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Research Article

Impact of temperature on ferric chloride performance in water coagulation

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ABSTRACT

Temperature has an essential function and becomes an important parameter in a coagulation process as it influences metal ion hydrolysis reaction rate. In order to get further explanation, a research using ferric chloride as a coagulant has been performed. The research aims to find out more about the effect of temperature on coagulation performance using turbidity, floc size, ferric, and water content parameter. The temperature 5℃–45℃ with an interval of 5ºC has been investigated to simulate field (i.e. outside) measurements in winter, spring and autumn, and summer, respectively. The result shows coagulation performance isaffected by temperature elevation. Turbidity gets lower for temperature between 5℃–40℃ and gets higher for temperature 45℃. Floc size becomes larger for temperature 5℃–40℃ and becomes smaller as temperature increase.At temperature between 5℃ and 15℃, the higher the temperature, the lower the ferric residue produced in coagulation water. For floc water contents, there is no virtually link between temperature and floc water contents. Temperature correlated well with turbidity value (-0.876) and floc size (0.985) but not correlated with ferric residue (0.366) and floc water content (0.179).

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INTRODUCTION

Coagulation is one of physicochemical processes that produce contaminants or particles agglomeration [1-3], where the agglomeration is essential to produce a larger size of floc. Larger and denser floc is preferred as it will settle more easily [4] and dewater more readily [5–7] which is effective to reduce turbidity and floc water contents, floc structure and its physical characteristics (size and density).

Amongst other parameters in coagulation, temperature is a key factor as it highly affects the metal ion hydrolysis reaction rate [8–10]. When the temperature increases, it will increase the reaction rate and vice versa [11]. In addition, the temperature also determines the distribution of coagulant [8] and the formation of the hydrolysis products, which, in turn, affects the coagulation and flocculation efficiency [12].

Ferric is one of common used metal coagulant amongst many synthetic coagulants [13] and has good coagulant properties [14]. Experimental research about temperature effects on the use of Fe coagulants for water and sludge treatment have been conducted [8, 10, 15–17]. Low water temperature causes poor coagulation due to inhomogeneous distribution of coagulation species as an impact of poor reaction rate. Ferric has a better performance than alum does under low temperature conditions [8]. In addition, [17] stated that low water temperature has an important effect on flocculation kinetics by decreasing the minimum solubility of $Fe(OH)_3$ in water. A higher temperature and pH play a significant role on an acceleration of the Fe (III) salt hydrolysis rate and a decrease on soluble polymeric iron species formation time [15, 16].

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On contrary, some of the findings indicated that temperature does not have an impact on coagulation efficiency [18, 19]. Moreover, another finding stated that temperature under 26 did not affect $Fe(OH)_3$ performance on sludge dewaterability as a result of sludge coagulation [10] because as temperature raises, it will inhibit the formation of iron salts due to reducing the amount of soluble oxygen.

Previous investigation mostly used low temperature in their investigation and due to contrary in previous investigation, further explanation is still needed to explain about the effect of temperature on ferric performance. This research investigates more the impact of temperature on ferric coagulant performance on important coagulation parameters such as turbidity removal, floc size, residual ferric and floc water content. This research study the effect of temperature on ferric performance simultaneously with wider range temperature. Temperature ranges from 5°C to 45°C has been used in this investigation. Temperatures of 5°C and 45°C used to simulate field (i.e. outside) measurements in winter, spring and autumn, and summer, respectively. The highest temperature may also reflect operating temperatures in laboratories located in warmer countries. All target temperatures were obtained by adjusting the temperature in the laboratory. By providing further information about the effect of temperature on ferric performance, it is hoped that the use of ferric can be more effective according to temperature setting in the coagulation process.

MATERIALS AND METHODS

Materials

Water sample was taken from The Intake of Water Treatment Plant in Siteba, Padang-West Sumatra, Indonesia. All samples were stored in plastic carboys and were kept in a refrigerator at 5°C before use. For Ferric chloride coagulant stock solution, it was prepared by adding 10 g ferric chloride powder into 1 L distilled water and stirred well to produce ferric solution.

Temperature Preparation

Wide temperature ranges from 5°C to 45°C has been used to simulate field (i.e. outside) measurements in winter, spring and autumn, and summer, respectively. All target temperatures were obtained by adjusting the temperature in the laboratory. Water temperature was set between 5°C and 45°C and was applied with an interval of 5°C using control temperature equipment to set temperature.

Coagulation Procedure

A 500 ml water sample was poured into a glass beaker followed by adding the coagulant Ferric Chloride (Sigma Aldrich Company Ltd., England, UK). Optimum coagulant dose was used. In order to reach a pH value of approximately 6.5, adjustment was with sulphuric acid (H2SO4) or sodium hydroxide (NaOH). The fluid was then mixed rapidly using a conventional jartest (Jartest JLTG VGLP, Velp Scientifica, Italy) at a variable high rate of 100 rpm for 60 seconds and then at a moderate rate of 40 rpm for 30 minutes to accommodate the agglomeration process. Floc or sediment was allowed to settle for 15 minutes.

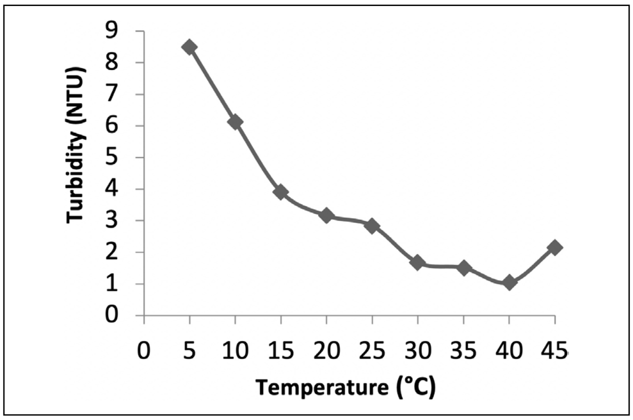

Figure 1. Correlation between temperature and turbidity using coagulant ferric chloride.

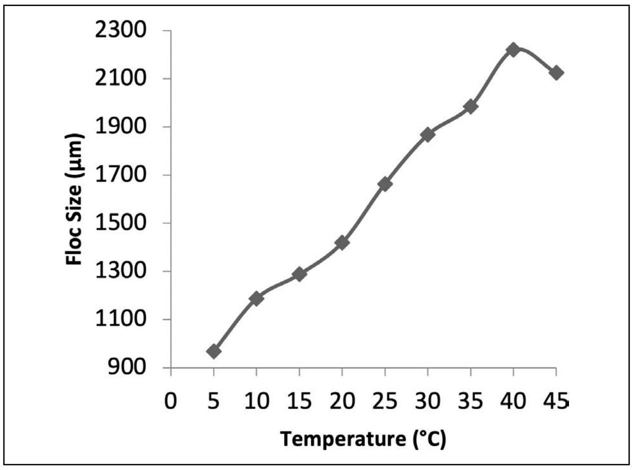

Figure 2. Correlation between temperature and floc size using coagulant ferric chloride.

Analytic Methods

Decanting process method was used to separate the supernatant and floc. This supernatant was used to measure water turbidity using Spectrophotometer UV Vis (Shimadzu, Japan) and ferric residue using Atomic Absorbance Spectrophotometer (Rayleigh WFX – 310/320, China). The settled floc in the bottom of a glass beaker was used to measure floc size using Shimadzu Optical Microscope and water floccontent using DTG (Shimadzu DTG-60, Japan).

RESULTS AND DISCUSSIONS

The Impact of Temperature on Turbidity

This research assessed the influence of different temperatures on coagulation performance by using ferric chloride as a coagulant. In the first stage, the effect of different temperatures on turbidity has been assessed. The impact of temperature between 5°C to 45°C with 5°C interval were compared each others. The result is presented in Figure 1.

Figure 1 shows the response of turbidity value to variations of temperature. The figure shows the turbidity value is getting lower as temperature increases at a temperature between 5°C and 40°C and is getting higher as temperature increases to 45°C.

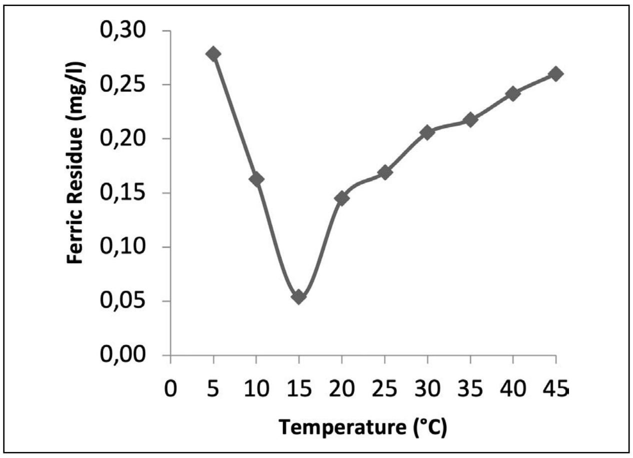

Figure 3. Correlation between temperature and ferric residue in water.

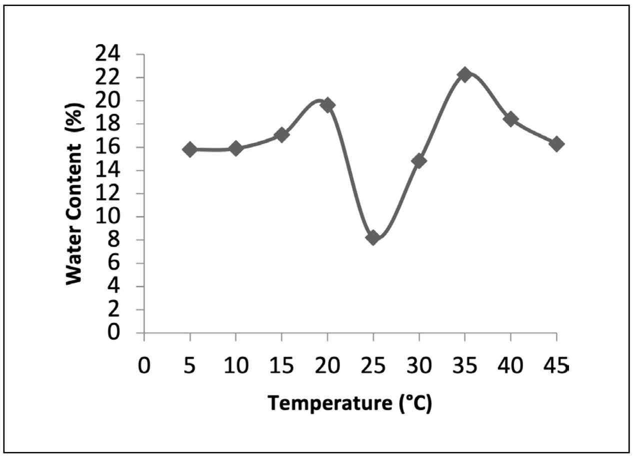

Figure 4. Correlation between temperature and floc water content using coagulant ferric chloride.

At a temperature between 5°C to 40°C, the result shows the higher temperature, the higher ferric ability to remove turbidity in water. Turbidity value at a temperature of 45°C gets higher than that at a temperature of 40°C which indicates a temperature of 40°C as the optimum temperature on turbidity removal using coagulant ferric chloride. Turbidity value in the water gets higher after the optimum temperature has exceeded. The addition of coagulant must be in accordance with the needs in forming flocs, because the concentration of coagulant greatly affects the collision of particles [1]. Flocs will be difficult to form if the addition of coagulant concentration is lacking, likewise the addition of too much coagulant can cause turbidity to occur again and the flocs are not formed properly

Figure 1 indicates that temperature plays an important role in turbidity removal. This result is similar to [8] results where temperature highly affected coagulation efficiency; different temperature delivers different impact. [15, 16] and [20] stated that increasing temperature can accelerate the Fe (III) salt hydrolysis rate and decrease soluble polymeric iron species formation time. Enough Fe (III) salt in solution will produce enough contact between salt and colloid then adsorb the colloid particles onto its surface and destabilize the otherwise stable colloid charge [21, 22] so that the turbidity will be removed efficiently.

Impact of Temperature on Floc Size

Coagulation efficiency and turbidity removal are correlated with floc size. Floc size investigation also has been examined to investigate the temperature's effect on floc formation. Using ferric chloride as a coagulant, a temperature between 5°C and 45°C was set to analyze the correlation between temperature and floc size (Fig. 2).

At a temperature between 5°C and 40°C, as the temperature increases, floc size gets larger but when temperature rises to 45□, floc size getting smaller. For temperature lower than 40□, the higher temperature, the larger floc size produced by ferric chloride in coagulation process. It is likely that the temperature's increase from 5□ to 40□ supports the agglomeration of colloid to perform larger ferric chloride floc size. This result related to [18] investigation, it is due to at the lower temperature, the floc will less compact compare to floc produced by higher temperature. Furthermore, coagulation mechanisms strongly influence floc size [12, 23]. As one of the factors that determines coagulation mechanisms, [8, 12] stated that temperature influences the distribution of the coagulant, hydrodynamic process and the formation of the hydrolysis products, which affect both coagulation and flocculation efficiency to form floc.

Impact of Temperature on Ferric Residue in Water

Coagulant residue in the water after process determines the coagulation performance [1]. To investigate furthermore the impact of temperature on ferric performance as a coagulant, this research has examined the investigation to observe the effect of temperature variations on ferric residue in water after coagulation process (Fig. 3).

Figure 3 shows that at a temperature between 5°C and 15 °C, the higher the temperature, the lower the ferric residue produced in coagulation water. On contrary, at a temperature between 15°C and 45°C, the higher the temperature, the higher the residual ferric produced in coagulation water. For temperatures under 15°C, the mechanisms can be explained by the result of [15] and [16] which stated that increasing the temperature and pH can accelerate the Fe (III) salt hydrolysis rate and decreases soluble polymeric iron species formation time. In contrary, for temperature above 15°C, the increasing temperature increase ferric oxidation rate and cause higher ferric concentration in water [24].

Impact of Temperature on Floc Water Content

Floc water content has a correlation with coagulation performance, the lower water content in floc will have the better coagulation process [25] confirmed sufficient coagulation condition is needed to enable a floc formation to separate and dehydrate easily. The observation of floc water content and its correlation with temperature has been performed using DTG apparatus and temperature between 5°C and 45°C. Figure 4 shows temperature variations affect on floc water contents.

Table 1. Correlation between temperature with turbidity, floc size, residual ferric and floc water contents

Variables	R
Turbidity	-0.876
Floc size	0.985
Ferric residue	0.366
Water content	0.179

Figure 4 inform that there is no correlation between temperature and floc water content using ferric chloride coagulant. Floc water contents increases as temperature decreases at temperature between 5ºC and 20ºC. As temperature increases to 25ºC, the floc water content is getting lower. Temperature of 25ºC is the best in this investigation as it produces the lowest floc water contents. Floc water contents get higher when temperature increases between 30ºC and 35ºC, then get lower at temperature between 40ºC and 45ºC.

Floc water contents is depended on the ability of floc to release the water (water dewaterability). The easier the floc to release the water, the lower the amount of water in floc and vice versa. The harder the floc to release the water, will be the higher the water contents in floc. As one of the important factor in coagulation process, the effect of temperature on sludge dewaterability have been investigated inconsistent on sludge dewaterability [10]. Floc physichochemical properties such as desorptivity, particle size composition and chemical constituent which is associated with flocculation efficiency, moderated the effect of temperature [25].

Correlation between Temperature with Turbidity, Floc Size, Residual Ferric and Floc Water Contents

Table 1 shows the correlation (r) between temperatures with coagulation variables in this study. The result shows that temperature has the strongest correlation with floc size (0.985), followed by turbidity (-0.876), ferric residue (0.366) and floc water contents (0.179).

From the correlation values of each variable, it is known that floc size is related to turbidity removal, where floc size determines the removal of water turbidity. The bigger of the floc size, the higher of turbidity removal. This is similar to the statement of [4] where the larger floc size reduces the turbidity better, because of its ability to settle easier, than the smaller floc size does.

Residual ferric does not correlated well with increasing temperature. This is due to temperature raise will reduced the amount of soluble oxygen and inhibits formation of iron salt [26]. As well as residual ferric, floc water contents does not correlated either with variation of temperature. This result confirms a statement from previous investigation where temperature does not have any impact on sludge dewaterability of coagulation floc using coagulant ferric [10] because temperature raises will eliminate the ability of coagulant ferric on sludge and floc formation due to the limit in formation of iron salt in responding temperature increases.

CONCLUSION

Temperature is one of the most important elements in coagulation process. To investigate the effect of temperature on Ferric Chloride performance, four parameters used in the investigation; turbidity value, floc size, residual ferric and floc water contents. Different temperatures result in different values on the four parameters. Turbidity value and floc size correlate well with temperature but not ferric residue and floc water contents. Among those four parameters, floc size has the strongest correlation with temperature which means the temperature variations influence the floc size more than turbidity value, residual ferric and floc water contents.

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DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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