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Comparative Study on The Effect of Plant-Based Coagulant on Wastewater Quality: A Systematic Review

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Abstract: Indiscriminate disposal of this wastewater (with or without an appropriate level of treatment) can cause water pollution and land pollution. This has a profound effect on the health of living beings apart from the impacts on the abiotic components such as soil and water. In general, wastewater treatment plants use inorganic coagulants that can be responsible for detrimental effects on water quality on public health due to their over-dosage. Thus, in this study the effectiveness of plant-based coagulants upon coagulation performance were analyzed in terms of qualitative analysis via systematic review. 30 studies related to the effect of plant-based coagulant were identified via PRISMA method. The criteria such as turbidity removal, amount of dosage and pH of water sample after treatment using plant-based coagulant were correlated via content analysis from systematic review. Overall, the findings obtained provide comprehensive information and act as reference on determination which Moringa Oleifera is the best plant-based coagulant based on the performance of removal efficiency (turbidity, COD and BOD) for wastewater treatment.

Keywords: Plant-based coagulant, Coagulation, Wastewater, Turbidity, COD, BOD, Removal Efficiency

1. Introduction

Rapid industrialization has posed many environmental threats due to wastewater generation through various industrial processes. Indiscriminate disposal of this wastewater (with or without an appropriate level of treatment) can cause water pollution and land pollution. This has a profound effect on the health of living beings apart from the impacts on the abiotic components [1]. The characteristics of wastewater have been studied in key parameters like turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and color. These parameters help gauge the level of potential hazard the effluent can pose to the environment and human health. Due to the potential toxicity, industrial effluents

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may require prior treatment before releasing into the environment. Improper disposal of the wastewater can cost liability in addition to their environmental impacts [2].

Usually, there are five major water treatment processes: coagulation, flocculation, sedimentation, disinfection, and filtration. Coagulation is an essential process in treating both surface water and industrial wastewater. Its application includes removal of dissolved chemical species and turbidity from the water via the addition of conventional chemical-based coagulants. While the effectiveness of these chemicals as coagulants is well-recognized, there are, nonetheless, disadvantages associated with usage of these coagulants such as ineffectiveness in low-temperature water, relatively high procurement costs, detrimental effects on human health, production of large sludge volumes and the fact that they significantly affect pH of treated water [3]. The use of natural substances for coagulation in place of chemicals is a promising alternative for industrial wastewater treatment. Natural coagulants are safe for consumption (owing to their plant origins) and are biodegradable in the environment. Plant components, which are otherwise considered waste, are an economical option compared to synthetic chemicals. Natural coagulation has been used for treating wastewater from various industries [2].

Thus, in this study, the effectiveness of plant-based coagulants were analyzed upon coagulation performance. The systematic review were conducted on qualitative analysis to determine the effects of plant-based coagulants with improved coagulation performance. The impact on the coagulation performance of plant-based coagulants were correlated via content analysis from a systematic review. The criteria such as turbidity removal, optimum dosage, dissolved oxygen and pH of water sample after treatment using plant-based coagulants are to be evaluated.

In wastewater treatment, coagulant plays an essential part in wastewater treatment and sewage reuse. But some kinds of inorganic coagulants used widely have disadvantages such as large dosage, low effect and harmful to the human body, high price and toxicity [4] To have low-cost, harmless and environmentally friendly surrogate coagulants, in the recent past, several studies have been carried out by testing different natural organic materials to produce bio-coagulants that are as high-performing as the chemical ones. Bio-coagulants are reliable to decrease water turbidity and remove potential toxic elements (PTEs) and pathogens from water [5]. The objective of this study is to identify the articles that reported on the effect of plant-based coagulant on wastewater quality, to analyze the effect of plant-based coagulants on wastewater quality and to correlate the effectiveness of plant-based coagulant on type of wastewater. The scope of this study includes the identification of articles regarding the plant-based coagulant on water quality via PRISMA method and systematic search between 2017 and 2021, The effect of plant-based coagulant will be evaluated via systematic review. Lastly, he effects on the coagulation performance of plant-based coagulant will be correlated via content analysis from systematic review. The criteria such as turbidity removal, optimum dosage, dissolved oxygen and pH of water sample after treatment using plant-based coagulants are to be evaluated.

2. Methodology

PRISMA is the most common method for choosing related articles based on the main keywords from reliable resources such as Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor Francis, Emerald Insight, SAGE, and Wiley Online Library and Oxford Journals. The PRISMA method allows researchers to obtain the existing literature and review process steps, identification, screening and eligibility, data abstraction, and data analysis. The materials and methods section, otherwise known as methodology, describes all the necessary information required to obtain the study results.

2.1 PRISMA

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement, published in 2009, was designed to help systematic reviewers transparently report why the study was done, what the authors did, and what they found [6]. Systematic reviews often lack awareness of shared guidelines that make them replicable and scientifically adequate. PRISMA provides a standard peer accepted methodology that uses a guideline checklist, which was strictly followed in this paper, contributes to the quality assurance of the revision process and its replicability. A review protocol was developed, describing the article selection criteria, search strategy, data extraction, and data analysis procedures [7].

2.2 Resources

The main database used for this study was Scopus and systematically searched between 2017 and 2021. Scopus is the primary peer-reviewed study with articles written in English and it is also a literature abstract and citation database: scientific journals, books, and proceedings from conferences. This database offers a detailed review of the scientific success worldwide in wide areas such as areas of science, technology, medicine, social sciences, and the arts and humanities with clever tools for research recording, interpretation and visualization.

2.3 Eligibility and Exclusion Criteria

The eligibility criteria were applied to refine the existing literature to select the most relevant research papers. Table 1 below summarizes the inclusion and exclusion criteria of this study.

Table 1: Inclusion and exclusion criteria

Criterion	Eligibility (Inclusion)	Exclusion
Publication Year	2017 to present	Less than year 2017
Language	English	Non-English
Document Type	Articles	Other than articles
Source Type	Journals	Other than journals
Subject Area	Agricultural and biological sciences, chemical engineering, chemistry, energy, engineering, environmental science, materials science, multidisciplinary	Other than agricultural and biological sciences, chemical engineering, chemistry, energy, engineering, environmental science, materials science, multidisciplinary

2.4 Process of Systematic Review

Four stages are involved for the integrative systematic review based on the Scopus database. In the systematic review process, the keyword was identified for the searching process as the first step. Few keywords such as coagulant, natural coagulant and plant-based coagulant and related to the effect of plant-based coagulant on wastewater quality were used to retrieve the related existing literature in the Scopus database. The search sections were set to title, abstract or keyword to obtain the related literature. Table 2 below shows the search string used for the searching process in the Scopus database.

Table 2: The search string used for systematic literature reviewing

Journal Database	Search String	Frequency of Hits

Scopus	(TITLE-ABS-KEY ("natural coagulant*" OR "plant based coagulant*" OR "plant-based coagulant*") AND TITLE-ABS-KEY ("waste water" OR "wastewater" OR "wastewater quality" OR "waste water quality") AND TITLE-ABS-KEY ("coagulation*" OR "wastewater treatment*" OR "waste water treatment*")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017))	179

179 articles were found that matched with the search strings resulting from the ScienceDirect database. There was no duplicate found during the identification stage as only one database was used. Meanwhile, 179 articles were screened and 57 articles excluded for a few reasons as stated earlier resulted in 122 articles involved in the eligibility stage. During eligibility, another 92 were excluded due to did not focused on plant-based coagulant and wastewater quality and unavailable data obtained. Finally, in the last step of the PRISMA flow diagram, only 30 studies were included after a detailed systematic review through the meta-data collected, which involves an incredibly time-consuming and challenging procedure. These articles were purposely chosen as they were highly focused on the topic of interest. PRISMA flow diagram was constructed as shown in Figure 1 as it is essential to be included in the construction of a research protocol for thorough systematic review.

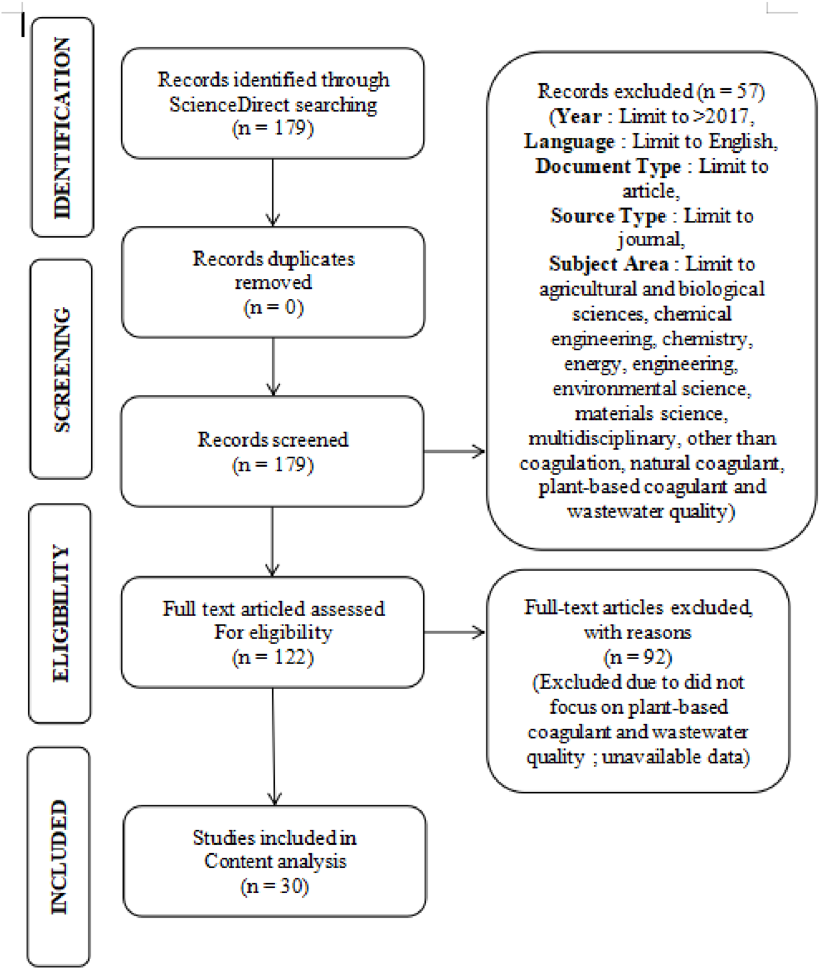

Figure 1: The PRISMA flow diagram of study

2.5 Data Abstraction and Analysis

Content analysis was conducted by using 30 shortlisted articles to respond to the study's research questions. Analysis of full papers was only conducted after abstracts were thoroughly analyzed. In this study, raw data such plant-based coagulation and wastewater quality were extracted.

3. Results and Discussions

In this section, 30 studies were included for content analysis and their characteristics are summarized in Table 3. These studies were selected for systematic review and were focused on content analysis.

Table 3 : Characteristics of studies included in content analysis

Author (Year)	Type of Plant-Based Coagulant	Type of Wastewater	Control Factors Parameters			Removal Efficiency Parameters		
			Coagulant Dosage (mg/L)	pH	Mixing Speed (rpm)	Turbidity (%)	COD (%)	BOD (%)

1.	Abidin Z.Z. *et al.*, (2021)	Jatropha Curcas seed	POME	120	3	100 rpm at 4 min,	99	53	59
		Jatropha Curcas press cake		140	2	40 rpm at 25 min	93	70	65
2.	Ahmad A. *et al.*, (2021)	Azadirachta indica (Neem)	Aquacultu re	0.3	-	180 rpm at 3 min, 10 rpm at 20 min	82.7	-	-
3.	Al-Gheethi A.A. *et al.*, (2021)	Moringa oleifera seeds	Laundry	120	7.96 and 8.37	30, 60, 90 and 120	83.63	48	32
4.	Ali E.N. *et al.*, (2021)	Moringa oleifera press cake (MOPC)	Balok River, Kuantan	-	7.45 and 7.54	200 rpm at 4 min, 40 rpm at 30 min	81.6	34.94	-
5.	Antunes A.D.S. *et al.*, (2021)	Moringa Oleifera	Animals slaughterh ouse	500	6.93 – 7.33	-	96.14	24.35	-
6.	Bortolatto R. *et al.*, (2021)	tannin-based	swine slaughterh ouse	-	-	-	96	50	-
7.	Bouchareb R. *et al.*, (2021)	processed Moringa Oleifera powder (PMOP)	wood processing	2000	7	100 rpm at 5 min, 50 rpm at 25 min	98.9	84.7	-
8.	Choong Lek B.L. *et al.*, (2020)	chickpea (Cicer arietinum)	POME	2600	6.69	140 rpm	86	56	-
9.	Chua S.-C. *et al.*, (2020)	lentil extract (LE)	agricultur al	88.46	4	150 rpm at 1 min, 30 rpm at 20 min	99.55	79.8	-
10.	Chung C.Y. *et al.*,	peanut–okra	POME	1000.1	11.6	150 rpm at 2 min	86.6	43.6	-

	(2020)	Wheat germ-okra		1170.5	12		92.5	34.8	-
11.	Deressa S. *et al.*, (2020)	jackfruit (Artocarpus heterophyllus) seeds	Residential laundry	2500	6	-	85.14	82.86	77.66
12.	dos Santos J.D. *et al.*, (2020)	Tanfloc POP	cassava starch	320	-	120 rpm at 2 min, 20 rpm at 15 min	94	36	-
13.	Dunoyer A.A.T. *et al.*, (2020)	Cardón Guajiro	domestic	1400	-	-	67.4	-	-
14.	Fard M.B. *et al.*, (2020)	Alyssum mucilage	synthesized bilge water	40.5	7.05	120 rpm at 5 min, 40 rpm at 15-45 min	96.25	84.63	-
15.	Gautam S. *et al.*, (2020)	Strychnos potatorum seed powder	industry	-	7	150 rpm at 2 min, 30 rpm at 30 min	84	-	-
16.	Giwa S.O. *et al.*, (2020)	Sodom apple (Calotropis procera)	textile	-	7	140 rpm at 3 min, 40 rpm at 7 min	69.48	-	-
17.	Hamidi D. *et. al.*, (2020)	Orchis mascula tuber starch	Oily-saline	4-320	5-9	120 rpm at 5 min, 40 rpm at 15-45 min	93	23	-
18.	Hassanien A.M.M. *et al.*, (2020)	Cicer Arietinum (CA) or chickpea seeds	Sewage water	40	3	80 rpm at 2 min	95.89	-	-

19.	Hoong H.N.J. *et al.*, (2020)	Hibiscus sabdariffa seeds	Congo red dye	209	2	100 rpm at 4 min, 40 rpm at 25 min	84	-	-
20.	Joaquin A.A.*et al.*, (2019)	seeds of Citrullus lanatus	sewage	50-150	5-7	150 rpm at 1 min, 50 rpm at 3 min	-	-	92.1
21.	Kusuma H.S. *et. al.,* (2018)	Ipomoea batatas leaves extract	Turbid water	1000	-	150 rpm at 2 min, 70 rpm at 10 min	96	-	-
22.	Land T.M.S. *et al.*, (2018)	Tanfloc SH	Fish processing industry	30-270	7.2	100 rpm at 2 min, 20 rpm at 10 min	96.199	50	-
23.	Landázuri-Rojas A.C. *et al.*, (2018)	Moringa oleifera (MO) Lam. seeds	Pilot Water Resource Recovery Facility (PWRRF)	50	7.4-7.7	100 rpm at 1 min, 20 rpm at 25 min	96	70	-
24.	Lim B.-C. *et al.*, (2018)	garden cress (Lepidium Sativum sp.) seed	Agricultural anthropogenic processes	-	5	150 rpm at 1 min, 30 rpm at 20 min	99.32	-	-
25.	Mateus G.A.P. *et al.*, (2018)	Moringa oleifera (MO)	dairy	3000	4.5	100 rpm at 2 min, 20 rpm at 10 min	99	96	-
26.	Maurya S.*et al.*, (2018)	Fresh banana (Musa acuminate) peels	municipal	400	7.7	120 rpm at 1 min, 30 rpm at 20 min	59.6	64	-

27.	Mohamed R.M.S.R. *et al.*, (2018)	Moringa oleifera	Scenedesmus sp. biomass from wet market	10-50	6.4	150 rpm at 10 min, 50 rpm at 20 min	97.5	-	-
28.	Mohammed Redha Z. *et al.*, (2018)	Moringa Oleifera (MO)	textile	4-8 mL	2-4	100 rpm at 4 min, 30 rpm at 20 min	81	-	-
29.	Muruganandam L. *et al.*, (2017)	AloeVera, MoringaOleifera and Cactus (O.ficus-indica)	Tannery waste	15	6	250 rpm at 15 min	59.43	37.82	-
30.	Novita E. *et al.*, (2017)	moringa seeds powder	Coffee processing	3000	4-9	400 rpm at 1 min, 150 rpm at 15 min	88.15	41.8	-

3.1 Systematic Review

Systematic reviews were conducted by implementing each of the procedures accurately. PRISMA flow chart was constructed to ensure the process of selecting articles and related studies that aligned with the research objectives. In addition, the selection of articles from trusted databases is included in PRISMA, followed by made selection of the best articles that matched with the main keywords. Hence, 30 studies were finalized to be used in the content analysis of the systematic review.

3.2 Quality of Articles

Scopus and Web of Science (WoS) are the best databases for systematic review research design. However, only Scopus was used as the primary database to search related articles in this study to save time during the process of articles selection.

3.3 Trend Analysis on the Effect of Control Factor on the Percentage of Turbidity Removal Efficiency of Wastewater

3.3.1 The Effect of Coagulant Dosage on Turbidity Removal

Jatropha Curcas seed and press cake have coagulant dosages of 120 mg/L and 140 mg/L, respectively, with the same mixing speed of 100 rpm for 4 minutes, according to Abidin et al., (2021). However, their turbidity removal percentages are 99 percent and 93 percent, respectively, and their COD removal percentages are 53 percent and 70 percent, respectively. At dosages of 120 mg/L and 140 mg/L, respectively, BOD removal is 59 percent and 65 percent. The coagulant dosage for Jatropha Curcas seed is lower than for press cake, resulting in a higher percentage of turbidity removal.

Overall, most of the different coagulants presented good results and removed turbidity to above 59 % for the different optimum concentrations. However, the maximum removal efficiency was obtained for 88.46 mg/L of lentil extract (LE) concentrations according to Chua et al., (2020), where turbidity and COD removal is 99.55 % and 79.80 %, respectively. It can be concluded that different coagulant dosage is based on the type of wastewater and the type of coagulant itself.

3.3.2 The Effect of pH on Turbidity Removal

Because the results of Abidin et al., (2021) and Chua et al., (2020) have a higher percentage of turbidity, the pH range of 2, 3, and 4 was also influenced. The pH level was acidic. However, as we can see from the studies conducted by Antunes et al., (2021), Bouchareb et al., (2021), Farb et al., (2020), Hamidi et al., (2020), Land et al., (2018), Landazuri-Rojas et al., (2018), and Mohamed et al., (2018), the percentages of turbidity removal were 96.14 %, 98.90 %, 96.25 %, 93.00 %, 96.19 %, 96.00 % and 97.50 % respectively where all of them were above 90.00 %. Their pH level is neutral (6-8). The initial characteristics of pH wastewater can vary depending on the type of coagulant used. In the study's analysis, the lowest pH was 2 and the highest pH was 12. This coagulant property is extremely valuable in wastewater treatment, whether as primary or tertiary treatment. After the coagulation process, no pH adjustment would be required in either case.

3.3.3 The Effect of Mixing Speed on Turbidity removal

According to the results of the investigation, the mixing speed had no effect on the rise in turbidity removal. There was no significant difference in turbidity removal between 100 rpm (99 percent), 180 rpm (82.7 percent), 200 rpm (81.6 percent), and so on. According to Novita et al., (2017), the removal was done at a high mixing speed of 400 rpm.

3.4 The Best Natural Coagulant According to the Best Percentage of Removal Efficiency

Based on the study analysis there are 10 out of 30 studies were used Moringa Oleifera (MO) as their natural coagulant for wastewater treatment. As mentioned above, Al-Gheeti et al., (2021), Ali et al., (2021), Antunes et al., (2021), Bouchareb et al., (2021), Landauri-Rojas et al., (2018), Mateus et al., (2018), Mohamed et al., (2018), Mohammed et al., (2018), Muruganandam et al., (2017) and Novita Et al., (2017), they were used Moringa Oleifera as plant-based coagulant because of its performance on the wastewater treatment and achieved high percentage of removal efficiency such as turbidity (83.63 %, 81.60 %, 96.14 %, 98.90 %, 96.00 %, 99.00 %, 97.50 %, 81.00 %, 59.43 % and 88.15 %, respectively), COD, and BOD. It can be concluded that Moringa Oleifera was the best natural coagulant based on their performance in removal efficiency for wastewater treatment.

4. Conclusion

This study emphasizes on the effect of plant-based coagulant on wastewater quality. These results obtained from this study proved that the objectives were successfully achieved. 30 studies on the effect of plant-based coagulants on wastewater quality were identified via PRISMA method. The effect of plant-based coagulants was analyzed via systematic review on wastewater quality. The criteria such as turbidity removal, amount of dosage and pH of water sample after treatment using plant-based coagulant were correlated via content analysis from systematic review. Overall, the findings obtained provide comprehensive information and act as reference on determination which Moringa Oleifera is the best plant-based coagulant based on the performance of removal efficiency (turbidity, COD and BOD) for wastewater treatment.

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References

[1] S. Maurya, & A. Daverey, Evaluation of plant-based natural coagulants for municipal wastewater treatment. 3 Biotech, 8(1). https://doi.org/10.1007/s13205-018-1103-8 (2018)

[2] S. Gautam, & G. Saini, Use of natural coagulants for industrial wastewater treatment. Global Journal of Environmental Science and Management, 6(4), 553–578. https://doi.org/10.22034/gjesm.2020.04.10 (2020)

[3] C.Y. Yin, Emerging usage of plant-based coagulants for water and wastewater treatment. Process Biochemistry, 45(9), 1437–1444. doi:10.1016/j.procbio.2010.05.030 (2010)

[4] J. Zhang, F. Zhang, Y. Luo, & H. Yang, A preliminary study on cactus as coagulant in water treatment. Process Biochemistry, 41(3), 730–733. doi:10.1016/j.procbio.2005.08.016 (2006)

[5] A. Benalia, K. Derbal, A. Panico, & F. Pirozzi, Use of acorn leaves as a natural coagulant in a drinking water treatment plant. Water (Switzerland), 11(1). https://doi.org/10.3390/w11010057 (2018)

[6] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, … D. Moher, The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. The BMJ. BMJ Publishing Group. https://doi.org/10.1136/bmj.n71 (2021)

[7] M. Abelha, S. Fernande, D. Mesquita, F. Seabra,, & A. T. Ferreira-Oliveira, Graduate employability and competence development in higher education-A systematic literature review using PRISMA. Sustainability (Switzerland), 12(15). https://doi.org/10.3390/SU12155900 (2020)