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Yamuna river water treatment using a natural coagulant of *Citrullus lanatus* seeds

Pratham Singh*, Isha Saxena

School of Chemical Engineering, Galgotias University, Greater Noida, Uttar Pradesh, India

*E-mail address: prathamsinghhh@gmail.com

ABSTRACT

The aim of this study is to evaluate the potential of *Citrullus lanatus* seeds (a natural coagulant) also known as Watermelon seeds in treating Yamuna River Water. The problem of water scarcity in developing nations requires an economical and feasible water treatment process like coagulation. The watermelon seeds were analyzed on different physicochemical water treatment parameters. To understand the efficiency of the coagulant; a jar test was conducted by varying dosage, mixing speed, pH, and temperature. At an optimum coagulant dosage of 250 mg/L, pH of 7, stirring speed of 100 rpm, and temperature of 30 °C, the maximum turbidity removal of 81% was observed. The study concludes that the *Citrullus lanatus* seeds can be used as an effective natural coagulant for water treatment in developing countries.

***Keywords*:** Yamuna river, watermelon seeds, physicochemical treatment, water treatment, natural coagulant, *Citrullus lanatus*

1. INTRODUCTION

Water is one of the most pivotal natural resources for most living organisms. The water on the earth is present in abundance but the availability of fresh drinking water is however limited. In the third world and developing countries like India, Bangladesh, and Nigeria the accessibility of safe drinking water is still a major challenge [1]. The limited financial resources and the increasing cost of water treatment plays a crucial role in these countries [2]. More than

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millions of people succumb to death due to consumption of contaminated water [3]. Apart from groundwater, surface water in the form of rivers, lakes, and pond are a feasible natural resource. Rivers bolster the growth of human civilization in terms of agriculture, industrialization, and urbanization. The quality of river water in India is degrading rapidly due to the discharge of untreated industrial and domestic waste directly into the water bodies. The increase in microbial level, organic matter, metals, and other toxic elements immensely affects the physicochemical and biological quality of the river [4]. In India, the river Yamuna is considered to be a holy river according to Hindu mythology. However, the river water is polluted and hazardous for domestic use because of declining water quality [5]. Therefore, water from any natural resource needs some sort of treatment prior to consumption [27, 28].

Safe potable drinking water should qualify the physical, chemical, and biological standards of the World Health Organization (WHO). It should have acceptable taste, odor, and appearance [6]. Water treatment typically includes three stages; namely primary secondary and tertiary treatment. Primary stage includes collecting and screening of water from the source. Secondary treatment includes purification using coagulation, flocculation, filtration, and membranes separation. The tertiary treatment stage involves the removal of color or odor using carbon treatment, pH balance, and disinfection [7]. Various parameters like turbidity, pH, microbial load, cost of operation, and chemical availability define the achievable quality of water after treatment. Techniques like ion exchange, reverse osmosis, chemical precipitation, membrane separation, and solvent extraction has several disadvantages including high capital investment, high operating cost, and large waste production [8]. The conventional method includes coagulation, flocculation, sedimentation, filtration, and disinfection for treating water [2].

1. 1. Coagulation

Coagulation is the process of destabilizing suspended and colloidal particles in the solution and react it with organic matters to form bigger particles. Since most colloids are negatively charged, they tend to repel each other before colliding. Hence, the surface charge makes the particle stable. Consequently, the introduction of positively charged ion is essential to destabilize the colloids heterogeneous mixture [9]. Coagulation is the rate-determining step in the water treatment because of the effective turbidity and particle removal [10]. Coagulants can be classified as a synthetic and natural coagulant. Synthetic coagulants like aluminum sulfate also known as alum, aluminum chloride, ferrous sulfate, ferric sulfate, and sodium aluminate are widely used in the industry. However, the cost of these chemical-based coagulants is high and can even cause pathological and neurological disorders resulting in Alzheimer and Dementia [11]. Whereas natural coagulants are harmless to human health as they have natural characteristics and contains polysaccharides and protein for effective water treatment. They are more economical and environmentally friendly when compared to synthetic coagulants. Natural plant-based coagulant includes Nirmali seeds, Moringa oleifera, White popinac, Tannin, Watermelon seeds, and Cactus. Previous studies have shown that the plant-based coagulant can treat low to medium (50-500 NTU) range turbid water [9].

1. 2. Watermelon (*Citrullus lanatus*) Seeds

Watermelon or *Citrullus lanatus* belongs to the cucurbit family and can be easily cultivated in most parts of the world including Asia, the Middle East, and Africa. The watermelon rinds have shown properties of mesoporous activated carbon, prepared by chemical activation using zinc chloride [12]. This activated carbon can even treat thallium present in the wastewater stream [13]. This agricultural waste can also be used as a biosorbent and a coagulant with alum for water treatment [11, 14]. Consequently, the watermelon seeds can be used as a biodiesel blend and as edible oil [15, 16]. Apart from the high availability of watermelon in the market, the potential application in various industries makes it economically feasible and hence making it a versatile fruit.

Watermelon seeds are high in protein (27.6%) and fat (47.5%) [17]. Synthetic coagulants like alum consist of Al_2O_3 and Fe_2O_3. Similarly, the element like Al_2O_3, Fe_2O_3, Na_2O, and SiO_2 are present in watermelon seeds which assist the coagulation process. [18]. Moreover, watermelon seed can be used for removal of metal like Lead (II) [19] and removal of Reactive Yellow (RY) 145 in water [20].

Therefore, the objective of this work is to treat River Yamuna water using watermelon seed (*Citrullus lanatus*) and determine the efficiency of the coagulant. The water quality is tested on various physicochemical parameters with variation in dosage, temperature, mixing speed, and pH.

2. MATERIALS AND METHODS

2. 1. Materials

The material used in this experiment includes watermelon seeds, air oven, digital thermometer, soxhlet extractor, Yamuna River water, weighing balance, turbidity meter, pH meter, conductivity meter, digital TDS meter, distilled water, n-hexane, flocculator, beakers, high-speed blender, sieve, pipette, and a stopwatch.

2. 2. Methods

2. 2. 1. Water Sample Collection

The sample water was collected from Yamuna River, near Okhla Barrage located in New Delhi, India. The sample water was stored and transported in a polyethylene container which was previously washed with distilled water.

2. 2. 2. Coagulant Preparation

Watermelon seeds were used as a coagulant for water treatment. The seeds were purchased from the local market located in South-East Delhi. The seeds were rigorously washed with tap water followed by distilled water.

To remove moisture content, the seeds were sun-dried for ten days and then dried in an oven at 60 °C for 1 hour. The poor-quality seeds were removed during the process. The seeds were crushed into powder form using a high-speed blender as shown in Figure 1. The 100g of blended seeds were placed in a Soxhlet extractor for 7 hours. 300 ml of n-hexane was used to extract seed oil and after complete extraction, the cake was washed with distilled water to remove unwanted hexane.

The cake was dried in an oven to achieve a constant weight. A 100 μm size mesh was used to screen the particles. The finer particles were used for further evaluation.

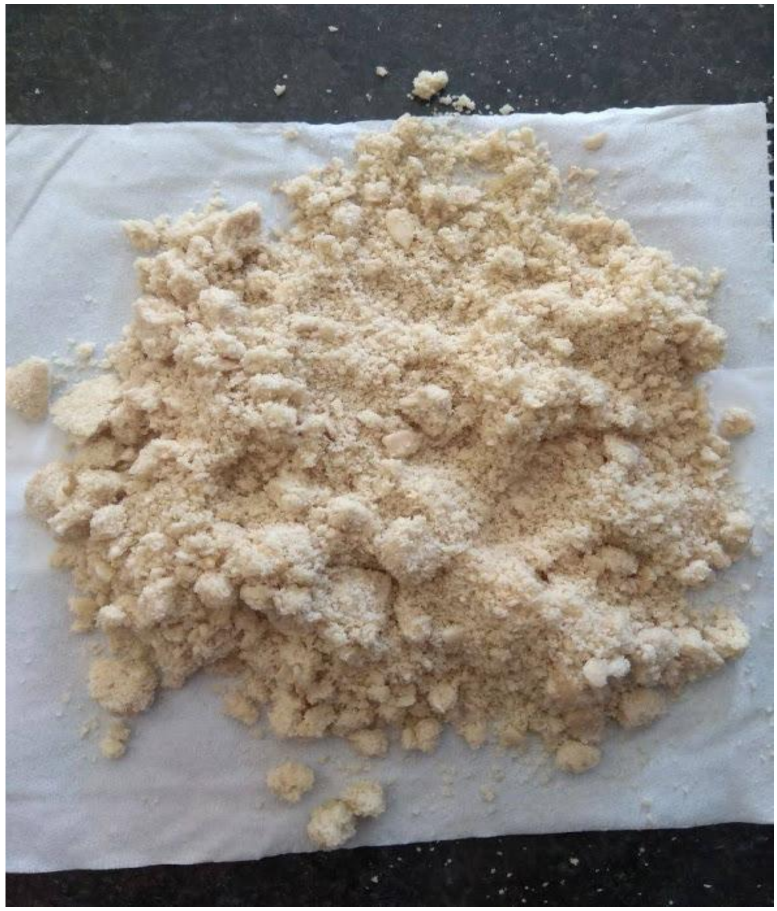

Figure. 1 Crushed *Citrullus lanatus* seeds.

2. 2. 3. Water Quality Tests

All the tests were performed using analytical grade instruments and following the standard guidelines for international water quality measurement.

1) pH

The pH of the water was observed using a pH meter before and after the treatment.

2) Colour

The colour was observed after treatment using a turbidity meter

3) Total Dissolved Solid (TDS)

The total dissolved solid was obtained using an electronic TDS meter.

4) Turbidity

The turbidity of the sample was observed using a turbidity meter.

5) Conductivity

The conductivity of the water sample was measured before and after treatment using a conductivity meter.

6) Conventional Jar Test

A conventional jar test is used for the coagulation and flocculation of the initial water sample. This includes six 1000 ml beakers and six spindle steel paddles for constant mixing. This observes the effect of coagulant dosage, mixing speed, temperature, and pH variation on the coagulation process. The coagulant dosage was varied from 50 mg/l to 300 mg/l with the constant addition of 50mg/l in each beaker. The pH, turbidity, temperature, conductivity, TDS, color, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were measured on the filtered liquid or filtrate. Now, considering a constant dosage of 250mh/l coagulant in six beakers, the pH was varied from 6-8.5. To make the water sample alkaline few drops of 1M NaOH was introduced. Consequently, few drops of 1M H_2SO_4 were added into the sample to make it acidic in nature. The above-mentioned coagulation-flocculation and filtration processes were repeated, and the parameters were measured.

The constant dosage of 250 mg/l was added to four beakers to observe the effect of coagulation with varying mixing speed. The speed was varied from 50 rpm to 200 rpm with a constant settling time of 20 minutes. After the coagulation-flocculation step, the filtrate was collected and measured on the water quality parameters. Similarly, at constant dosage, the temperature of the sample was varied from 10 °C to 40 °C. The quality of the water sample was measured after the above-mentioned processes were completed.

3. RESULTS AND DISCUSSIONS

The oil extracted from watermelon seed using soxhlet extractor is approximately 48% and is analogous to the result illustrated by A. Rai et al. (2015) [21] reporting 52.37% of watermelon seed oil. The initial quality of raw water collected from Yamuna River is tested on different physicochemical properties as shown in Table 1. The sample is compared with the standard drinking water quality guidelines of the World Health Organization (WHO) [6] and the Bureau of Indian Standards (BIS) [22].

Table 1. Yamuna River water quality on different parameters.

PARAMETERS	UNIT	INITIAL SAMPLE	WHO STANDARD	BIS STANDARD
pH	-	7.4	6.5-8.5	6.5-8.5
Temperature	°C	27.62	25-30	25
Conductivity	µS/cm	1058.4	1400	<3000 µS/cm
BOD	mg/l	24.48	-	<2

COD	mg/l	53.6	-	<5
DO	mg/l	2.8	-	>6
Turbidity	NTU	47.4	<4	<5
Color	TCU	293	<15	<15
TDS	mg/l	761.5	<600	<2000

The pH, temperature, and conductivity of the water are well within the WHO range. However, the turbidity, TDS, and color are above the WHO range and do not qualify for safe drinking water. Similarly, the BOD and COD are high, and Dissolved Oxygen (DO) is negligible when compared with BIS standards. B. N. Bhat et al. (2018) [4] illustrates the water quality of the Yamuna river is dependent upon the seasonal condition. The negligible amount of DO and high turbidity is the result of direct and indirect waste entering the river stream from neighboring industrial, agricultural, and domestic activities.

3. 1. Dosage Variation Analyses

The dosage of the coagulant is varied from 50 mg/L to 300 mg/L with a constant increment of 50 mg/L. The settling time after the coagulation-flocculation process is 20 minutes and then the filtrate is tested for the pH, temperature, TDS, turbidity, color, conductivity, BOD, and COD. Table 2 shows that the dosage of 250 mg/L reduces maximum turbidity to 9.2NTU and also significantly decreases the TDS (33%), BOD (78%), and COD (72%) of the water.

Table 2. Effect of dosage variation on coagulation.

S.NO.	DOSAGE (mg/L)	pH	TEMPERATURE (°C)	TDS (mg/L)	TURBIDITY (NTU)	COLOR (TCU)	CONDUCTIVITY (µS/cm)	BOD (mg/L)	COD (mg/L)
1	50	6.69	26.4	556	21.1	48	1022	14.3	32.2
2	100	6.81	26.7	543	16.7	53	1048	9.5	26.6
3	150	6.9	26.6	545	16.3	67	1067	7.4	17.3
4	200	6.85	26.6	524	14.5	82	1075	6.6	22.8
5	250	7.1	26.3	510	9.2	84	1062	5.2	14.7
6	300	7.18	26.5	526	13.2	97	1083	5.3	14.28

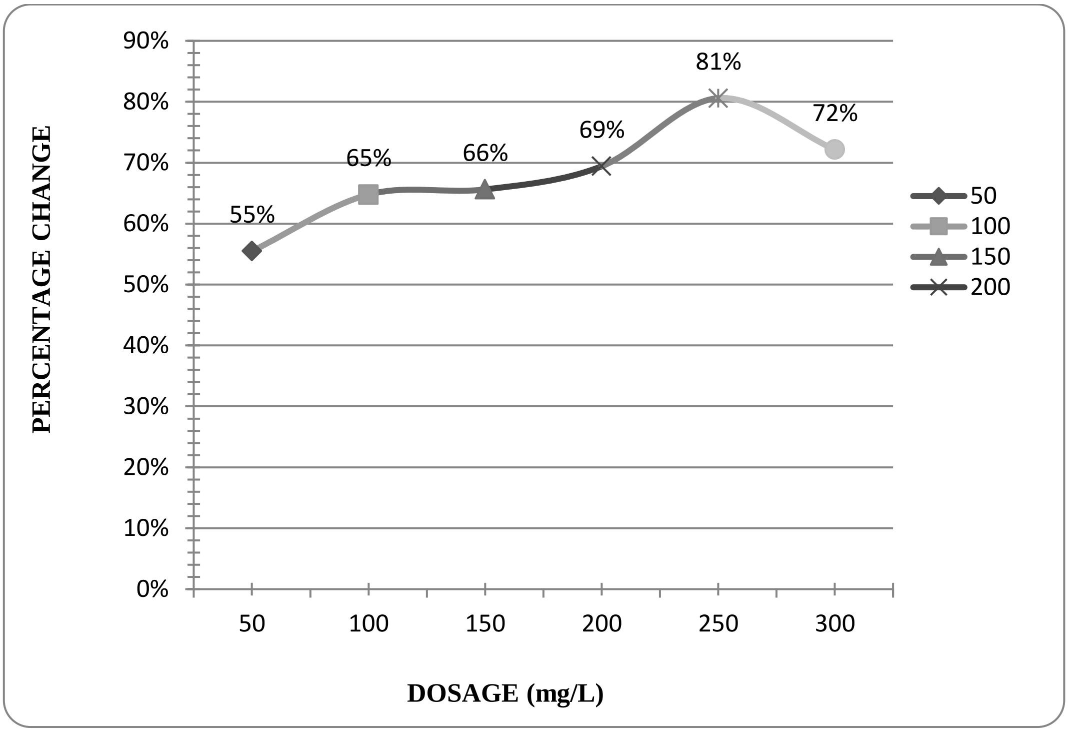

Figure 2. Percentage change in turbidity with respect to dosage variation

Optimum dosage is the one that reduces the maximum amount of turbidity in the water [23]. Figure 2, illustrates that the maximum change of 81% in turbidity is observed at 250 mg/L, hence, the optimum dosage is 250 mg/L. The 81% change in turbidity is analogous to the 86% change observed by I.M. Muhammad et al. (2015) [23]. The watermelon seeds are positively charged which absorbs and neutralizes the negatively charged collides in water. The inadequate dosage of coagulant may result in poor coagulation. Whereas the high concentration of coagulant will decrease the surrounding impurities once equilibrium is achieved. The settling particle will not be able to coagulate past optimum dosage as observed at 300 mg/L [24].

3. 2. pH Variation Analyses

The coagulation process is immensely affected by the pH change since coagulation takes place in a limited range. The sample is varied in alkaline to acidic in the range of 6-8.5. Table 3. demonstrates that 7 is the optimum pH for coagulation with the lowest value of turbidity (8.95NTU) and color (81TCU). Previous studies have shown alkaline solution can increase the electrostatic attraction and acidic solution can increase electrostatic repulsion [20]. Hence, the changing pH can affect the light absorption properties of the sample and as a result, a varying color is observed.

3. 3. Effect of Mixing Speed on Coagulation

Table 4, explains the effect of mixing speed on the coagulation process is not very significant. The mixing speed is varied from 50-200 rpm at a constant interval of 50 and 20 minute of settling time is allowed after stirring. The temperature and pH remain neutral throughout the process. However, the conductivity and color increase with an increase in stirring speed. The optimum mixing speed is observed at 100 rpm with a turbidity removal of 9.37NTU. The lower mixing speed will improve turbidity removal due to reduced shearing of flocs in the sample and the result is in accordance with James M. Ebeling et al. (2004) [25].

Table 3. Effect of pH variation on coagulation at a dosage of 250 mg/L.

S.NO.	pH	TEMPERATURE (°C)	TDS (mg/L)	TURBIDITY (NTU)	COLOR (TCU)	CONDUCTIVITY (µS/cm)
1	6	26.9	652	11.5	84	1656
2	6.5	26.4	634	14.2	87	1579
3	7	27.1	643	8.95	81	1243
4	7.5	27	537	9.7	89	1063
5	8	26.9	524	10.24	93	915
6	8.5	27.4	527	10.8	95	965

Table 4. Effect of mixing speed variation on coagulation at a dosage of 250 mg/L.

S.NO.	SPEED (in rpm)	pH	TEMPERATURE (°C)	TDS (mg/L)	TURBIDITY (NTU)	COLOR (TCU)	CONDUCTIVITY (µS/cm)
1	50	6.88	26.7	9.4	10.1	79	1048
2	100	7.06	26.8	8.7	9.37	82	1059
3	150	7.02	26.8	9.5	11.96	85	1087
4	200	7.14	26.6	9.8	16.2	89	1094

3. 4. Temperature Variation Analyses

The temperature of the initial water sample is varied from 10 °C to 40 °C at a constant dosage of 250 mg/L. Feng Xiao et al. (2007) [26] demonstrates the negative impact of temperature change on coagulation kinetics and aggregation rate. Hence, it is important to understand the effect of temperature variation on natural coagulants. Studies have shown the thermo-resistance properties of natural coagulant protein [1].

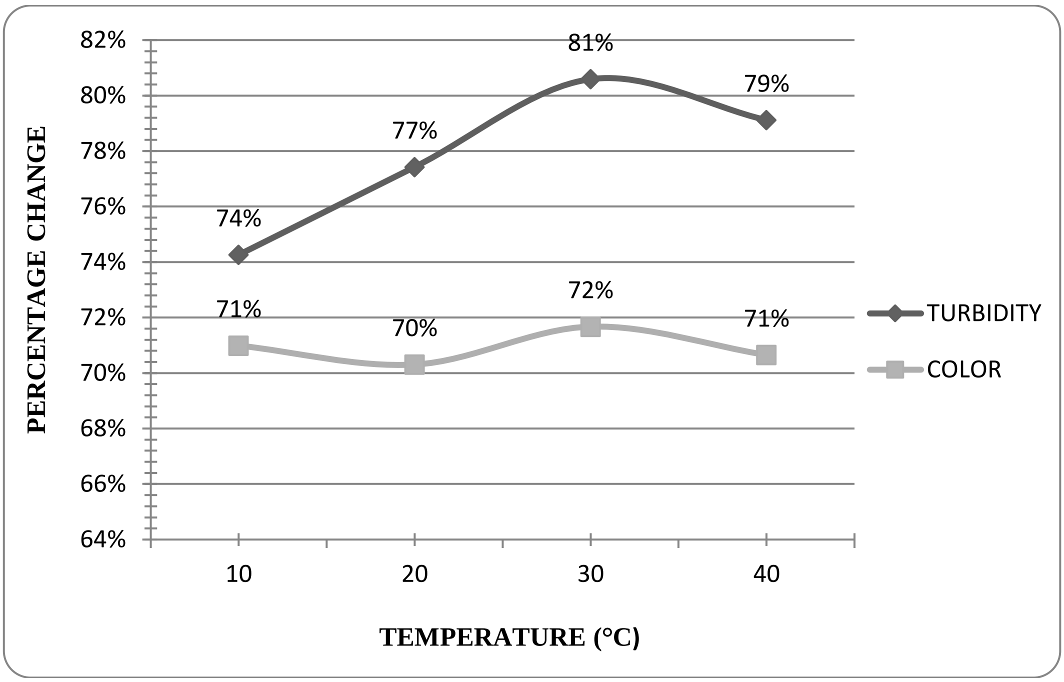

Figure 3. Percentage change in turbidity and color with respect to temperature variation

Table 5. Effect of temperature variation on coagulation at a dosage of 250 mg/L.

S.NO.	TEMPERATURE (°C)	pH	TDS (mg/L)	TURBIDITY (NTU)	COLOR (TCU)	CONDUCTIVITY (μS/cm)
1	10	6.46	540	12.2	85	1042
2	20	6.87	583	10.7	87	1067
3	30	6.54	598	9.2	83	1084
4	40	6.67	602	9.9	86	1134

From Table 5, the TDS and conductivity of the filtrate are increasing with an increase in temperature. The turbidity remains greater at 12.2NTU at 10 °C as compared to 9.2NTU at °C. Figure 3, shows the highest percentage change in turbidity and color at 30 °C. Thus, moderate room temperature is considered best for the coagulation process as explained by Ezeh Ernest et al. (2017) [24].

4. CONCLUSION

In this study, we have concluded that the watermelon seeds can act as a potential natural coagulant to treat the Yamuna River water. Natural coagulants like *Citrullus lanatus* seeds are feasibly available and its application will help to reduce the cost of water treatment in developing countries. The maximum purification of the water was observed at optimum dosage of 250 mg/L, optimum pH of 7, optimum mixing speed of 100 rpm, and optimum temperature of 30 °C. Although the turbidity and color of the filtrate were above the limit of WHO standard drinking water guidelines, the 81% reduction in turbidity is commendable considering the financial limitations and nonhazardous nature of watermelon seeds. Moreover, the coagulant protein of watermelon seeds is found to demonstrate thermo-resistance properties and is suitable for a warm environment. To further improve the quality of the water, the natural coagulant can be combined with synthetic coagulants. Hence, watermelon seeds perform as a natural coagulant and are effective in treating Yamuna River water.

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