Environmental and Toxicology Management (2024), **4.1**, 1–8

REVIEW ARTICLE

Coagulation-floculation process in water remediation

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Article history:
Received : 2024/02/05
Revised : 2024/02/15
Accepted : 2024/03/25
Available Online : 2024/04/29
DOI : 10.33086/etm.v4i1.6693

Abstract

The importance of water treatment to maintain water quality for safe consumption and prevent environmental pollution. Coagulation flocculation is one of the simple and low-cost Point Of Use (POU) technologies in treating water and wastewater. The use of coagulation-flocculation methods in water treatment effective in separating suspended solids and colloids in wastewater and surface water. The coagulation-flocculation process allows four or one of the basic coagulation mechanisms to occur, including double-layer compression, charge neutralization, interparticle bridging, and sweep coagulation or sweep flocculation. Determining the success of the coagulation-flocculation process is based on several things such as the type of coagulant used, the amount of coagulant dose added, the pH of the water to be treated, the level of turbidity, the speed of stirring, and the temperature of the water.

Keywords: Coagulation-flocculation, POU, Water, Pollution.

INTRODUCTION

Water treatment is an important process in maintaining the quality of water so that it is safe to use and consume. In addition, water treatment can reduce environmental pollution due to waste disposal from human activities. In recent decades, water treatment technology has developed rapidly, one of which is using the coagulation-flocculation method. This methodis a simple, low-cost development of Point Of Use (POU) technology, also effective in separating suspended solids and colloids from wastewater and surface water, thereby significantly improving water quality (Miller, 2008). POU technology that refers to systems designed to provide water treatment solutions directly at the point of use, such as in hospitals, laboratories, or other healthcare facilities. This technology aims to ensure that the water used meets the required quality standards. POU systems are effective in improving water quality in healthcare facilities by reducing harmful contaminants by up to 99% (Sipayung and Fiarni, 2020).

The coagulation-flocculation method is the initial stage in water treatment that aims to remove contaminants in the form of fine particles and colloids. The coagulation process involves adding a chemical agent (coagulant) to the water which then causes the particles to destabilize and clump

together. Flocculation then changes small particles into large flocs that are easy to filter out of the treatment system.

In practice, the coagulation-flocculation method has been successfully used in various water treatment applications, from the chemical industry to surface water treatment. Alum and PAC coagulants are effective in removing surface water turbidity up to 61.48% with alum and 58.52% with PAC (Rosariawari and Mirwan, 2013). Therefore, the coagulation-flocculation method can be an effective and efficient solution in maintaining water quality, so that it can be applied to various water resource management programs in the future.

MATERIALS AND METHODS

This study utilizes a literature review of approaches, that aims to comprehensively examine the coagulation-flocculation process in water remediation. The main focus of this literature review is to identify the types of effective coagulants and flocculants, the mechanism of coagulation-flocculation, and the factors that affect the performance of this process in various water conditions. In addition, the advantages and disadvantages of coagulation-flocculation methods based on the type of coagulant used will be analyzed.

RESULTS AND DISCUSSION

Coagulation-flocculation

Coagulation-flocculation is a physical and chemical water treatment method. This method aims to separate pollutants and colloidal particles dissolved in water. Physical treatment includes fast and slow stirring processes, and sedimentation. While chemical treatment includes ionization processes, compound binding, charge exchange, and particle destabilization (Musfira, 2022).

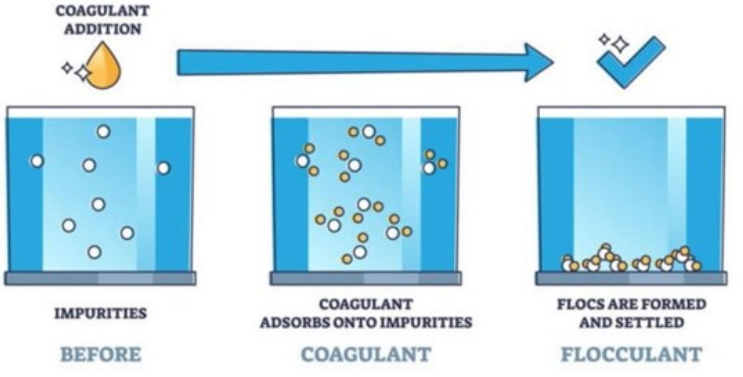

Figure 1. Coagulation-flocculation proccess (Fluidra, 2022)

Coagulation is the process of adding chemicals (coagulants) which aims to bind and coagulate colloidal particles in water or wastewater. Coagulation of colloidal particles occurs when a coagulant is added which has an opposite ion charge to the ion charge in the water so that charge neutralization occurs which causes the particles to attract each other and then form flocs and settle. In this process, the addition of coagulants is followed by a rapid stirring process in a short time. Flocculation is a continuation process of coagulation, which is a slow stirring process that aims to collect and enlarge the size of floc particles. In this process, agglomeration of colloidal particles will occur due to interactions between particles during the slow stirring process. Particles that combine with each other will form flocs with larger sizes. When the size of the floc increases, its mass will also increase so that the sedimentation process becomes faster.

Coagulant

Coagulant is a chemical compound in the form of a cationic substance added to the coagulation process as a binder for small particles dissolved in water, then producing sediment (Hendrawati et al., 2016). The addition of coagulant can form positive ions which then interact with negative particles in water. This process causes the neutralization of the electrostatic charge on colloidal particles, so that they lose stability and begin to attract each other to form flocs. Coagulants are divided into 2 types, they are chemical coagulants (synthesis) and natural coagulants (natural coagulants).

1. Chemical coagulant

   Chemical coagulants generally come from metals such as Al and Fe. This coagulant is the type of coagulant most widely used in the coagulation-flocculation process. Chemical coagulants usually have high ion concentrations and can provide rapid results in reducing water turbidity. However, the use of chemical coagulants can also cause environmental problems because they leave chemical residues in the treated water. Some examples of chemical coagulants include aluminum sulfate (Al2(SO4)3), ferrous sulfate (FeSO4), ferric sulfate (Fe2(SO4)3), polyferrous sulfate (PFS), polyferric chloride (PFC), and polyaluminium chloride (PAC) (Verma et al., 2012).

2. Natural coagulant

   Natural coagulants (natural coagulants) can come from plants, animals, and microorganisms. The content of active ingredients in plants is important to know before using them as coagulants. Plants with protein, polyphenol, and polysaccharide content have the potential to be used as natural coagulants (Kristianto, 2017). These contents are commonly referred to as polyelectrolytes (Yin, 2010). The mechanism of polyelectrolytes as coagulants is related to the interparticle bridging and charge neutralization processes, namely the particle destabilization process because polyelectrolytes act as charge neutralizing agents in water during coagulation, and are able to act as particle bridges that bind particles along the polymer chain they have (Metcalf et al., 2014). The following is a comparison between chemical coagulants and natural coagulants.

Table 1. Quality of hospital liquid waste

	Chemical coagulant	Natural coagulant
Excess	1) limited usage 2) Effective in remove the turbidity 3) Can be used in various pH conditions 4) Easy obtained in market	1) Available in large quantities 2) Relatively cheaper price 3) The volume of mud produced is less and is not toxic to the environment 4) The floc formed is stronger and more stable 5) Potential for utilized as technology appropriate use for processing water for reachequal distribution of clean water availability.
Lack	1) Low efficiency at cold temperatures 2) Can reduce the ph level 3) Produces large amounts of sludge and is difficult to degrade 4) Potential to cause health problems (alzheimer's)	1) Natural coagulant requires several stages of preparation and varying treatments, depending on source of natural coagulant active ingredients before use 2) Only can applied at certain pH conditions

Basic Mechanism of Coagulation-Flocculation

In general, there are four basic mechanisms of coagulation-flocculation, namely Double-Layer Compression, Charge Neutralization, Interpracticle Bridging, and Sweep Coagulation/Floculation. The following is an explanation of the four basic mechanisms of coagulation-flocculation.

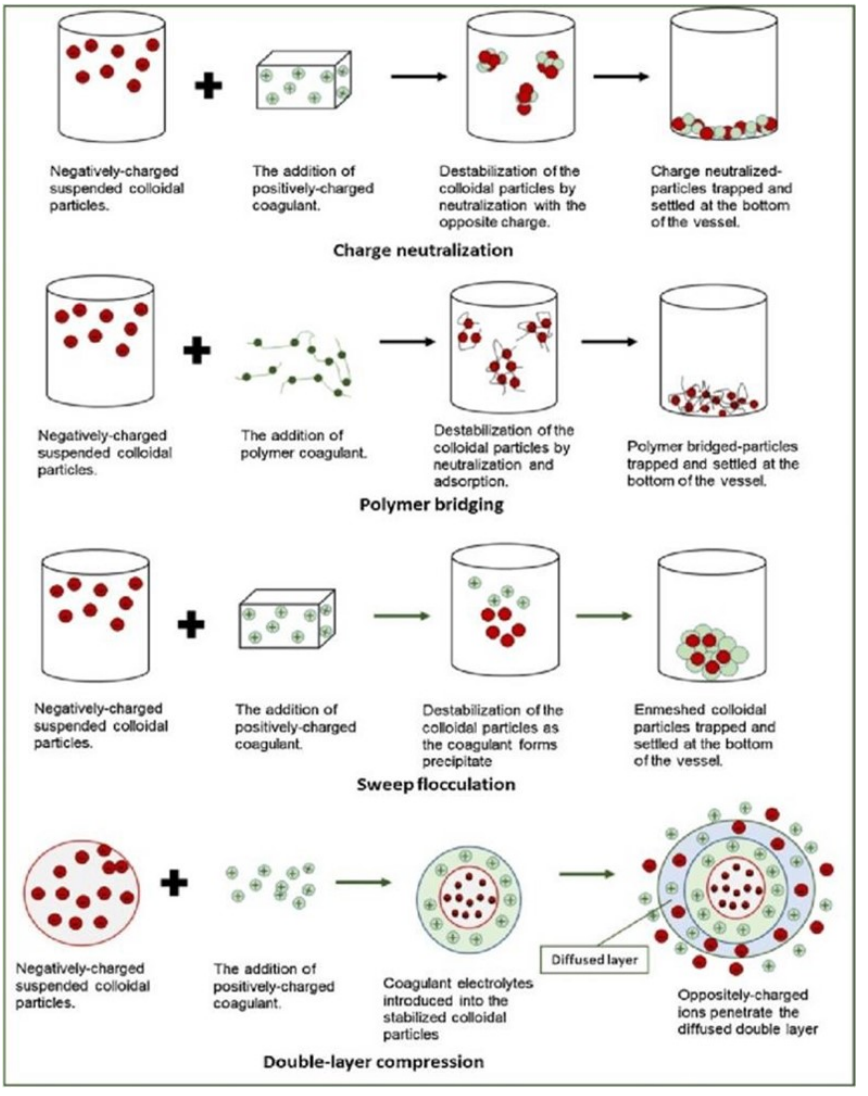

Figure 2. Basic mechanism of coagulation-flocculation (Owodunni and Ismail, 2021)

1. Double layer compression

   Double-Layer Compression is a mechanism where most particles are suspended in negatively charged water which causes the repulsive force between particles to be low (Sheng et al., 2023). The addition of coagulants to stable colloidal dispersions increases the electrolyte concentration, so that oppositely charged ions will diffuse through the double layer surrounding the particles. This causes the formation of a double layer surrounding the particles which then becomes denser and smaller. Electrolyte compression will continue to reduce the repulsive

force between particles and increase the van der Waals force and encourage binding between two colloidal particles (Choy et al., 2015). Then there is destabilization of the colloid which allows the formation of flocs.

2. Charge neutralization
   Coagulant is a substance with a positive charge (divalent) that is opposite to the colloid. The difference in charge causes the coagulant to be attracted towards the colloid and charge neutralization occurs (Choy et al., 2015). This factor is a factor that plays a very important role in this stage is the coagulant dose.
3. Interparticle bridging
   At this stage, polymers or long chains will be formed that bridge between colloidal particles. Then particle aggregation occurs which will form larger particles (Ghernaout, Khums, et al., 2020). The rate of particle aggregation can be influenced by molecular weight and charge concentration. The greater the weight of a molecule, the greater the formation of flocs (Tetteh and Rathilal, 2019).
4. Sweep coagulation/flocculation
   At this stage, colloidal particles will be trapped in floc growth. Then the colloidal particles will be trapped and then settle and disappear from the suspension (Alazaiza et al., 2022).

Coagulation-Flocculation Success Factor

In carrying out water treatment using the coagulation-flocculation method, there are factors that influence its success, some of these factors include:

1. Coagulant dosage
   Additions The dose of coagulant in the coagulation-flocculation process needs to be considered (Putra et al., 2020). Using a dose that is too low is not enough to neutralize the charge on the surface of colloidal particles. Excessive doses can reduce coagulation performance and cause repulsive forces between particles to reappear (Kristianto et al., 2019).
2. Types of coagulants
   Coagulant divided into 2 types, namely chemical coagulants and natural coagulants. The type of coagulant can affect the results of water treatment. Differences in the types of coagulants used will cause differences in the mechanisms that occur during the coagulation process (Kurniawan et al., 2020).
3. pH
   pH depends on the type of coagulant used in the coagulation-flocculation process. Because not all coagulants can work effectively at varying pH levels (Putra et al., 2020). Lower pH values tend to be positively charged so they can react with negatively charged colloids and particulates to form insoluble flocs (Kristijarti et al., 2013).
4. Turbidity
   Interaction between coagulant and colloidal particles will cause collision and then form floc. In solutions with high turbidity levels there are many suspended colloidal particles. The greater the number of suspended colloidal particles, the greater the intensity of collision. This has an impact on the resulting flocs becoming larger and stronger and the time required for floc formation is shorter (Amran et al., 2018). Conversely, if the number of colloidal particles is small, the resulting floc will be smaller and can slow down the sedimentation time which results in an increase in the duration of sedimentation (Odiyo et al., 2017).
5. Stirring speed and time
   Stirring is an important step in a coagulation process. Stirring aims to distribute the coagulant evenly in the water sample in the coagulation process. In this factor, the stirring

speed is important to determine the homogeneity and dispersion of the coagulant. The best stirring speed ranges from 40–200 rpm (Ding et al., 2019).

6. Temperature

   Good temperature is needed during the coagulation process because can increase the efficiency of other factors. A good temperature during the coagulation process is at a warm temperature because at a warm temperature the movement and collision of particles will be faster so that it can affect the agglomeration process in the formation of flocs (Bahrodin et al., 2021). At low temperatures, it causes a decrease in the efficiency of floc formation so that the flocs formed are small and require a longer time (Joudah, 2014).

CONCLUSIONS

Coagulation-flocculation is the result of combining chemical and physical methods in water treatment. Coagulants in the coagulation-flocculation process function as pollutant removers through four basic mechanisms including double-layer compression, charge neutralization, interparticle bridging, and sweep coagulation/flocculation. Two types of coagulants, namely chemical and natural, have their own advantages and disadvantages. The success of water treatment using coagulation-flocculation depends on the type of coagulant, coagulant dosage, pH, turbidity level, stirring speed, and temperature.

Author contributions

Nur Fadillatur Ro'in: Conceptualization, analysis, writing draf, and editing.

Conflict of Interest

There is no conflict of interest in this study.

Acknowledgment

The researcher would like to thank all who contributed to this research.

Data availability

Data related to the findings of this study are available at the corresponding author.

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