Engineering Research Journal

journal homepage: https://erj.journals.ekb.eg/

Impact of Natural Coagulants on Primary Sedimentation Performance

H. M. Hussein[1], Sohier Mansour[2], Samy Tharwat[2,*], Mina Danial[2]

[1]Department of Civil Engineering, Faculty of Engineering, Ain Shams University, 11517, Cairo, Egypt

[2] Civil Engineering Department, Faculty of Engineering, Materia, Helwan University, Egypt.

[*]Corresponding author: Samytharwat201@m-eng.helwan.edu.eg

Abstract

The waste generated from various human activities promotes environmental degradation. Improper handling of sewage and waste generated through societies pollutes freshwater bodies. Chemical coagulants have limited success in treating wastewater. So, natural coagulants can be the most suitable alternative to chemical ones. Samples of wastewater from Belkas wastewater treatment plant were treated by coagulation, flocculation, and sedimentation to assess the impact of natural coagulants on primary sedimentation performance. Experiments were conducted using various doses of Moringa oleifera seed powder (MOSP) and banana peel powder (BPP) using jar test equipment. Turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and pH were measured before and after treatment to determine the removal efficiency of turbidity, TSS, BOD5, and COD and the effect of dosage on pH. Results showed that the best dose for (MOSP) at 500 mg/l increased the removal efficiency of turbidity, TSS, BOD5, and COD to 94.39%, 98.97%, 92.35%, and 88.28%, respectively. However, the best dose for (BPP) at 140 mg/l increased the removal efficiency of turbidity, TSS, BOD5, and COD to 69.32%, 64.37%, 61.31%, and 44.23%. No major effect was recorded due to using (MOSP) and (BPP) on pH.

Keywords

Natural Coagulants, Primary Sedimentation, Wastewater

Nomenclature

WWT	Wastewater treatment
MOSP	Moringa oleifera seed powder
BPP	Banana peel powder
TSS	Total suspended solids
BOD	Biochemical oxygen demand

DOI: 10.21608/erj.2024.311686.1088

Received 12 August 2024; Received in revised form 22 November 2024; Accepted 24 November 2024

Available online 01 December 2024

COD	Chemical oxygen demand
$TSS_{(i)}$	Initial total suspended solids
$BOD_{(i)}$	Initial biochemical oxygen demand
$COD_{(i)}$	Initial chemical oxygen demand
$TSS_{(f)}$	Final total suspended solids
$BOD_{(f)}$	Final biochemical oxygen demand
$COD_{(f)}$	Final chemical oxygen demand

1 Introduction

Water is major to all living beings including humans. Water reservoirs such as rivers, lakes, and oceans contribute to the hydrological cycle and conserve ecosystem equilibrium [1], [2] . In addition to being used by humans, water is essential for aquatic life as it serves as their habitat and ultimately provides humans with a source of protein. However, achieving high water quality is difficult. As a result, the issue of water scarcity will worsen, with a majority of the world's population unable to access clean drinking water [3]. The amount of domestic wastewater generated has experienced a substantial increase over the past few decades [4]. In developing countries, there are more than 1.6 million people are using polluted water among them, most of the people suffer from water-associated diseases [5]. Before disposal of the wastewater into bodies, wastewater has to be treated using technologies and converted raw water sources into drinking water [2]. To confirm compliance with environmental regulations and resource reuse, effective wastewater resource treatment and contamination prevention are desired [6]. There are three major phases physical, chemical, and biological procedures in wastewater treatment that remove. physical, chemical, and biological are the three major phases that remove the contamination from wastewater during treatment[7].

The first stage in treating wastewater removes about 50% total suspended solids and 30% BOD. The performance and efficiency of primary sedimentation can be increased due to using coagulants. the crucial water and wastewater treatment processes are coagulation and flocculation. Coagulation and flocculation are used for water and wastewater treatment widely to remove, turbidity, suspended solids, organic matter, and colour [8, 9]. There are destructive health and environmental impacts due to using positive chemical combinations such as ferric chloride and aluminium sulfate during the conventional coagulation process. Using chemical coagulants in treated wastewater can lead the way to high quantities of chemical residues, toxic sludge and health risks [10]. The most common chemical coagulants used in wastewater treatment are ferric chloride, calcium carbonate, Inorganic and polyaluminium chloride. [8]. The adoption of natural coagulants in wastewater treatment represents a significant step towards developing sustainable and environmentally friendly technologies. A natural coagulant that is extracted from plant sources is not developed as it was first discovered decades ago [11]. Moringa oleifera [12], Jatropha curcas [13] and bagasse [14] are investigated in research in recent years. Table 1 summarized the applications of natural coagulants in wastewater treatment.

Table 1: Applications of natural coagulants in wastewater treatment

Types of wastewater	Natural coagulant	Removal performance	References
Landfill leachate	Moringa oleifera seed	Heavy metals: Fe (100%) Cu (98%), Pb (78.1%)	[12]
Landfill leachate	Basil	COD (64.4%), Colour (52.2%)	[15]
Kaolin Wastewater	Jatopha curcas seed	Turbidity (96%)	[16]
Paint industry	Cactus	Color (88.4%) COD (78.2%)	[17]
STP Wastewater	Carcia papaya seed	Turbidity (41.89%) COD (66.67%)	[18]
River water	Moringa oleifera seed	Turbidity (62.5%) Coliform bacteria (70-93.3%) Mesophilic bacteria (93.7-98.3%)	[19]
POME	Moringa oleifera seed	TSS (95.4%) Turbidity (88.3%) NH4-N (89.8%) Color (90.2%) Oil and grease (87.1%)	[20]
Landfill leachate	Jackfruit seed starch (JSS)	COD (26.85%)	[21]
Confectionary	Cactus	TSS (92.2%) COD (95.6%)	[22]

This research aims to study the effects of natural coagulants, Moringa Oleifera Seeds Powder (MOSP) and Banana Peel Powder (BPP), on improving sedimentation performance. Increasing the removal efficiency of TSS, Turbidity, BOD5, COD, and pH reduces the size of secondary units and minimizes the time and energy required for aeration.

2 Materials and methods

2.1 Wastewater sources

The municipal wastewater samples were collected from the effluent of the grit removal chamber at Belkas WWTP. The selected samples were analysed at the Belkas wastewater treatment plant lab. The wastewater samples characteristics are shown in the table 2.

Table 2: Wastewater samples characteristics

Parameter	Range	Measuring device
pH	6.8-7.7	pH meter
Turbidity (NTU)	80-120	Turbidity meter
TSS (mg/l)	170-200	TSS meter
COD (mg/l)	320-430	COD reactor
BOD (mg/l)	130-290	BOD incubator

Table 3: Testing devices

pH meter:	
Producing Company	HANA instrument Europe (Romania)
Use	Measurement of pH in samples
Digital Balance :	
Serial number	85463
Model	Shimadzu (AEU-210)
Producing Company	Kyoto - Japan
Use	Estimation of weights
COD reactor :	
Serial number	980200017233
Model	45600
Producing Company	HACH-USA
Use	Digestion of samples at a temperature of 150°C
Vacuum pump:	
Serial number	80611
Model	DINKO(D-95)
Producing Company	DINKO- Spain
Use	Pumping and vacuuming air.
BOD_5 incubator:	
Serial number	794077240
Model	IRE - 160
Producing Company	Raypa- Spain
Use	Sample storage for BOD5 experiment at 20°C
DO meter bench top :	
Serial number	C9006719
Model	58 YSI
Producing Company	YSI- incorporated USA
Use	Measurement DO.
Laboratory Mixer:	
Serial number	18
Model	2160092
Producing Company	EVOLO1
Use	Tlupmams-Italy

2.2 Natural coagulants preparation

Two natural coagulants were used (MOSP) and (BPP). The husk around each seed was removed manually from Moringa oleifera seeds. Then grind the kernel using an electric blender to obtain fine powder. The 5% concentration of solution was used in this study (5gm of powder in 100ml tap water) [23]. At room temperature, the mixture was stirred for 10 minutes with a stirrer. Using 474-grade filter paper to filter The suspension as shown in figure 1. The filtrate solution extracted from the vacuum pump was then utilized as a natural coagulant at Jar test [24].

The banana peels were gathered for domestic use. For a week, Banana peel was sun-dried, then oven-dried at 60°C for 20 minutes and ground to a fine powder with a mortar pestle. The powder (1 g) was suspended in 100 mL of distilled water, mixture for 15-45 minutes on a magnetic stirrer at room temperature, and as shown in figure 1, filtered using a vacuum pump to produce aqueous extracts of banana peels [25].

Fig.1: Vacuum Pump and Filter Paper

2.3 Experimental Works Procedures

A standard jar test apparatus manufactured by VELP was used in coagulation, flocculation, and sedimentation in all experiments. Each experiment was conducted three times and the median was taken into consideration. The wastewater is collected freshly every day. The collected sewage samples were evenly distributed among the six jars after thorough mixing as shown in figure 2. Coagulant dosage was then added in varying proportions (according to the experimental plan) in each jar. At 120 rpm for 1 minute, it was stirred to confirm the homogeneous distribution of the coagulation. A slow mixing was conducted at 20 rpm for 20 minutes to ensure formation of the flocs[26]. Subsequently, a quiet settlement for 30 minutes was permitted. The samples of the supernatant were taken from the middle of the beaker and examined for the various parameters (Turbidity, TSS, BOD_5, COD and pH) according to the methodology of the 21st edition Standard Methods for the Examination of Water and Wastewater (APHA, 2005) [27], at the end of the settling time. All experiments were tested at a lab room temperature of 26±2°C. Turbidity, TSS, COD, and BOD_5 removal were calculated according to Eq. (1) through (4).

$$Tur\ removal\ \% = \frac{turbidity\ (i) - turbidity(f)}{turbidity(i)} \quad (1)$$

$$TSS\ removal\ \% = \frac{TSS(i) - TSS(f)}{TSS(i)} \tag{2}$$

$$COD\ removal\ \% = \frac{COD(i) - COD(f)}{COD(f)} \tag{3}$$

$$BOD\ removal\ \% = \frac{BOD(i) - BOD(f)}{BOD(i)} \tag{4}$$

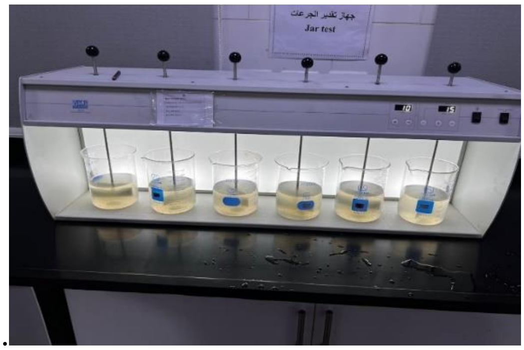

Fig.2: Jar test

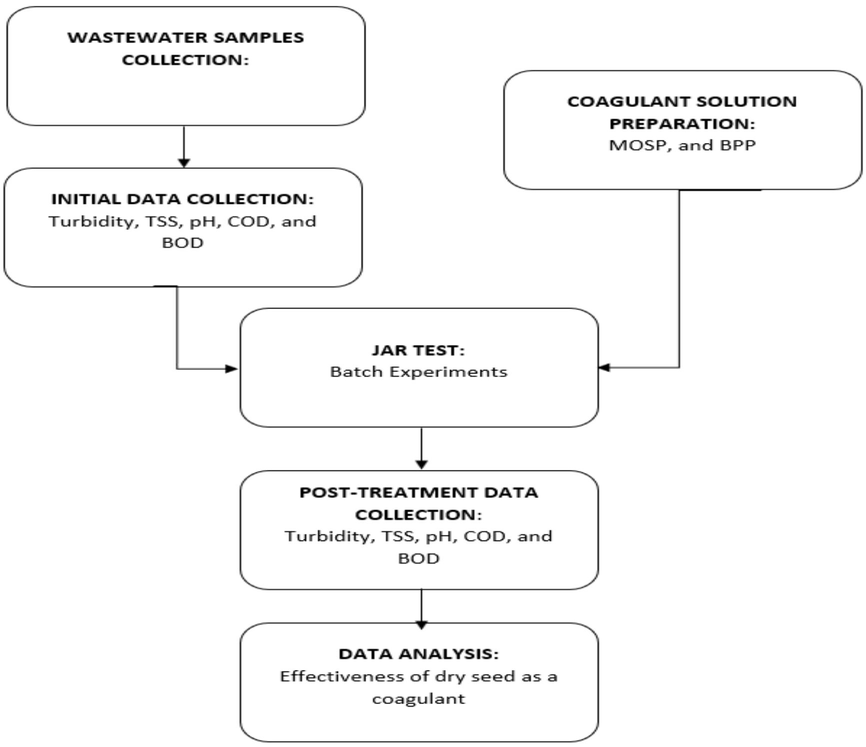

Fig.3: Schematic diagram for the experimental procedure

Table 4: Experimental Plan

NO.	MOSP Dosage mg/L	BPP Dosage mg/L
1	0	0
2	100	20
3	200	40
4	300	60
5	400	80
6	500	100
7	600	120
8	700	140
9	800	160
10	900	180
11	1000	200
12	1100	220

3 Results and discussions

3.1 Effect of (MOSP) dose on the Turbidity, TSS, BOD_5 and COD removal efficiency and pH

A 5% concentration Solution (5gm of powder in 100ml tap water) of dry seeds (MOS) was used as a coagulant to evaluate the effect on primary sedimentation performance. according to the hypothesis trials and previous studies, different doses were utilized to obtain the best dose of 100 to 1100 mg/l to jar in addition to a blank jar with no coagulant. The rapid mixing was at 120 rpm for 1 min, followed by slow mixing at 20 rpm at 20 min to confirm formed the flocs, and then the time for settling was 30 min. After that, the examined samples were taken from the supernatant from the middle of the beaker to analyse the various parameters (Turbidity, TSS, BOD, COD and pH).

The initial turbidity was 97.8 NTU. As shown in figure 4, adding 500 mg/l of MOSP led to a reduction in turbidity to a minimum level of 5.5NTU with a turbidity removal efficiency of 94.39%. The turbidity removal efficiencies ranged from 64.72% to 94.39%. However, the Turbidity removal was 58.01% for blank samples.

The initial TSS was 191 mg/l. As depicted in figure 5, adding 500 mg/l of MOSP resulted in a significant reduction of TSS to a minimum level of 2.0 mg/l with TSS removal efficiency of 98.97%. The TSS removal efficiencies ranged between 81.31% to 98.97%. However, the TSS removal was 58.95% for blank samples.

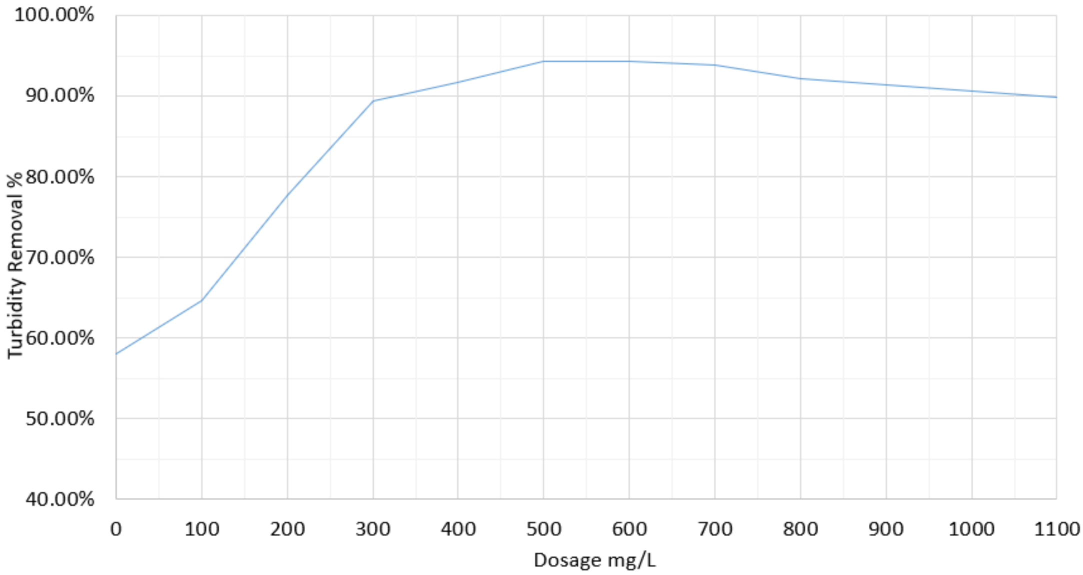

Fig.4: Effect of MOSP dose on turbidity removal

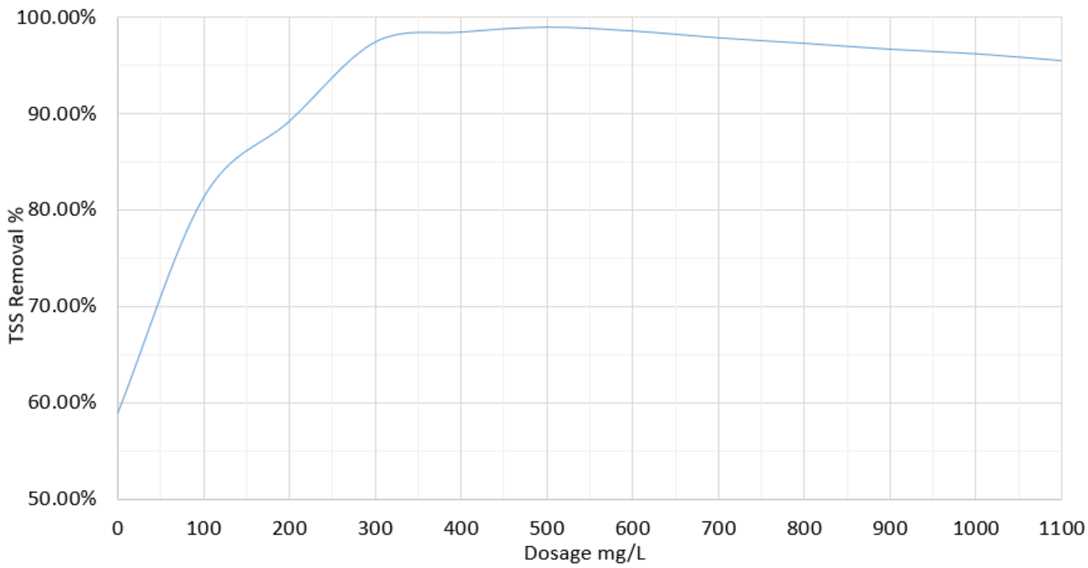

Fig.5: Effect of MOSP dose on TSS removal

The initial BOD_5 was 211 mg/l. The addition of 600 mg/l of MOSP led to a reduction in BOD_5 to a minimum level of 16.15 mg/l with BOD_5 removal efficiency 92.35%. The BOD_5 removal efficiencies ranged from 73.38% to 92.35%. In contrast, the BOD_5 removal was 48.75% for blank samples as shown in figure 6.

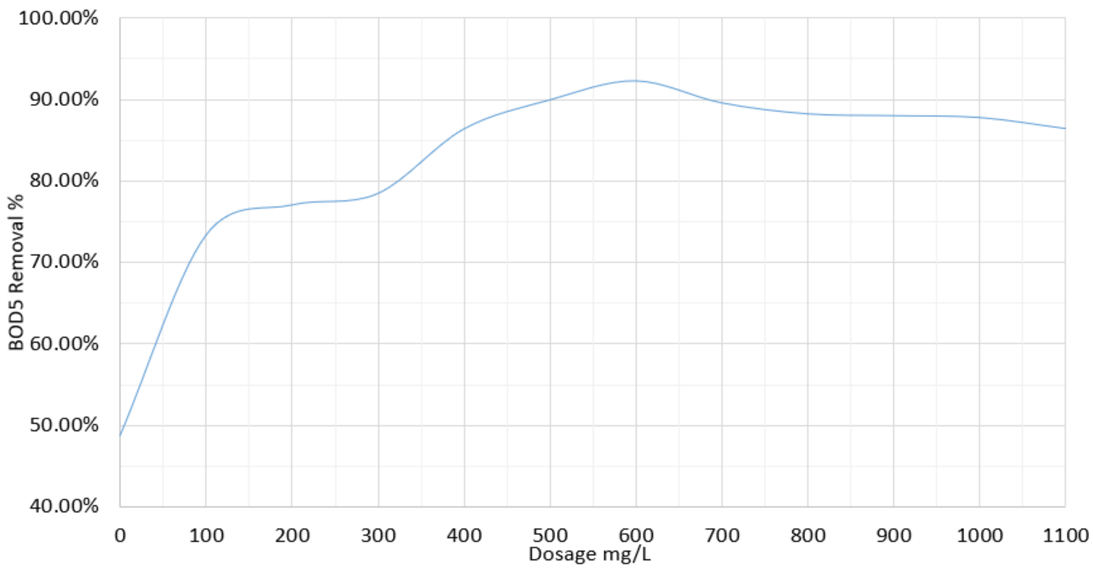

Fig.6: Effect of MOSP dose on BOD_5 removal

The initial COD was 320 mg/l. As shown in figure 7, adding 500 mg/l of MOSP led to a reduction in COD to a minimum level of 37.52 mg/l with COD removal efficiency of 88.28%. The COD removal efficiencies ranged from 75.05% to 88.28%. However, the COD removal was 54.91% for blank samples. The addition of more coagulants to wastewater results in more active coagulant sites that would attract and absorb contaminants. In addition, Adding coagulants to wastewater neutralizes the electrical load to zero zeta potential, allowing contaminants to be attracted and absorbed by the coagulants [28, 29]. Excessive coagulant dosage of more than the optimum dosage can contaminate wastewater. Excess coagulant saturates the surface of colloids. The saturated coagulant stabilizes particles and creates a repulsive force between contaminants, preventing flocs formation [11].

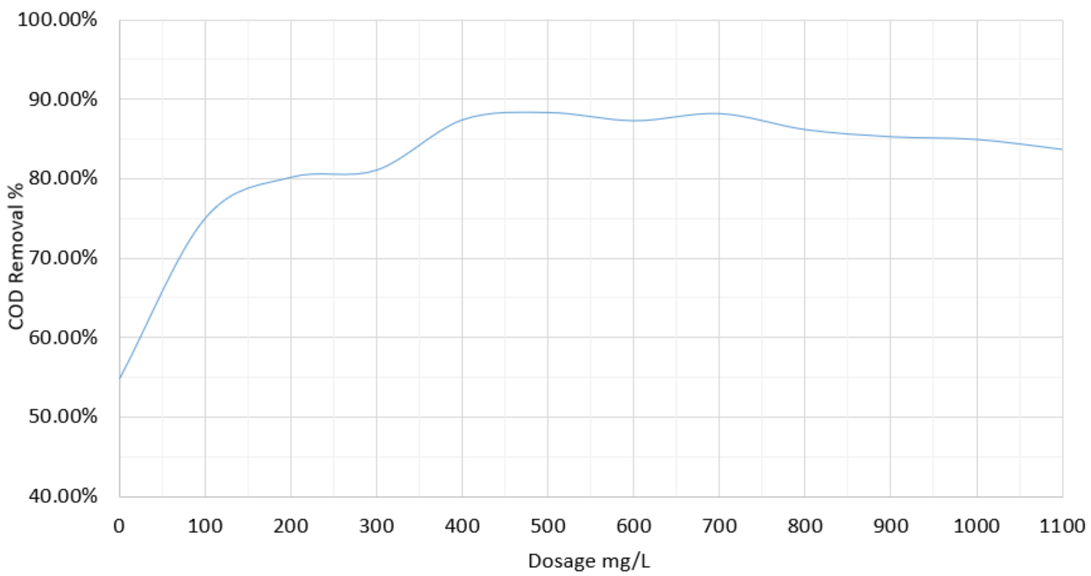

Fig.7: Effect of MOSP dose on COD removal

The following figure shows the effect of MOSP dose on pH.

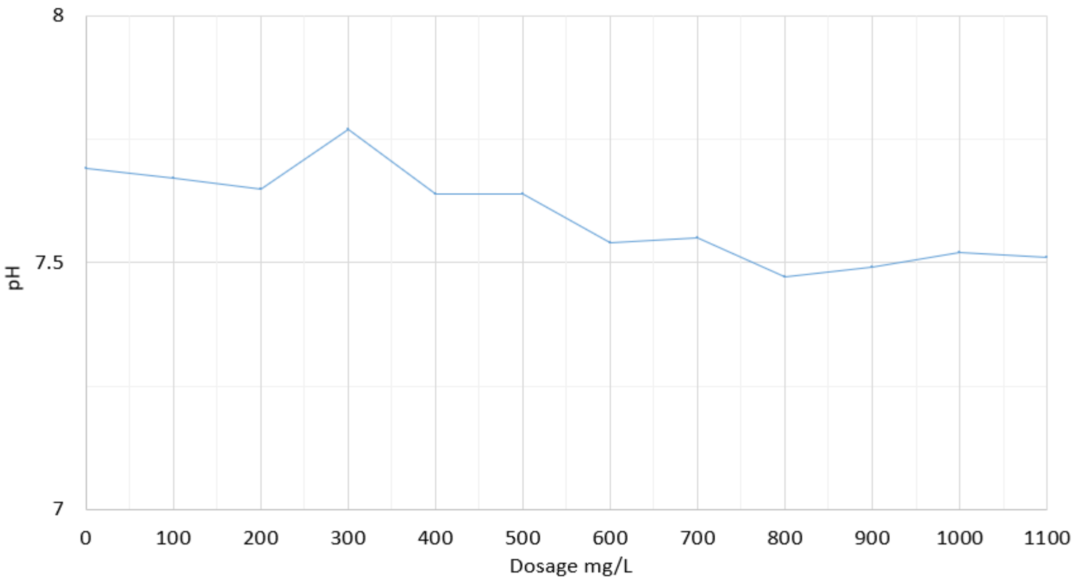

Fig.8: Effect of MOSP dose on pH

3.2 Effect of (BPP) Dose on the turbidity, TSS, BOD5 and COD removal efficiency and pH

Solution with 1% concentration (1gm of powder in 100ml tap water) of dry peels was used as a coagulant to evaluate the impact on Primary Sedimentation Performance. According to the hypothesis, trials, and previous studies, different doses were utilized to obtain the best dose of 20 to 220 mg/l to jar in addition to a blank jar with no coagulant. The rapid mixing was at 120 rpm for 1 min, followed by slow mixing at 20 rpm at 20 min to confirm formed the flocs, and then the time for settling was 30 min. After that, the examined samples were taken from the supernatant from the middle of the beaker to analyse the various parameters (Turbidity, TSS, BOD, COD and pH).

As shown in figure 9, the initial turbidity was 99.4 NTU, adding 140 mg/l of BPP led to an increase in turbidity removal efficiency to 69.32% with remaining turbidity at 30.5 NTU. The turbidity removal efficiencies ranged from 60.06% to 69.32%. However, the Turbidity removal was 61.19% for blank samples.

Adding 140 mg/l of BPP led to an increase in TSS removal efficiency to 64.37% with TSS 62 mg/l which the initial TSS was 174 mg/l. The TSS removal efficiencies ranged from 45.39% to 64.37% as illustrated in figure 10. However, the TSS removal was 48.03% for blank samples.

The initial BOD_5 was 305 mg/l, applying BPP with 140 mg/l led to an increase in BOD_5 removal efficiency to 61.31% which BOD_5 118 mg/l. The BOD_5 removal efficiencies ranged from 46.88% to 61.31% as shown in figure 11. However, the Turbidity removal was 50.31% for blank samples.

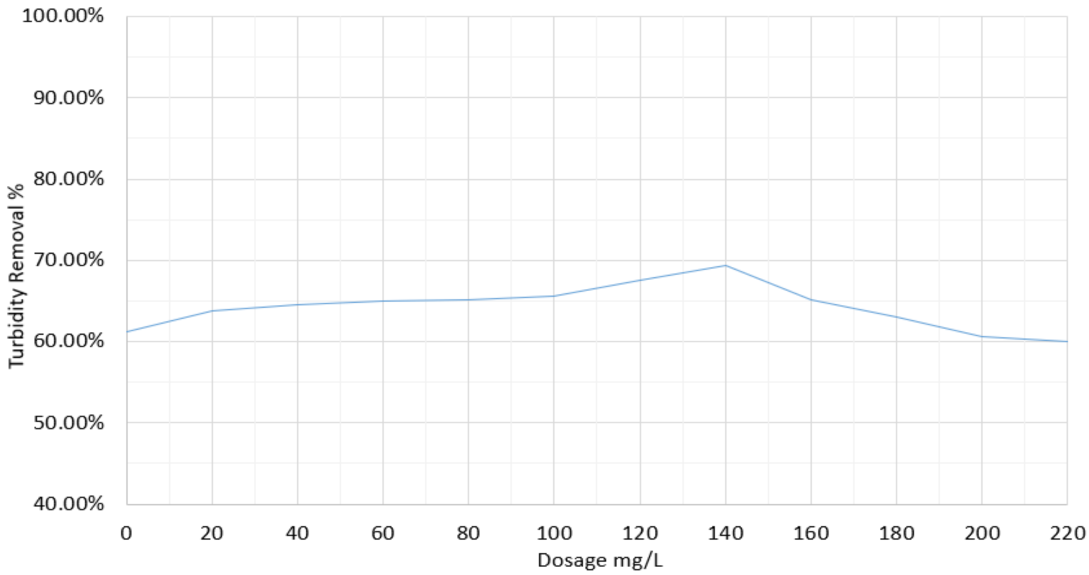

Fig.9: Effect of BPP dose on turbidity removal

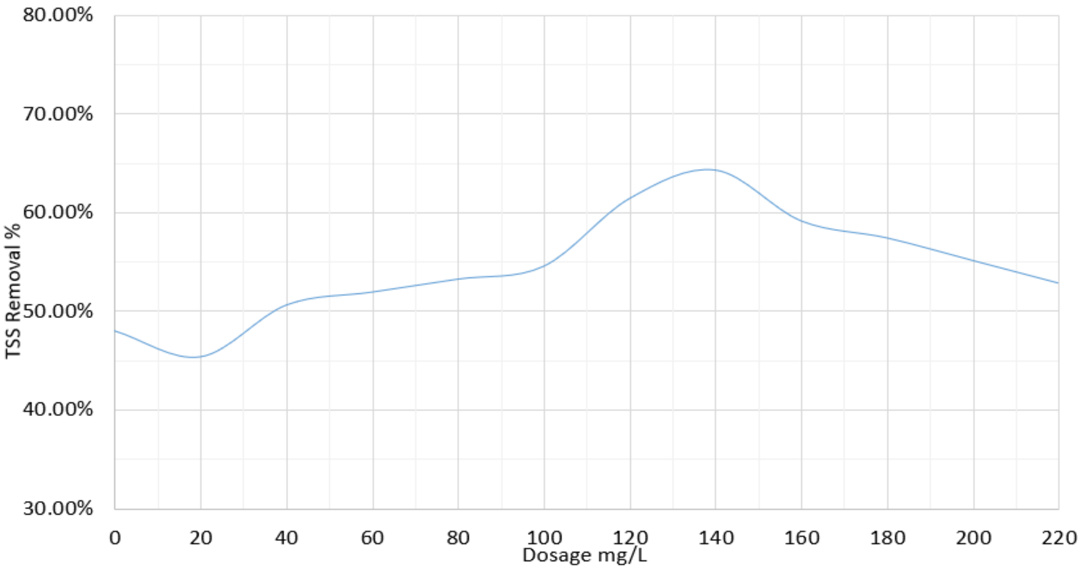

Fig.10: Effect of BPP dose on TSS removal

Initial COD was 416 mg/l. Adding 140 mg/l of BPP led to a reduction in COD to a minimum level of 232 mg/l with COD removal efficiency 44.23%. The COD removal efficiencies ranged from 37.98% to 44.23%. However, the COD removal was 40.09% for blank samples as shown in the reaction between the coagulant and the particles might be prevented due to the higher concentration of coagulant more than the optimum value in wastewater. Due to the overdose, this led to colloidal particle destabilization and charge reversal. Cationic substances were formed as a result of the hydrolysis of the coagulant in wastewater, which is absorbed by negatively charged molecules. The mechanism of particle destabilization enables the flocculation process to occur, and coagulant overdose may interfere with this process [6, 30].

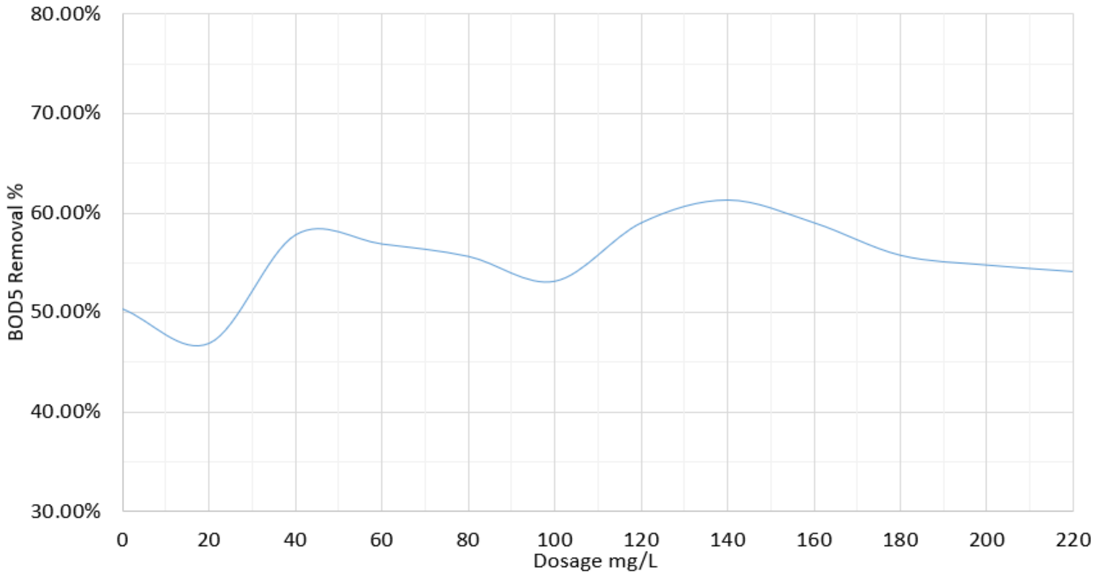

Fig.11: Effect of BPP dose on BOD_5 removal

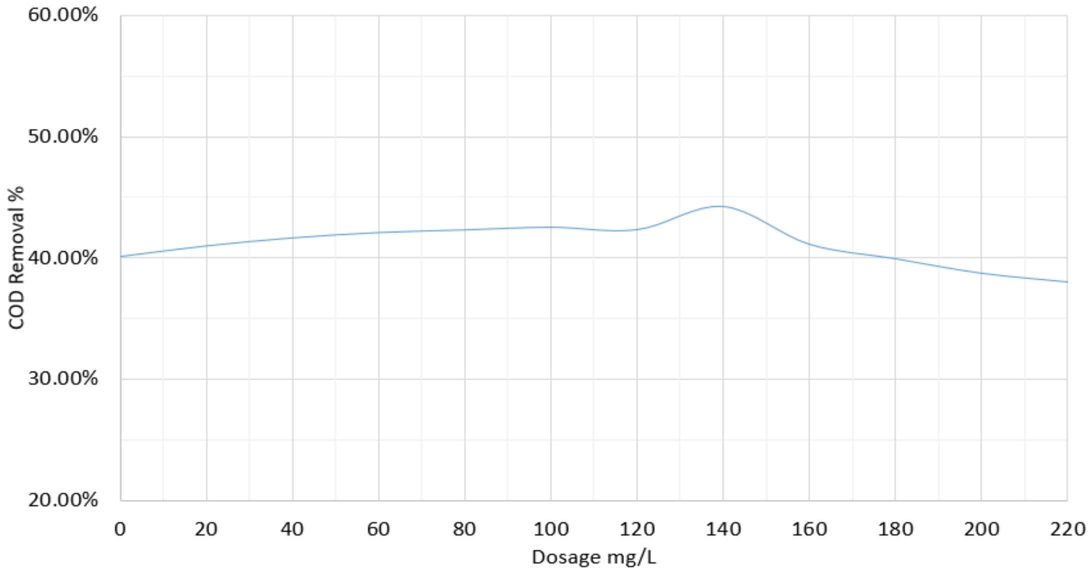

Fig.12: Effect of BPP dose on COD removal

The effect of MOSP dose on pH is shown in the following figure.

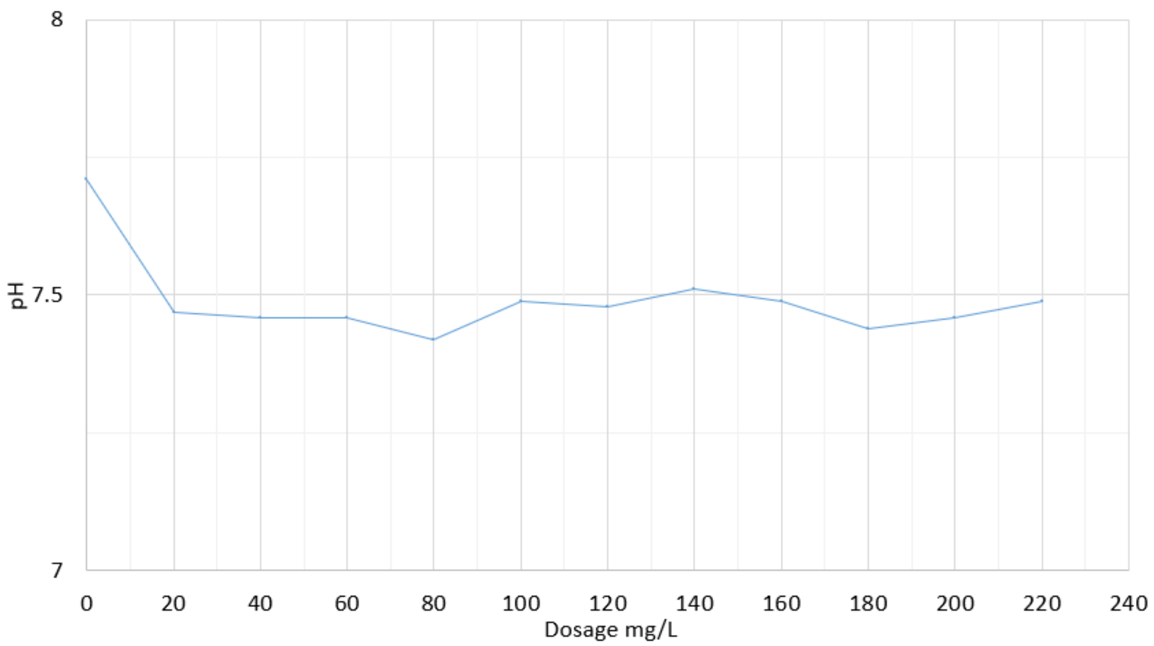

Fig.13: Effect of BPP dose on pH

3.3 Comparison between MOSP and BPP on turbidity, TSS, BOD_5, and COD removal efficiency

The following table shows the difference between MOSP and BPP in the removal efficiency of turbidity, TSS, BOD_5, and COD and the best dosage of each coagulant.

Table 5: The comparison between MOSP and BPP and accepted removal efficiency

Parameter	MOSP removal efficiency %	MOSP Dosage mg\l	BPP removal efficiency %	BPP Dosage mg\l	Accepted removal efficiency %
Turbidity	94.39	500	69.32	140	>50
TSS	98.97	500	64.37	140	>50
BOD	92.35	600	61.31	140	>40
COD	88.28	500	44.23	140	>40

4 Conclusion

- Applying (MOSP) at a dose of 500 mg/l resulted in turbidity and TSS removal efficiency of 94.39% and 98.97% respectively, and the COD removal efficiency was 88.28%. While using dose of 600 mg/l the BOD_5 removal efficiency was 92.35%.
- Applying (BPP) at a dose of 140 mg/l resulted in turbidity, TSS, BOD_5 and COD removal efficiency of 69.32%, 64.37%, 61.31% and 44.23% respectively.
- The over doses of BPP led to high concentration of organic matter and COD.
- Applied (MOSP) and (BPP) have no major effect recorded in pH value.

- MOSP and BPP are derived from abundant and renewable sources, such as plant seeds. This makes them potentially more cost-effective, especially in regions where these materials are locally available. Their sustainable nature also offers environmental benefits, as they are biodegradable and do not contribute to pollution or waste.
- Increasing the removal efficiency of TSS, Turbidity, BOD5, COD, and pH reduces the size of secondary units and minimizes the time and energy required for aeration.

5 Conflict of interest

Conflict of interest: The authors declare that they have no conflict of interest

6 Data availability

All data analyzed during this study are included in this article. The raw data that support the findings of this study are available on request from the author.

7 Finding

All data analyzed during this study are included in this article.

8 Acknowledgments

This research was supported by the Civil Engineering Department, Faculty of Engineering Mataria, Helwan University and No financial support was received.

9 Reference

1. Nath, A., A. Mishra, and P.P. Pande, *A review natural polymeric coagulants in wastewater treatment.* Materials Today: Proceedings, 2021. **46**: p. 6113-6117.
2. Kumar, V., N. Othman, and S. Asharuddin. *Applications of natural coagulants to treat wastewater− a review*. in *MATEC Web of Conferences*. 2017. EDP Sciences.
3. Das, N., N. Ojha, and S.K. Mandal, *Wastewater treatment using plant-derived bioflocculants: green chemistry approach for safe environment.* Water Science and Technology, 2021. **83**(8): p. 1797-1812.
4. Natarajan, R., F. Al Fazari, and A. Al Saadi, *Municipal waste water treatment by natural coagulant assisted electrochemical technique—Parametric effects.* Environmental technology & innovation, 2018. **10**: p. 71-77.
5. Sowmeyan, R., J. Santhosh, and R. Latha, *Effectiveness of herbs in community water treatment.* International Research Journal of Biochemistry and Bioinformatics, 2011. **1**(11): p. 297-303.
6. Mokhtar, N., M. Priyatharishini, and R. Kristanti, *Study on the effectiveness of banana peel coagulant in turbidity reduction of synthetic wastewater.* International Journal of Engineering Technology and Sciences, 2019. **6**(1): p. 82-90.
7. Metcalf, et al., *Wastewater engineering: treatment and resource recovery*. 2014: McGraw Hill Education.
8. Abidin, Z.Z., et al., *Optimisation of a method to extract the active coagulant agent from Jatropha curcas seeds for use in turbidity removal.* Industrial Crops and Products, 2013. **41**: p. 319-323.
9. Benalia, A., et al., *Application of Plant-Based Coagulants and Their Mechanisms in Water Treatment: A Review.* Journal of Renewable Materials, 2024. **12**(4).

10. Montuori, P., et al., *Metals loads into the Mediterranean Sea: estimate of Sarno River inputs and ecological risk.* Ecotoxicology, 2013. **22**: p. 295-307.
11. Bahrodin, M.B., et al., *Recent advances on coagulation-based treatment of wastewater: Transition from chemical to natural coagulant.* Current Pollution Reports, 2021. **7**(3): p. 379-391.
12. Shan, T.C., et al., *The use of Moringa oleifera seed as a natural coagulant for wastewater treatment and heavy metals removal.* Applied Water Science, 2017. **7**: p. 1369-1376.
13. Sibartie, S. and N. Ismail. *Potential of Hibiscus sabdariffa and Jatropha curcas as natural coagulants in the treatment of pharmaceutical wastewater*. in *MATEC web of conferences*. 2018. EDP Sciences.
14. Chitra, D. and L. Muruganandam, *Performance of natural coagulants on greywater treatment.* Recent Innovations in Chemical Engineering (Formerly Recent Patents on Chemical Engineering), 2020. **13**(1): p. 81-92.
15. Rasool, M.A., et al., *Use of a plant-based coagulant in coagulation–ozonation combined treatment of leachate from a waste dumping site.* Ecological Engineering, 2016. **90**: p. 431-437.
16. Abidin, Z.Z., et al., *A preliminary study on Jatropha curcas as coagulant in wastewater treatment.* Environmental technology, 2011. **32**(9): p. 971-977.
17. Vishali, S. and R. Karthikeyan, *Cactus opuntia (ficus-indica): an eco-friendly alternative coagulant in the treatment of paint effluent.* Desalination and Water Treatment, 2015. **56**(6): p. 1489-1497.
18. SS, A.A., et al., *Factorial design and optimization of date stone as a natural coagulant for organic and heavy metals removal from industrial wastewater.* 2023.
19. Alo, M., C. Anyim, and M. Elom, *Coagulation and antimicrobial activities of Moringa oleifera seed storage at 3° C temperature in turbid water.* Advances in Applied Science Research, 2012. **3**(2): p. 887-894.
20. Jagaba, A., et al., *Sustainable use of natural and chemical coagulants for contaminants removal from palm oil mill effluent: A comparative analysis.* Ain Shams Engineering Journal, 2020. **11**(4): p. 951-960.
21. Yusoff, M.S. and N.A. Mohamad Zuki, *Optimum of treatment condition for Artocarpus heterophyllus seeds starch as natural coagulant aid in landfill leachate treatment by RSM.* Applied Mechanics and Materials, 2015. **802**: p. 484-489.
22. Sellami, M., et al., *Cactus juice as bioflocculant in the coagulation–flocculation process for industrial wastewater treatment: a comparative study with polyacrylamide.* Water Science and Technology, 2014. **70**(7): p. 1175-1181.
23. Elmolla, E.S., et al., *Natural products for surface water coagulation: an alternative sustainable solution for rural areas.* International Journal of Environmental Research, 2020. **14**: p. 489-499.
24. Ndabigengesere, A. and K.S. Narasiah, *Quality of water treated by coagulation using Moringa oleifera seeds.* Water research, 1998. **32**(3): p. 781-791.
25. Daverey, A., N. Tiwari, and K. Dutta, *Utilization of extracts of Musa paradisica (banana) peels and Dolichos lablab (Indian bean) seeds as low-cost natural coagulants for turbidity removal from water.* Environmental Science and Pollution Research, 2019. **26**(33): p. 34177-34183.

26. Vargas, M.A., et al., *Safety in Wastewater Treatment Plants and the use of Natural Coagulants as an Alternative for Turbidity.* Chemical Engineering Transactions, 2022. **91**: p. 301-306.
27. Federation, W.E. and A. Association, *Standard methods for the examination of water and wastewater.* American Public Health Association (APHA): Washington, DC, USA, 2005. **21**.
28. Momeni, M.M., et al., *Using chitosan/CHPATC as coagulant to remove color and turbidity of industrial wastewater: optimization through RSM design.* Journal of Environmental Management, 2018. **211**: p. 347-355.
29. Ahmed, H.M., et al., *Evaluation of different natural waste materials as bio-coagulants for domestic wastewater treatment.* Desalination and Water Treatment, 2024. **317**: p. 100034.
30. Getahun, M., et al., *Chemical oxygen demand removal from wet coffee processing wastewater using indigenous natural coagulants: Optimization through response surface methodology.* Desalination and Water Treatment, 2024. **317**: p. 100217.