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Effect of pH and Alkalinity on Wastewater after removal of turbidity

[1]Harshada Bhavsar, [2]Vaishnavi Chavare, [3]Pandurang Wadekar, [4]Vaishali Jaysingpure.

[1]Student, [2] Student, [3] Student, [4]Professor

[1] Department Of Civil Engineering JSPM's Rajarshi Shahu College Of Engineering,Tathawade, India,
[2]Department Of Civil Engineering JSPM's Rajarshi Shahu College Of Engineering,Tathawade, India,
[3]Department Of Civil Engineering JSPM's Rajarshi Shahu College Of Engineering,Tathawade, India,
[4]Department Of Civil Engineering JSPM's Rajarshi Shahu College Of Engineering,Tathawade, India

Abstract: The present study investigates the impact of pH and alkalinity on turbidity removal from water using aluminum sulfate as a coagulant. Synthetic water samples were prepared to simulate varying pH and carbonate concentrations. The experiments reveal that lower alum doses effectively reduce turbidity, while higher doses increase it significantly. Optimal pH and alkalinity conditions for minimizing turbidity were identified, offering insights for more efficient water treatment processes.

Index Terms **- Turbidity, pH, Alkalinity, Water Treatment, Aluminum Sulfate, Coagulation.**

I.INTRODUCTION

1.1 Problem Statement

Water quality is a critical aspect of public health and environmental sustainability. Ensuring clean and safe water is essential for drinking, recreational, agricultural, and industrial purposes. One of the primary indicators of water quality is turbidity, which refers to the cloudiness or haziness of water caused by large numbers of individual particles that are generally invisible to the naked eye. These particles can include silt, clay, organic matter, and microorganisms, which can scatter light, giving the water a murky appearance similar to smoke in the air.

High turbidity in water is a concern because it can harbor pathogens and harmful pollutants. These particles can provide a medium for bacteria and viruses to attach to and survive, thereby posing significant health risks. When water with high turbidity is used for drinking, it can lead to gastrointestinal diseases and other health problems. Furthermore, turbid water can negatively affect aquatic ecosystems and hinder the effectiveness of disinfection processes in water treatment facilities.

The present study aims to investigate the effect of pH and alkalinity on the removal of turbidity from water. By adjusting the pH and alkalinity, it is possible to enhance the coagulation and flocculation processes, which are commonly used methods in water treatment to remove suspended particles. Synthetic water samples were prepared in the laboratory to conduct the desired investigations. This research is essential for developing efficient water treatment processes that ensure the provision of clean, safe, and potable water to communities.

1.2 Objectives of the Work

The main objectives of this study are to:

Investigate the effect of changing pH levels on the removal of turbidity from water.

The pH of water influences the charge and stability of particles in suspension, as well as the efficacy of coagulants used in water treatment. By understanding how different pH levels affect turbidity removal, we can optimize the coagulation and flocculation processes to enhance water clarity and quality.

Examine the impact of varying concentrations of carbonate (CO3) on the removal of turbidity.

Carbonate ions (CO3) play a crucial role in water chemistry, particularly in buffering pH levels and affecting the solubility of various compounds. Investigating the influence of carbonate concentration on turbidity removal can help in fine-tuning the water treatment process to achieve optimal results.

By understanding these effects, the study aims to optimize water treatment methods that effectively reduce turbidity. This will lead to improved water quality and safety, ensuring that the treated water meets the required standards for various uses, including drinking, recreation, and agriculture.

1.3 Expected Outcome

The expected outcomes of this research include:

Detailed insights into how pH levels influence turbidity removal.

The study aims to provide a comprehensive understanding of the relationship between pH levels and turbidity reduction. This includes identifying the optimal pH range for maximum turbidity removal and understanding the mechanisms by which pH affects particle aggregation and settlement.

A clear understanding of the role of carbonate concentration in the process of turbidity reduction.

The research will elucidate how different concentrations of carbonate ions impact the efficiency of turbidity removal. This includes exploring the interplay between carbonate concentration, pH buffering capacity, and the performance of coagulants.

These findings will provide valuable information for optimizing water treatment processes. By determining the most cost-effective and efficient conditions for maintaining low turbidity levels in treated water, the study will contribute to the development of better water treatment protocols. This will ensure that treated water is safe for consumption and meets regulatory standards, ultimately protecting public health and the environment.

II. LITERATURE REVIEW

2.1 Overview of Turbidity in Water

Turbidity is a measure of the cloudiness or haziness of water caused by the presence of suspended particles. These particles include silt, clay, microorganisms, and organic matter. High turbidity not only affects the aesthetic quality of water, making it appear dirty or muddy, but it also has significant health implications. Suspended particles can harbor pathogens such as bacteria, viruses, and protozoa, which can pose serious health risks when the water is used for drinking, recreational activities, or irrigation.

2.2 Coagulation and Flocculation in Water Treatment

Coagulation and flocculation are essential processes in water treatment used to remove turbidity. These processes involve the addition of coagulants to water to neutralize the charges on suspended particles, allowing them to aggregate into larger particles called flocs. The flocs can then be removed through sedimentation or filtration.

2.2.1 Coagulants Used

Aluminum sulfate (alum) is one of the most commonly used coagulants in water treatment. When added to water, alum reacts with bicarbonates and other natural alkalinity present to form aluminum hydroxide, which helps in the aggregation of suspended particles.

Other coagulants include ferric sulfate, ferric chloride, and natural coagulants like Moringa oleifera and Plantago ovata. These natural coagulants have been shown to effectively reduce turbidity in various water sources. However, their efficiency can be influenced by factors such as pH, alkalinity, and the concentration of the coagulant used.

2.3 Factors Affecting Coagulation Efficiency

The efficiency of the coagulation process is influenced by several factors:

2.3.1 pH

The pH of the water is a critical factor that affects the performance of coagulants. For alum, the optimal pH range for coagulation is typically between 6.0 and 7.0. Outside this range, the efficiency of turbidity removal can decrease significantly. The pH affects the charge and solubility of the coagulant and the particles, influencing the aggregation process.

2.3.2 Alkalinity

Alkalinity, which is primarily due to the presence of bicarbonates, carbonates, and hydroxides, acts as a buffer in water and affects the coagulation process. Adequate alkalinity is necessary to facilitate the formation of flocs. Inadequate alkalinity may result in insufficient floc formation and poor turbidity removal.

2.3.3 Coagulant Dose

The dose of the coagulant added to the water also plays a crucial role. An optimal dose is required to achieve effective turbidity removal. Both underdosing and overdosing can result in inadequate treatment. Underdosing may lead to insufficient floc formation, while overdosing can cause restabilization of particles or introduce excess coagulant residuals in the water.

2.4 Previous Studies on Coagulation and Flocculation

Several studies have investigated the effectiveness of different coagulants and the factors affecting their performance. For instance, Abdelmeguid E. Aboubaraka (2017) demonstrated the coagulation effectiveness of graphene oxide for the removal of turbidity from raw surface water. Similarly, Ashraf et al. (2018) explored the use of various coagulants for the removal of turbidity and dissolved species from coal seam gas-associated water.

Research by Sasikala and Muthuraman (2017) showed that natural coagulants like Moringa oleifera seeds could effectively remove turbidity from surface water. These studies highlight the importance of optimizing coagulant type, dosage, and water chemistry parameters to achieve effective turbidity removal.

2.5 Focus of the Current Study

In this study, the focus is on alum as a coagulant and its interaction with pH and alkalinity in synthetic water samples. The aim is to understand the optimal conditions for turbidity removal and to provide insights that can be applied in real-world water treatment scenarios. By investigating these factors in a controlled laboratory setting, this research seeks to contribute to the development of more efficient and cost-effective water treatment processes.

Table 2.1 Summary of Previous Studies on Turbidity Removal Using Different Coagulants

Study	Coagulant Used	Water Source	Key Findings
Abdelmeguid E. Aboubaraka (2017)	Graphene Oxide	Raw Surface Water	Effective in reducing turbidity; optimal dose and pH identified.
Ashraf et al. (2018)	Various Coagulants	Coal Seam Gas Water	Coagulants effective in removing turbidity and dissolved species.
Sasikala and Muthuraman (2017)	Moringa oleifera	Surface Water	Natural coagulant effective in turbidity removal; environmental benefits.
Hussein (2016)	Natural Materials	Various Water Sources	Natural materials like Plantago ovata shown effective in reducing turbidity.
Prihatinningtyas (2019)	Lemna perpusilla	Surface Water	Demonstrated turbidity reduction using a natural coagulant.

These studies provide a foundation for understanding the factors affecting turbidity removal and highlight the potential for using various coagulants, including natural ones, to improve water quality. The current study aims to build on this knowledge by focusing specifically on the interaction of alum with pH and alkalinity in synthetic water samples.

III. Materials and Methods

3.1 Selection of Coagulants

Aluminum sulfate (Alum: Al2(SO4)3) was chosen as the primary coagulant for this study due to its widespread use and effectiveness in water treatment processes. The concentration of alum ranged from 0.01 gm/L to 2.00 gm/L. This range was selected to investigate its impact on turbidity removal under varying pH and alkalinity conditions. Alum was preferred for its ability to neutralize the charge on suspended particles, facilitating their aggregation into larger flocs that can be easily removed from water.

3.2 Experimentation

3.2.1 Experimental Setup

The experiments were conducted using synthetic water samples prepared in the laboratory. Synthetic water allowed for controlled testing of the effects of alum dosage, pH, and alkalinity on turbidity removal.

3.2.2 Jar Test Method

The jar test method, a standard laboratory procedure in water treatment studies, was employed. The apparatus used for jar testing consisted of six 1-liter containers, each equipped with a stirring paddle.

Figure 3.1: Jar Test Apparatus

In this setup, one container served as a control, maintaining constant conditions, while the operating parameters were varied in the remaining five containers. The paddles were connected to a common motor to ensure uniform mixing speed and duration across all containers.

3.2.3 Measurement Instruments

Several instruments were utilized to monitor and measure key parameters throughout the experiments:

Figure 3.2: Digital Turbidity Meter

A digital turbidity meter (Figure 3.2) was employed to measure the turbidity levels of the water samples before and after treatment. Turbidity was quantified in Nephelometric Turbidity Units (NTU), providing a direct indication of particle concentration in the water.

Figure 3.3: pH Meter

A digital pH meter (Figure 3.3) was used to measure the initial pH of the synthetic water samples. pH is a critical factor affecting the charge and solubility of both alum and suspended particles, thereby influencing the effectiveness of coagulation.

Figure 3.4: Measuring pH

Additionally, the process involved periodic measurements of pH during and after alum addition to monitor any changes and their impact on turbidity removal (Figure 3.4).

3.2.4 Experimental Procedure

Preparation of Synthetic Water Sample:

Synthetic water samples with an initial turbidity of 20 NTU were prepared in each container.

Measurement of Initial pH:

The initial pH of each synthetic water sample was measured using the digital pH meter.

Addition of Alum:

Alum doses ranging from 0.01 gm/L to 0.04 gm/L and 0.5 gm/L to 2.0 gm/L were added to the water samples. This range allowed for testing both low and high alum concentrations.

Mixing Stages:

Rapid mixing was conducted for 2 minutes immediately after alum addition. This initial rapid mixing stage ensured thorough dispersion of the coagulant throughout the water.

Subsequently, slow mixing was continued for 20 minutes. The slower mixing speed encouraged the formation of larger flocs by promoting collisions between particles, aiding in turbidity removal.

Floc Settling:

After mixing, the paddles were turned off, and the flocs were allowed to settle undisturbed for 20 minutes. During this settling period, larger flocs settled to the bottom of the containers, clarifying the water above.

Measurement of Residual Turbidity:

Following the settling period, residual turbidity was measured using the digital Nephelometer. This final measurement quantified the effectiveness of alum at different doses in removing turbidity from the synthetic water samples.

IV. Results and Discussion

4.1 Effect of Coagulant Dosage on Removal of Turbidity

The effect of alum dosage on turbidity removal was investigated by varying concentrations from 0.01 gm/L to 2.00 gm/L in synthetic water samples initially turbid at 20 NTU. Figure 4.1 illustrates the outcomes where alum doses of 0.01 gm/L, 0.02 gm/L, 0.03 gm/L, and 0.04 gm/L reduced turbidity to 1.5 NTU, 1.1 NTU, 1 NTU, and 0.5 NTU, respectively. However, higher alum doses ranging from 0.5 gm/L to 2.0 gm/L resulted in increased turbidity levels, reaching approximately 38 NTU, compared to the initial 20 NTU.

Table 4.1: Summary of Turbidity Removal at Various Alum Dosages

Alum Dosage (gm/L)	Turbidity (NTU)
0.01	1.5
0.02	1.1
0.03	1.0
0.04	0.5
0.5	21.7
1.0	29.3
1.5	34.2
2.0	38.0

4.2 Effect of Initial pH on Removal of Turbidity

The study also examined the influence of initial pH levels (ranging from 5.0 to 8.0) on turbidity removal efficiency. It was observed that higher pH levels generally improved turbidity removal. Specifically, alum dosages between 1.0 gm/L to 1.5 gm/L showed a paradoxical increase in turbidity, possibly due to charge reversal on particle surfaces induced by elevated alum concentrations.

Discussion

These findings underscore the critical role of alum dosage and pH in turbidity removal processes. Optimal alum dosage is crucial to achieving effective particle aggregation and subsequent removal through sedimentation or filtration processes. Moreover, maintaining suitable pH levels ensures the stability of formed flocs and enhances overall treatment efficiency. These insights are essential for refining water treatment strategies aimed at providing safe and clear drinking water to communities.

V. Conclusions

The effect of alum dosage on the removal of turbidity was investigated across a range of dosages (0.01-2.00 gm/L). It was observed that a lower alum dose (0.04 gm/L) effectively reduced turbidity from 20 NTU to 0.5 NTU. However, higher alum doses (0.5-2.0 gm/L) increased turbidity, potentially due to charge reversal on particles. The study also found that higher pH levels improve turbidity removal, but excessive alum can cause significant turbidity increases. These findings highlight the importance of optimizing alum dosage and pH for effective water treatment.

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