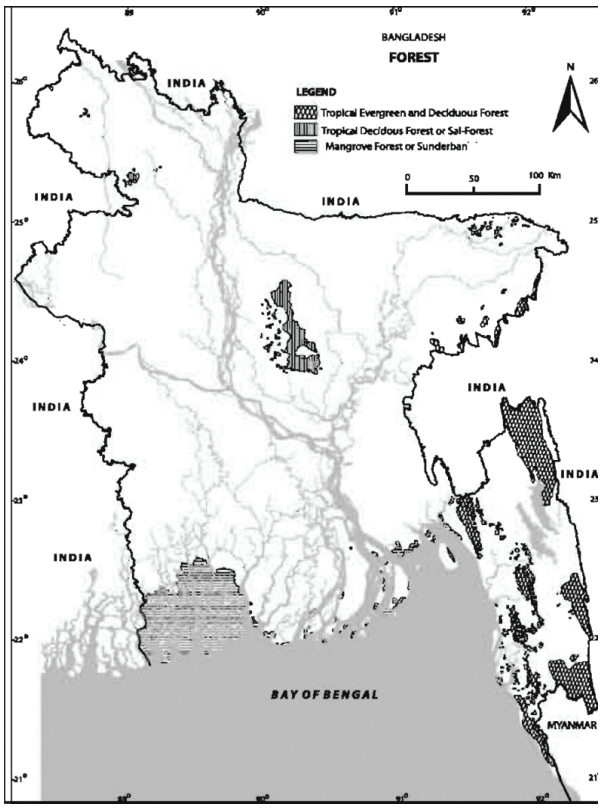

Figure 2: The Forest Lands of Bangladesh.

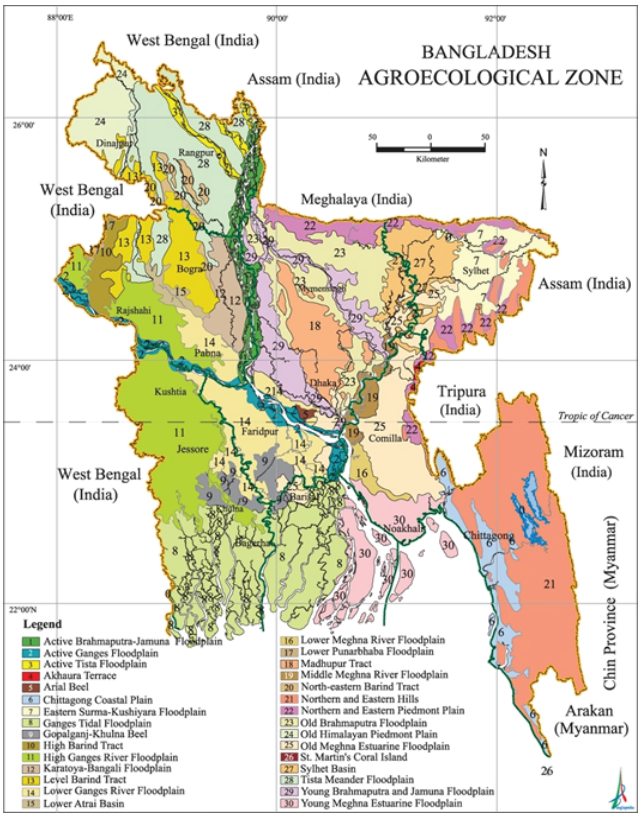

Figure 3: Bangladesh Agro-Ecological Zone.

acidic in reaction. General soil types include predominantly Grey Floodplain soils. Organic matter content is low in ridges and moderate in basins [11].

The river Dhaleshwari, is a prominent river in Bangladesh. Dhaleshwari is a distributary, 160 kilometres (99 mi) long, of the Jamuna River in central Bangladesh. It starts off the Jamuna near the northwestern tip of Tangail District. After that it divides into two branches: the north branch retains the name Dhaleshwari and merges with the other branch, the Kaliganga River at the southern part of Manikganj District. Finally, the merged flow meets the Shitalakshya River near Narayanganj District. This combined flow goes southwards to merge into the Meghna River. The average depth of Dhaleshwari is 122 feet (37 m) and maximum depth is 265 feet (81 m). Every year, Tangail is severely affected by flood severely. 16 drowning deaths, over 600,000 people affected, 50,000 still marooned, over 18,000 hectares of standing crops damaged, schools, temples, mosques, and roads completely or partially damaged due to flood in 2020 (Figure 3). In Tangail the Dhaleshwari was flowing at 105 cm over the danger level in 2020 [11]. The scarcity of potable water is a mentionable issue during the flood. Especially, as Nagarpur is situated at the bank of the river Dhaleshwari, people residing there face more trouble during flood. Especially people suffer from scarcity of drinking water during flood.

Water sample collection

Sample collection site: Water samples were collected from Dhaleshwari River in Nagarpur Upazila of Tangail District. Three different sampling sites were labeled respectively as Dhaleshwari A, Dhaleshwari B, Dhaleshwari C. The sample collection sites are pointed out in Google Maps in the pictures below (Figures 4-6):

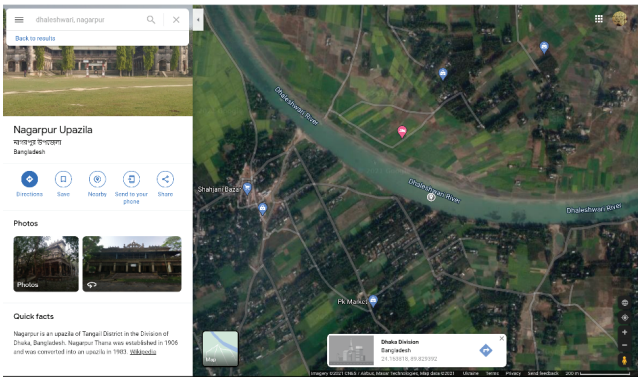

Figure 4: Dhaleshwari A.

Materials:

1. 6 × 500 ml bottles
2. 1 × pole of 5 feet length
3. Marker Pen

Sample collection process: The sample collection process was initiated on 2 February 2021. At first, the bottle was submerged at the sampling site and was partially filled with water. Then the bottle was shaken and then the water was thrown away. This Field Rinse process was initiated three times to ensure the bottle's not being contaminated. After triple field rinse process, the bottle was attached to the 5 feet

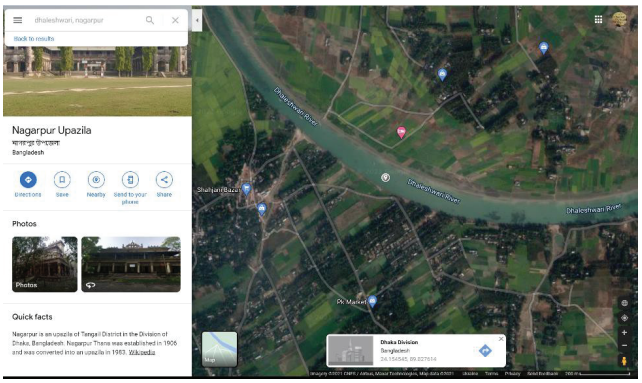

Figure 5: Dhaleshwari B.

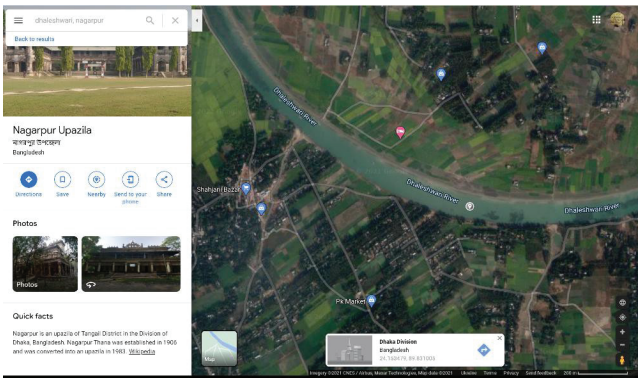

Figure 6: Dhaleshwari C.

long pole. Using the pole, the bottle was submerged upside down approximately 5 feet deep into the river. Then the bottle was put upside down to let the water fill the bottle. Then the bottle was brought back using the pole. This process was repeated for the 6 samples, for each site one sample was treated and the other was not treated.

Storage of samples: The samples were stored in a cold, dark place where direct sunlight cannot reach. The samples were stored in this way for approximately 24 hours.

Plant sample collection

Strychnos potatorum seeds were imported from Tamil Nadu, India *via* The National Botanical Garden. The seeds were collected on 27 January 2021.

Preparation of seed extract

The *Strychnos potatorum* seeds were dried in room temperature for 2 days. After 2 days the seeds were powdered using a pestle and mortar. The seeds were bashed and muddled under the pestle and turned to powder. The pestle and mortar were made of wood and the seed were bashed and muddled for approximately 5 minutes with moderate force. Approximately 200 grams of *Strychnos potatorum* seeds were bashed and muddled and turned into 200 grams of *Strychnos potatorum* powder [12] (Figure 7).

Treatment of sample with *Strychnos potatorum* and labeling:

Figure 7: *Strychnos potatorum* plant seeds.

Treating the samples with *Strychnos potatorum*: On 3 February 2021, approximately 24 hours after sample collection, the samples were treated with *Strychnos potatorum*. For treatment, out of the 6 samples, three samples (one from each collection sites) were taken and 58.35 gram (11.67 gram per 100 mL) of *Strychnos potatorum* powder was released in the water and stirred well at 60 rpm. The coagulants were allowed to flocculate for 20 minutes and settle for 10 minutes according to our experiment of the effect of flocculation and settling time. Soon after stirring the process began and solids started to rest at the jar floor and started forming sludge. Less turbid and cleaner looking water from above the jar was taken out with a cup.

Experimentation of the Effect of Flocculation and Settling Time and Reusability: The experiment was carried out by varying the flocculation and settling time between 10 to 60 minutes, and 2 to 15 minutes respectively at a constant speed of 60 rpm.

An increase in flocculation time up to 60 minutes caused a general decrease in residual turbidity of settled water. Further increase in flocculation time decreased the efficiency of coagulation. The optimum flocculation time is in the range of 20 to 30 minutes.

As the settling time was increased up to 15 minutes, the final turbidity progressively decreased. However, the removal of a major portion of the turbidity took place in the first 10 minutes. Further experiments showed that the size and settleability of flocs were affected by the ionic concentration of water. Flocs were found ill formed in a poorly mineralized water. The study also found the Nirmali seeds to have no reusalibity in treating the water samples.

Physio-chemical analysis of collected sample and treated sample

The collected and treated samples were analyzed for different physio-chemical parameters such as pH, HCO_3, Na, Mg, Ca, K, Cl, NTU, TCU etc. For analysis, the three collected and three treated samples (Total 6 Samples) were brought to a fishery, 'Golden Fisheries' on 3 February 2021. The tests were carried out by Mr. Abu Taher and Mr. Kamrul Islam of 'Golden Fisheries' using water testing kits (pH meter, turbidimeter, jar tester) of the fishery in our presence.

Results

Water test results

(N.B: The serial numbers for sample names in table 1 represent the following samples throughout table 1-4)

(N.B: The samples were treated with a dose of 116.67 gram/liter of *Strychnos potatorum* seed powder.)

Cost analysis

Approximately a dosage of 116.67 gram/liter of *Strychnos potatorum* was used in our tests. These seeds were bought at a market price of 1.54 USD/kg. The calculation is described below:-

Preparation of 1000 grams of *Strychnos potatorum* powder costs=1.54 USD Preparation of 1 gram of *Strychnos potatorum* powder costs=(1.54/1000) USD

Therefore, preparation of 116.67 grams of *Strychnos potatorum* powder costs=((1.54/1000) × 116.67) USD

=0.18 USD

So, it will cost only 0.18 USD to treat 1 liter of water with *Strychnos potatorum*.

In the flood affected areas of Bangladesh, the most widely used coagulant is Potash Alum. Our study found that the current market price of potash alum in Bangladesh is 10 USD per 1000 grams. And the optimal dosage of potash alum is 25 gram/litre [13].

Total cost to treat 1 litre of water with potash alum=((10/1000) × 25) USD

=0.25 USD

Table 1: Water samples collected from different locations around Dhaleshwari River.

S.No	Sample Name	Types of water sample
1	Dhaleshwari A	River
2	Dhaleshwari B	River
3	Dhaleshwari C	River
4	Treated Dhaleshwari A	River
5	Treated Dhaleshwari B	River
6	Treated Dhaleshwari C	River

Discussions

In table 5, the samples treated using *Strychnos potatorum* is compared with WHO Standards for drinking water to justify whether it could be drink or not. The comparison shows that all the parameters are within WHO standards.

N.B: Total hardness ($CaCO_3$) is calculated using the data from table 4. Water hardness (mg/L)=Ca(mg/L) × 2.497+Mg(mg/L) × 4.118.

Aside from the coagulants, we have not considered other water treatments methods other than sedimentation. Because due to the infrastructure of Bangladesh, government efforts cannot be seen at all during floods to provide potable water to the flood affected people of Bangladesh. Other methods such as drum filters and porous media filtration are costly at large scale, which the government is not able to provide during the floods.

The government is seen struggling to provide relief materials to the flood affected let alone safe drinking water. In this case we have come upon a solution, which can be implemented at larger scale with very minor investments. And, the nature of the study, which only concerns the flood affected people of Bangladesh and giving them a cheaper, hassle free solution at large scale, has prevented as from assessing other water purification methods.

According to our cost analysis, we can say that to treat a liter of water it will cost 0.18 dollar or 18 cents which is cheaper than traditional alum and other natural coagulants which is 0.25 dollar. As the seeds were imported, the cost is slightly higher than the cost when the project would be implemented in Bangladesh and the seeds would be distributed to flood affected populace of Bangladesh. This proves the project's cost effectiveness.

Strychnos potatorum is a deciduous tree as we have seen in the Chapter 3.1. That means, it grows well in Tropical Deciduous Forest zones. Bangladesh has Tropical Deciduous Forest Zones as we have seen in Chapter 3.2. Dinajpur, Rangpur, Tangail, Mymensingh, Gazipur, Rangpur are situated in Deciduous forest zone, where our study area, Tangail is also situated. *Strychnos potatorum* prefers loamy soil. Our study area, Nagarpur of Tangail is situated in AEZ-8 where loamy soils are found. So, *Strychnos potatorum* can be grown in Bangladesh.

As Stychnos potatorum can grow in Bangladesh and the samples treated with *Strychnos potatorum* meet WHO drinking water standards, it can replace the chemical coagulants commonly used by

Table 2: Physical and chemical parameters of water samples collected around Dhaleshwari river before treating with *Strychnos potatorum* seed.

S.No	NTU	TCU	pH	HCO_3 mg/L	Ca mg/L	Cl mg/L	Mg mg/L	Na mg/L	K mg/L	Na_2CO_3 mg/L	BOD (mg/L)	COD (mg/L)	CFU Per 100 mL
1	23.3	30	7.6	4.3	1.8	2.9	1.8	3.3	0.3	1.1	105	290	21
2	15	33.3	7.9	3.3	1.9	1.7	1.4	2.6	0.3	0.6	110	300	28
3	19.1	44.03	7.5	2.4	2.0	4.3	1.7	2.7	0.3	0.4	112	380	40

Table 3: Physical and chemical parameters of water samples collected around Dhaleshwari river after treating with *Strychnos potatorum* seed.

S.No	NTU	TCU	pH	HCO_3 mg/L	Ca mg/L	Cl mg/L	Mg mg/L	Na mg/L	K mg/L	Na_2CO_3 mg/L	BOD (mg/L)	COD (mg/L)	CFU Per 100 mL
1	4.1	10.7	6.7	5.2	1.9	4.1	2.5	3.91	0.85	1.6	5	170	2
2	3.3	12.6	6.9	8.0	2.8	3.8	3.3	4.3	1.12	0.8	10	180	3
3	5.0	14.5	6.3	4.6	2.3	1.7	2.9	0.72	0.40	0.9	12	190	5

Table 4: WHO Standards [13].

Parameters	WHO Standards
pH	6.5-8.5
HCO_3 (mg/l)	<500
Cl (mg/l)	<5.0
Na (mg/l)	<200
K (mg/l)	<20
Na_2CO_3 (mg/l)	-
NTU	<5
TCU	<15
Total Hardness ($CaCO_3$)	<500
BOD (mg/L)	<30
COD (mg/L)	<250
CFU per 100 mL	<5

Table 5: Comparison of treated samples with WHO Standards.

Parameters	Treated Dhaleshwari-A	Treated Dhaleshwari-B	Treated Dhaleshwari-C	WHO Standards
pH	6.7	6.9	6.3	<6.5-8.5
BOD (mg/l)	5	10	12	<30
COD (mg/l)	170	180	190	<250
CFU per 100 ml	2	3	5	<5
HCO_3 (mg/l)	5.2	8.0	4.6	<500
Cl (mg/l)	4.1	3.8	1.7	<5.0
Na (mg/l)	3.9	4.7	0.72	<200
K (mg/l)	0.85	1.12	0.40	<20
Na_2CO_3 (mg/l)	1.6	0.8	0.9	-
NTU	4.1	3.3	5.0	<5
TCU	10.7	12.6	14.5	<15
Total Hardness ($CaCO_3$)	15	20.5	17.6	<500

the flood affected people of Bangladesh. As these chemical coagulants produce DBPs which causes health concerns, replacing them with *Strychnos potatorum* will save people from health issues. This project will decrease environment pollution because replacing those synthetic chemical coagulants with biodegradable *Strychnos potatorum* will be good for the environment as a whole as there will be less chemical waste. Also, this project will require planting *Strychnos potatorum* trees which will improve the environment and distributing them to flood affected populace will increase the peoples' awareness regarding tree plantation and drinking safe water.

Conclusions

All of these tests and research help us to come to the conclusion that *Strychnos potatorum* seeds are very effective natural coagulant and it can be used as a natural coagulant in flood affected and rural areas of Bangladesh. Comparison of the treated samples with WHO standards in table 5 shows that the water treated using *Strychnos potatorum* is drinkable. It is also cost effective as we can treat a liter of water for only 0.18 dollars or 18 cents which is cheaper than other coagulants available in Bangladesh which is 0.25 dollars per litre. Our research also shows that *Strychnos potatorum* trees can be easily grown in Bangladesh without much trouble as these trees grow in Deciduous Forests and these forests are present in Bangladesh and the soil type also matches. So *Strychnos potatorum* will be able to replace the widely used chemical coagulants used by affected people during floods. Therefore, these trees can be planted in the flood affected areas and its seeds can be easily distributed among the populace in time of need.

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