The Utilization of Sedimentation Pond Acid Mine Drainage Sludge as Coagulant to Reduce COD and TSS Concentration in Domestic Wastewater

Nurul Shafira Daradjat1 and Setyo Sarwanto Moersidik1*

1 Environmental Engineering Study Program, Civil Engineering Department, University of Indonesia, Depok – Indonesia
*Email: ssarwanto@eng.ui.ac.id

Abstract. Acid mine drainage (AMD) treatment leaves residue in the form of sludge that contains large amounts of metal, silica, ferric, and alum. This research aims to determine the capabilities that AMD sludge-synthesized coagulant has in reducing COD and TSS concentration in domestic wastewater. The domestic wastewater sample used in this research is an artificial domestic wastewater with a COD concentration of 285 mg/l and a TSS concentration of 245.31 mg/l. After going through Acidification process, AMD sludge coagulant contains Si (43.66%), Fe (30.02%), dan Al (12.35%). A jar test is then performed in order to determine the optimal coagulant dosage. In this process, a coagulant dosage of 40 mg/l; 60 mg/l; 80 mg/l; 100 mg/l; 140 mg/l; 180 mg/l; and 200 mg/l was used with 100 mg/l being the optimal coagulant dosage. The AMD sludge containing the optimal coagulant dosage of 100 mg/l is found to be able to reduce COD concentration by 34.74% and TSS concentration by 95.63% from the tested domestic wastewater sample. This research can illustrate the vast potential that the AMD sludge has as a coagulant.

1. Introduction

The rise of coal mining activity has resulted in various negative impacts on the surrounding environment, one of which is contamination of acid mine drainage. Acid mine drainage is the water that comes from mines or rocks that contain certain sulphide minerals that are exposed and in an oxidized state. Acid mine drainage is the water that is formed due to the oxidation of FeS minerals [1]. The term acid mine drainage is used because it comes from mining activities, including operational mining sites, tunnels, open pits, waste rock piles, and mine tailings [2]. There are two methods that are generally used to treat acid mine drainage, namely active processing method and passive treatment method [3]. The methods of treating acid mine drainage, whether active or passive, produces a residue in the form of sludge originating from sediment from the neutralization process. The sludge produced from the acid mine drainage treatment process has the characteristic of low density due to its high water-content. The sludge produced from the treatment of acid mine drainage is then processed using three principles: solid-liquid separation, sludge drying, and sludge disposal [4]. The produced acid mine drainage sludge (AMDS) is then directed into a settling and storage pond [5]. In general, the sludge produced by the treatment of acid mine drainage has a pH level that tends to be alkaline; it can maintain its pH level for quite a long time. This sludge has a low density because it has high water content and contains many metal elements such as Cu, Ni, Fe, and Zn [4]. The acid mine drainage sludge has overall long-term chemical stability. Acid mining sludge contains a mixture of various metal hydroxides and/or oxides that can be regenerated and reused [4]. The three main metals contained in acid mine drainage sludge are Si (39.77%), Fe (33.10%), and Al (12.73%) [6]. These three elements have the potential to be reused as coagulants. These coagulants can be used to purify domestic wastewater in areas around coal mining and in other areas by means of coagulation-flocculation. COD is the total amount of oxygen needed to enable the chemical oxidation of organic materials. This degradation process can take place both biologically (biodegradable) and non-
biologically (non-biodegradable), forming carbon dioxide and water [7]. COD level is a measure of water pollution caused by organic substances that can be naturally oxidized using K₂Cr₂O₇ or KMnO₄ [8]. In general, TSS is the mass (mg) or concentration (mg/l) of organic and inorganic elements that are present in bodies of water due to turbulence. TSS usually consists of fine particulate matters with a diameter of less than 62 µm [9]. The measurement of TSS in water is very useful for analyze levels of pollution and discharge. It can also be used to evaluate the strength of water, domestic discharge, and as a determinant of the efficiency of the processing unit to be built [10].

2. Materials and method

2.1. Materials and chemicals
The material used in this study is sludge from the sedimentation pond of acid mine drainage produced by the coal mining processing activities at Tanjung Enim, South Sumatera. Then, the acid mine drainage sludge sample must be dried at a temperature of 103°C to 105°C. The chemicals used in this study is 4M H₂SO₄ for sludge acidification.

2.2. Coagulant recovery
Coagulant recovery has two steps: acidification and mixing. The acidification process is the most common process used to recover coagulants due to it being cost-effective and easy to implement. The acidification process in this study was carried out using 4M H₂SO₄. Acidification is carried out until the pH level reaches 1.5. The acid mine drainage sludge sample was put into a beaker glass of 10 grams to then be dissolved and added with H₂SO₄. H₂SO₄ was chosen as an acidification agent because it has several advantages: lower costs, better convenience, and safer in its use compared to other acids. The mixing process in this study is conducted at a speed of 220 RPM for 15 minutes. The mixing process is carried out by placing a beaker glass from the acidification process on a stirring plate and then stirring using a magnetic stirrer. This process is carried out to stabilize the coagulants that have been recovered previously via the acidification process. Following this, the characterization stage is conducted on the recovered coagulant.

2.3. Coagulant characterization
The characterization of acid mine drainage sludge serves to determine the elements of the sludge in more detail through the following three methods: X-Ray Diffraction (XRD) test where PANalytical X’Pert Pro MPD tools were used to analyse 1-2 grams of acid mine drainage sludge sample and X-Ray Fluorescent (XRF) Test where PANalytical Epsilon tools were used to analyse 1-2 grams of acid mine drainage sludge sample that has been transformed into dry powder.

2.4. Artificial domestic wastewater making process
In this research, an artificial domestic wastewater sample is made as closely as possible to resemble real domestic wastewater. According to Miao, et al. [11], artificial domestic wastewater can be made by mixing the following ingredients according to their respective dosage. C₆H₁₂O₆, also known as carbohydrate, acts as a compound that stimulates the presence of COD concentrations in artificial domestic wastewater. NH₄Cl is an ammonia-containing compound that imitates fecal waste, urine, and food scraps that are present in real domestic wastewater. The addition of KH₂PO₄ and K₂HPO₄ acts as a source of phosphate in artificial domestic wastewater. NaHCO₃ acts to provide alkaline contents in artificial domestic wastewater which is usually derived from household cleaning detergents in real domestic wastewater. Meanwhile, MgSO₄.7H₂O and CaCl₂.2H₂O are acidic salts.
Table 1. Compositions of Artificial Domestic Wastewater.

| Name Of Compound | Compositions (mg/l) |
|------------------|---------------------|
| C₆H₁₂O₆          | 260.2               |
| NH₄Cl            | 191                 |
| NaHCO₃           | 200                 |
| KH₂PO₄           | 11                  |
| K₂HPO₄           | 18                  |
| MgSO₄.7H₂O       | 10                  |
| CaCl₂.2H₂O       | 10                  |

Domestic wastewater has COD concentration levels ranging from 200 to 780 mg/l and TSS concentration levels ranging from 120 to 360 mg/l. To enable better determination of TSS concentration in artificial domestic wastewater, the range of values is converted into a turbidity value as to facilitate the addition of kaolin. The TSS value is converted using the following graph and formula:

![Graph and Formula for the Correlation between Turbidity and TSS.](image)

**Figure 1.** Graph and Formula for the Correlation between Turbidity and TSS. (TU Delft, 2002)

2.5. Coagulant dosage testing process using jar test
The coagulation testing process with acid mine drainage sludge as a coagulant using the jar test method refers to SNI 19-6449-2000. In this study, four 1000 ml glass beakers will be used, each of which will be half-filled (500 ml) by the artificial domestic wastewater sample. The dosage tested was 40 mg/l, 60 mg/l, 80 mg/l, 100 mg/l, 140 mg/l, 180 mg/l, and 200 mg/l with a stirring speed of 200 RPM for five minutes and 45 RPM for 10 minutes.

2.6. COD and TSS test
COD will be measured in accordance with SNI 06-6989.2-2009, namely the closed reflux method by spectrophotometry. Meanwhile, TSS measurements will be carried out by converting the turbidity...
concentration value into TSS. This is due to the fact in domestic wastewater, TSS greatly affects turbidity [12]. The calculation of TSS through the turbidity value is an economical and efficient way that accelerates this research [13].

3. Result and discussion

3.1. Characterization analysis
XRD testing on the acid mine drainage sludge samples showed that the samples contained magnetite, quartz, kaolinite, and metahalloysite. According to Amanda [6] kaolinite and metahalloysite are parts of the sediments formed by clay and silt which give an indication of the shape of alumino-silica mineral. This is consistent with the results of the acid mine drainage sludge XRF test. The acid mine drainage sludge that has been activated and converted into a coagulant has high quartz content. Quartz is a mineral that has a hexagonal crystal structure and is made of silicon dioxide (SiO2). The XRF test results on the acid mine drainage sludge sample showed that the sample contained 26 metal content in the form of elements and oxides. The three elements that are most abundant in the sample are Si (39.77%), Fe (33.19%), and Al (12.73%). Two of the three largest constituents of the acid mine drainage sludge are elements that can be used as coagulants. The most popular coagulants to be used to treat wastewater are coagulants that contain Alum (Al) and iron (Fe). After the acid mine drainage sludge coagulant has gone through the acidification process, there was a significant change in the percentage content of Si which increased to 43.66%. Meanwhile, for the other two elements, the majority experienced a percentage decrease with Fe becoming 30.02% and Al becoming 12.35%. This indicates that the coagulant derived from acid mine drainage sludge is a coagulant which has a base or primary element in the form of silica, meaning that it has the opportunity to become a coagulant with good removal ability due to the presence of Fe and Al elements.

3.2. Coagulant dosage, COD, and TSS testing analysis
The initial COD value was recorded at a coagulant dose of 0 mg/l. The initial COD value obtained was 285 mg/l. The method for acquiring this value is obtained by referring to the book “Wastewater Treatment Plants: Planning, Design and Operation” by Syed R. Qasim [12]. The quality standard used as a reference is the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 68 of 2016 concerning Domestic Wastewater Quality Standards. In this regulation, the maximum permissible COD concentration is 100 mg/l. The lowest COD concentration obtained from the test results is 186 mg/l, meaning that it has not met the governing quality standards.

![Figure 2. Concentration and Removal Rate of COD in Artificial Domestic Wastewater using Acid Mine Drainage Sludge as Coagulant.](image)

In obtaining the initial TSS value, references are taken from Syed R. Qasim [12]. In the literature, it is stated that the TSS range of domestic wastewater is 120 to 360 mg/l. The initial TSS value of 245.31
mg/l is taken; this value is also the TSS value of the artificial domestic wastewater samples. Artificial domestic wastewater samples treated using the coagulation method using acid mine drainage sludge as coagulant showed relatively clean water in plain view. This shows the ability of the acid mine drainage sludge coagulant to precipitate organic and inorganic particles into floc, which then reduces the TSS concentration in the wastewater. In this study, it can be observed that the TSS concentration value can be reduced to a value of 10.73 mg/l which meets the governing quality standards for domestic wastewater in Indonesia. This means that coagulation using coagulants derived from acid mine drainage sludge is a feasible option for treating domestic wastewater, especially in terms of removing its TSS concentration level. The maximum TSS removal rate occurs when the duration of sedimentation is 45 minutes. It also observed that when the coagulant dosage exceeds 100 mg/l, the removal rate will drastically decrease. This phenomenon can be observed from the three sedimentation durations. When a coagulant dosage of 140 mg/l is used, the average removal rate can only go up to 60% or 70%, while when using a coagulant dosage of 100 mg/l, the removal rate at each coagulation duration shows a number in the range of 90%.

![Figure 3. Removal Rate of TSS in Artificial Domestic Wastewater Processed using Acid Mine Drainage Sludge Coagulant.](image)

4. Conclusion

This study produces several conclusion points that answer the formulation of problems and research objectives that have been stated at the beginning of writing. The process of preparing acid mine drainage sludge into a coagulant through activation by acidification using 4M H₂SO₄ produces a coagulant with the main elements of Si (43.66%), Fe (30.02%), and Al (12.35%) which indicates that the acid mine drainage sludge coagulant is a coagulant that has a silica-based material but still has the removal ability of an iron-based coagulant. A jar test using acid mine drainage sludge as coagulant with a range of dosage of 40 mg/l, 60 mg/l, 80 mg/l, 100 mg/l, 140 mg/l, 180 mg/l, and 200 mg/l results in an optimum dosage of acid mine drainage sludge coagulant of 100 mg/l, which reduces COD concentration by 34.74% (from the initial COD concentration of 285 mg/l to 186 mg/l) and reduces TSS concentration by 95.63% (from the initial TSS concentration of 245.31 mg/l to 10.73 mg/l) with an optimum sedimentation duration of 45 minutes. The COD concentration of the produced artificial domestic wastewater samples did not meet the quality standard (maximum of 100 mg/l). Meanwhile, the TSS concentration of artificial domestic wastewater samples has met the governing quality standards (maximum of 30 mg/l). Reusing acid mine drainage sludge into other products as a coagulant is an effective way to reduce environmental problems that can be caused by the accumulation of sludge that is produced as a by-product of the treatment processes of acid mine drainage. This is especially important because the handling of environmental pollution should not only be focused on purifying acid mine drainage so as not to pollute the environment; it must be done
thoroughly so that the by-products produced do not become a new waste-related problem that may harm the environment.

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