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COCONUT SHELL ACTIVATED CARBON AS AN ALTERNATIVE SEDIMENTATION AGENT IN WATER PURIFICATION SYSTEM

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An investigation on the use of coconut shell activated carbon as sedimentation agent of dirty water is reported. The aim of the research is to find an alternative substance which can be used as sedimentation agent in a water purification system, which is badly needed in areas hit by natural disaster such as earth quake, flood and landslide. Carbon made of coconut shell was chosen due to its ample availability as a waste product in most places all over Indonesia. This was physically activated by heating it in an oven at 120°C for 30 minutes and chemically activated by soaking it in 40%-80% sulfuric acid, H_2SO_4 , for 24 hours. This coconut shell activated carbon was then mixed with simulated dirty water and the sedimentation velocity of the dirt coagulant was then observed. The results were then compared to those of the well known commercial sedimentation agents for water purification system, *aluminum sulfate*, $Al_2(SO_4)_3$ and *poly aluminum chloride* ($AlCl_3$)_n. The results show that by using coconut shell activated carbon the dirt coagulants are much quicker to sediment compared to those of *aluminum sulfate* and *poly aluminum chloride*. By using 1 gram activated carbon in 1 liter dirty water the sedimentation velocity were observed to be ranging from $(3.98 \pm 0.08) \times 10^{-3}$ m/s to $(4.51 \pm 0.03) \times 10^{-3}$ m/s. On the other hand by using *aluminum sulfate* and *poly aluminum chloride* the sedimentation velocities of the dirt coagulant are $(2.57 \pm 0.06) \times 10^{-3}$ m/s and $(2.47 \pm 0.06) \times 10^{-3}$ m/s respectively.

Keyword: Coconut shell activated carbon, Sedimentation agent, Coagulant, Aluminum sulfate, Poly aluminum chloride.

Introduction

Geographically Indonesia is located in a ring of fire. Therefore, there are hundreds of tectonic and volcanic earth quakes in a year. Earth quake causes well water to shake and results in dust and dirt on the bottom of the well to disperse throughout the water. Consequently, the well water in the disastrous area is dirty and leaves people without clean water for washing, drinking and cooking. The same problem occurs when an area is hit by flood, tsunami, and landslide. Unfortunately people cannot stay long without clean water. Consuming dirty water may cause the spreading of diarrhea, cholera, and other related diseases, which could endanger people's life. In order to avoid the worst scenario a simple, cheap, and easy way of cleaning dirty water is badly needed.

More than sixty percents of 240 million Indonesian populations live in villages and remote areas. Most of them consume water from the well. Due to bad water management system more than half of people living in urban areas also rely on the well water. When an area is hit by earthquake, flood, tsunami, or landslide the well water becomes extremely dirty. The dirt and dust in the bottom of the well are dispersed in the well water due to the quake, flood, tsunami, and landslide. This dispersion of dirt

belongs to colloidal dispersion which is relatively stable. Ions from minerals in the dirt contribute to electrostatic kinetic stability.[1]-[3] Studies on charged particles have been done extensively using Phase Analysis Light Scattering (PALS).[4]-[8] A review on various techniques for colloidal particle surface charge determination has been published by Suparno.[9] It takes days to weeks to sediment the dirt in the water naturally.

Most people use *aluminum sulfate*, $Al_2(SO_4)_3$ or *poly aluminum chloride*, $(AlCl_3)_n$ to clean the water.[10] These two substances are not only known as sedimentation or flocculating agent but also known as anti-perspirant and deodorant.[11] They put tens to hundreds grams of *aluminum sulfate* or *poly aluminum chloride* (PAC) in the well and wait for the dirt to sediment to get the clean water. These substances promote coagulation among the dirt and the dirt coagulants are then sediment to the bottom of the well resulting in cleaner water. However, it takes too long to clean dirty water using these two substances. People living in the disastrous areas cannot live for too long with dirty water. Therefore, an alternative substance should be found to accelerate sedimentation of the dirt in the well water.

A research has been done to investigate coconut shell activated carbon as alternative sedimentation agent to clean the water. Coconut shell has been chosen since as a waste product it is available in huge amount all over Indonesia. Most Indonesians consume coconut in their daily life. After the coconut being consumed, the shell was usually thrown away or in some cases being burnt. Massive use of coconut can be found in coconut oil industries. These industries produce a huge amount of coconut shell waste product. It is easy to find piles of coconut shell in and around coconut oil industries and most of them end up being burnt.

The use of coconut shell as activated carbon in various areas [12]-[16] inspired us to make use of it as sedimentation agent. Therefore, an extensive work has been done in an effort to make it a better substance for sedimentation of the dirt inside the water. The coconut shell has to be carbonated in an extremely high temperature in a closed tight carbonation chamber. No air is allowed to flow into the chamber to prevent oxidation that results in ashes. The resulting carbon was then being cooled slowly. The coconut shell carbon was then crust and grind into fine pieces of approximately 50 meshes. These fine pieces of coconut shell carbon were then physically and chemically activated before being used as sedimentation agent. The superiority of coconut shell activated carbon as sedimentation agent was shown by measuring the sedimentation velocity of the dirt coagulants and comparing the results with those of commercial sedimentation agents, *aluminum sulfate* and *poly aluminum chloride*.

Carbonation, Carbon Activation, and Sample Preparation

Carbonation process of the coconut shell was done in a closed tight carbonation chamber at $400^\circ C$ for 2.5 hours. The process of pyrolysis occurs in the chamber resulting in carbon. If the air is flowing into the chamber the oxidation process occurs instead of pyrolysis, resulting in ashes. The resulting coconut shell carbon was then being cooled slowly inside the chamber to avoid contact with air.

The coconut shell carbon was crust and grind to small pieces. These small pieces of carbon were then sifted to 50 meshes. This means that there are 50 pieces of carbon powder standing in a row of one inch. This size is equivalent to 368 micrometer. The sieve to small size is designed to enlarge the surface area and this is useful to accommodate more dirt particles to adsorb onto the surface of activated carbon. Studies on micrometer size colloidal particles may be done using Dynamic Light Scattering.[17]-[19]

The carbon powder was separated into 5 groups and each of them was chemically activated by soaking it in the solution of 40% - 80% sulfuric acid for 24 hours. Sulfuric acid is colorless and soluble in water. It is very strong acid and decomposes protein and lipid. It is commonly used as electrolyte and cleaning agent. The chemical activation using sulfuric acid is designed to destroy organic materials trapped inside the pores of the carbon powder. The trapped materials reduce the capacity of the pores significantly. The destroyed organic materials were then thrown away by rinsing the carbon under flowing clean water. The results were then dried up using oven at $90^\circ C$ and being kept away from contact with water.

Physical activation was done prior to the research. This was aimed to evaporate water molecules from the carbon pores to ensure maximum capacity of the pores. The maximum capacity of the pores is very essential, since it represents maximum absorption of the dirt in the chamber of pores and maximum adsorption of the dirt on the wall of the pores. The physical activation was done in an oven and for this purpose the temperature of the oven was set to be 120°C for 30 minutes.

Simulated dirty water sample is made by diluting 25 grams of dirt in a liter of clean water. The dirt was made of soil powder. This was stirred for 30 second before being ready to use as sample. A gram of coconut shell activated carbon (chemically activated in 40% of sulfuric acid) was added into a liter of sample and then stirred manually for 30 minutes. The mixture of sample and activated carbon was placed into measuring tube to allow the observation of sedimentation in a relatively long distance.

When the dirt coagulant is falling to the bottom of the measuring tube, at first it experiences accelerated motion due to gravitational force of the earth. In this case the gravitational force, F_g is given by

$$F_g = mg \quad (1)$$

where m is the mass of the falling dirt and g is the acceleration.

However, this motion was challenged by the viscous force that is increasing with the increase of the velocity of the dirt, v . The viscous force for a spherical object is given by

$$F_g = 6\pi\eta Rv \quad (2)$$

where η is the viscosity of the solution, R is the radius of the moving object and v is the velocity of the object. The gravitational force causes the dirt to move faster. However the higher the velocity of the falling dirt the higher the viscous force. This means that the two forces will soon reach their equilibrium and at the equilibrium the dirt moves in a constant sedimentation velocity.

The determination of the sedimentation velocity was done by the measurement of sedimentation time, Δt needed by the dirt coagulants to sediment across 10 cm distance, Δx . The average sedimentation velocity, v is calculated by using Equation 3:

$$v = \frac{\Delta x}{\Delta t} \quad (3)$$

In order to get more accurate result, the sedimentation time measurements were done 20 times each and the value used in the calculation is the average of 20 measurements. In order to understand the influence of chemical activation to the sedimentation velocity the same process was repeated by using 50% - 80% sulfuric acid activated carbon. Furthermore, to understand the influence of the amount of the carbon to the sedimentation velocity the process was repeated for 1-5 grams of activated carbon mixed with a liter of the sample.

The Performance of Commercial Sedimentation Agents

Commercial sedimentation agents such as aluminum sulfate and poly aluminum chloride are commonly used to clean water in the well. The white crystal aluminum sulfate is more popular compared to poly aluminum chloride. One gram of aluminum sulfate is dissolve in the simulated dirty water sample and stirred for 30 seconds. This was then left for 60 seconds in a measuring tube before the measurement of sedimentation time started. The sedimentation time of the dirt coagulant across 10 cm distance in the sample was measured for 20 times each and the average of these values was used to calculate the sedimentation velocity using Equation 3. This was done repeatedly for 1-5 grams of aluminum sulfate and poly aluminum chloride.

Figure 1 shows the performance of aluminum sulfate and poly aluminum chloride to sediment the dirt in simulated dirty water. By using 1-5 grams aluminum sulfate the sedimentation velocity was

calculated to be in between $(2.57 \pm 0.06) \times 10^{-3}$ m/s to $(2.97 \pm 0.06) \times 10^{-3}$ m/s. These results were relatively higher compared to those of using 1-5 grams poly aluminum chloride which are ranging from $(2.15 \pm 0.05) \times 10^{-3}$ m/s to $(2.47 \pm 0.06) \times 10^{-3}$ m/s. These results quantitatively answer the question why people prefer to use aluminum sulfate than poly aluminum chloride.

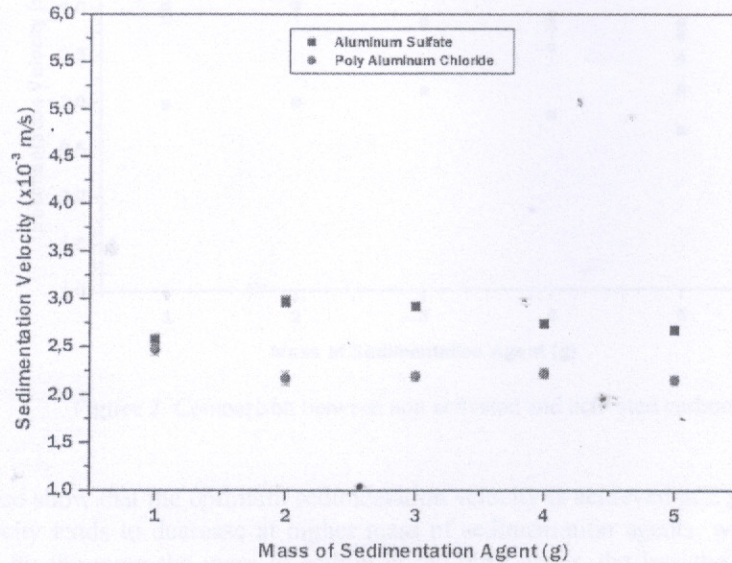


Figure 1. Sedimentation velocity using commercial Sedimentation Agent.

Contribution of Activation to the Increase of Sedimentation Velocity

In order to appreciate the role of chemical activation to increase the sedimentation velocity the data of sedimentation velocity using carbon without being activated and using activated carbon are presented in Figure 2. The mass of carbon for both types is varied from 1-5 grams. As for the activated carbon, there were five groups being identified by the concentration of sulfuric acid, H_2SO_4 used to chemically activate the carbon. The concentrations of sulfuric acid for the five groups of carbon were 40%-80% respectively with 10% increment.

Figure 2 shows that the sedimentation velocity of the dirt coagulants by using carbon without activation is ranging from $(2.68 \pm 0.03) \times 10^{-3}$ m/s to $(3.10 \pm 0.03) \times 10^{-3}$ m/s. On the other hand the best performance was achieved by using 60% sulfuric acid activated carbon. The sedimentation velocity by using 60% sulfuric acid activated carbon is ranging from $(3.80 \pm 0.06) \times 10^{-3}$ m/s to $(4.75 \pm 0.11) \times 10^{-3}$ m/s. There is an increase of approximately 40-50 percents of the sedimentation velocity by using activated carbon. This is understandable since chemical activation destroyed any organic materials blocking the pores and they were flushed during the rinsing process leaving the pores widely open and ready to absorb the dirt from the sample. The more the dirt trapped inside the pores of activated carbon in a short time the quicker the dirt falls to the bottom of the measuring tube. The fewer the dirt trapped inside the pores the slower the dirt falls, since the carbon itself tend to stay at the surface of water due to its specific mass that is less than the specific mass of water. The most likely cause bringing carbon to fall is the dirt coagulant that is trapped inside the pores by the process of absorption and the dirt that is stuck on the surface of carbon by the process of adsorption.

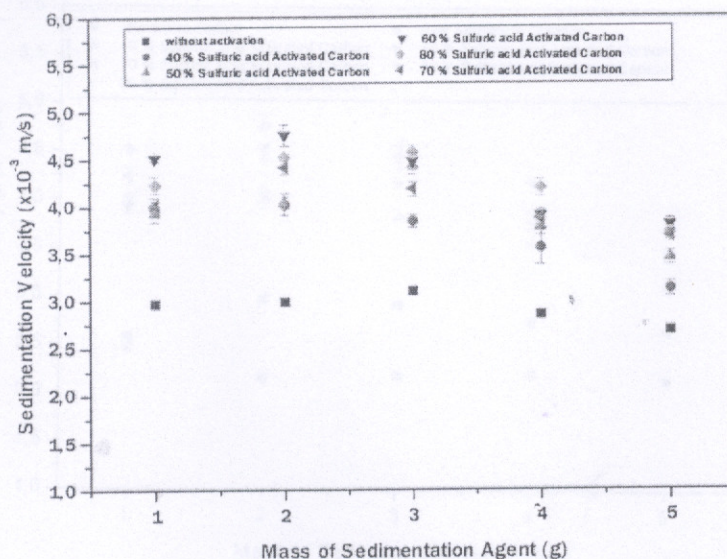


Figure 2. Comparison between non activated and activated carbon.

The data also show that the optimum sedimentation velocity is achieved at 2 grams of sedimentation agent. The velocity tends to decrease at higher mass of sedimentation agents, which is carbon. This is possibly caused by the more the mass of carbon in the dirty water, the less the dirt trapped inside the individual carbon that brings both of them down. The less dirt in the individual carbon the less gravitational force that drags the carbon along with the dirt downs. This means that the equilibrium force condition is achieved at relatively low viscous force, which means relatively low sedimentation velocity.

Comparison of Commercial Sedimentation Agent to Activated Carbon

The performance of various activated carbons as sedimentation agents will not be justified without comparison to the performance of commercial sedimentation agents. This research observed 5 different activated carbons. Originally they are the same carbon that is chemically activated using 5 different sulfuric acid concentrations, which are 40%, 50%, 60%, 70% and 80%. The commercial sedimentation agents used in this research are aluminum sulfate and poly aluminum chloride.

Figure 3 presents sufficient data showing that sedimentation velocities due to various activated carbons are much greater than those of due to commercial sedimentation agents. The difference in sedimentation velocity is significantly high at one gram of sedimentation agents. At this point the highest sedimentation velocity due to commercial sedimentation agent is $(2.57 \pm 0.06) \times 10^{-3}$ m/s which is represented by aluminum sulfate. On the other hand, the highest sedimentation velocity due to in house sedimentation agent, which is activated carbon, is $(3.98 \pm 0.03) \times 10^{-3}$ m/s. This is approximately 55% higher compared to that of commercial aluminum sulfate. Higher sedimentation velocity means quicker to clean the water. This might be caused by sufficiently large space in pores that is capable of absorbing a large amount of dirt and sufficiently large surface area that is capable of facilitating adsorption of the dirt on the surface of the carbon. However another research should be done to uncover the contribution of absorption and adsorption of the dirt individually.

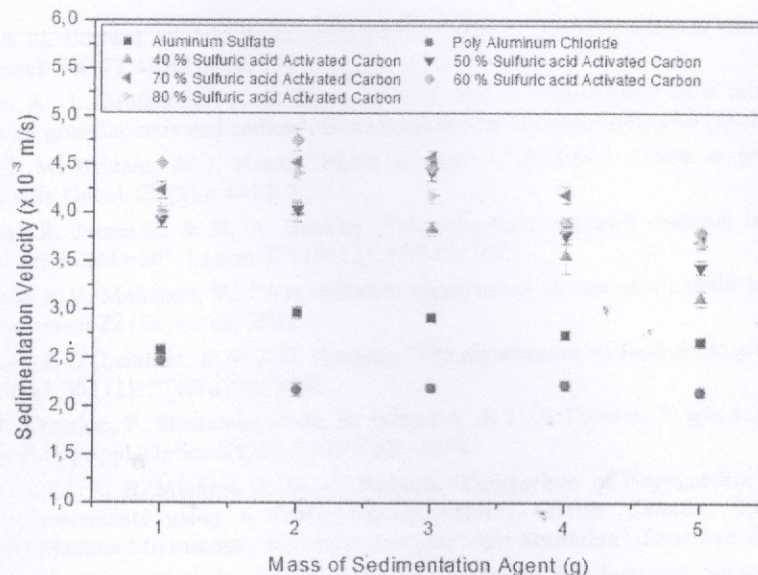


Figure 3. Comparison between commercial sedimentation agent and activated carbon.

Conclusion

From the above discussion it can be concluded that the sulfuric acid activated carbon can be used as an alternative sedimentation agent. In fact it contributes to higher sedimentation velocity compared to those of commercial aluminum sulfate and poly aluminum chloride. Furthermore, it was uncovered that chemical activation greatly increases the performance of carbon as a sedimentation agent. A more work should be done to understand the contribution of absorption and adsorption individually to the performance of activated carbon as an alternative sedimentation agent.

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