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Adsorption of Cu(II) and Zn(II) on Liquid Waste of Electroplating Home Industry using Silica based Adsorbent Prepared from Glass Waste

Yunita Pardiyana Saputri*, Erfan Priyambodo
* Department of Chemistry, Universitas Negeri Yogyakarta

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Corresponding Author:

Yunita Pardiyana Saputri,
Dep. of Chemistry
Universitas Negeri Yogyakarta

Email:
yunitapardiyana28@gmail.com

ABSTRACT

This study aims to (1) knowing the optimum pH and adsorption contact time of Cu(II) and Zn(II) ions in liquid waste of electroplating by silica gel prepared from glass waste, and (2) knowing the adsorption of Cu(II) and Zn(II) ions in liquid waste of electroplating by silica from glass waste. Synthesis of silica gel using sol gel method. In this method, a powder of glass waste is reacted with sodium hydroxide solution to form sodium silicate. Hydrochloric acid solution was added into the sodiumsilicate to form silica gel. Adsorption of Cu(II) and Zn(II) metal ions was done by batch method at various pH and contact time. The experiments shows that (1) the optimum pH and the optimum contact time for Cu(II) adsorption was 7 and 3 hours, therefore the optimum pH and the optimum contact time for Zn(II) was 8 and 3 hours, (2) the adsorption effectiveness of Cu(II) and Zn(II) in liquid waste of electroplating by silica from glass waste occurred in pH 7 for 3 hours were 99.9300% and 95.4200%.

Keywords: *siica based adsorbent, glass waste*

1. INTRODUCTION

Heavy metals are metals that able to affect human health even in a long period of time from sources of pollution (Jaishankar et al, 2014). Home industry that produces electroplating waste in Yogyakarta is Kotagede's silver handicraft industry center which contains heavy metal cations, such as Cu^{2+} and Zn^{2+} which have exceeded the quality standard of water waste (Padmaningrum, 2008). Ions such as Cu^{2+} and Zn^{2+} are the most important heavy metals which is required by the body but it can cause toxic effects if over consuming (Yudo, 2006). Almost all craftsmen do not care about waste cycling and they only make septic tanks to accommodate the water waste by adding the alum into be sediment, then the liquid throw away to the environment (Padmaningrum & Marwati, 2008).

Various methods of water waste cycling to eliminate the anion content and heavy metal cations contained in liquid waste very widely, one of them is by adsorption (Padmaningrum, 2008). The adsorption method is generally based on the interaction of metals with functional groups presenting on the surface of adsorbent through interaction of complex formation (Yu et al, 2003). This adsorption usually occurs on the solid surfaces that are rich in functional groups, such as: -OH, -NH, -SH and -COOH (Li, Lee, & Gullett, 2003). The adsorption will be maximum if it is done on various optimum variables, including pH, contact time, etc (Abdel-Ghani& Elchaghaby, 2007).

Material such as silica gel can be used as adsorbents. It is used because it is easy to produce. Besides, it gives some advantages, that is very inert, hydrophilic, high thermal and mechanical stability. Glass waste is one material that silica gel can be dispensed from.

The main compound of glass is silicon dioxide (SiO_2) with more than 70% of the total compound mixture (Coleman, Li & Raza, 2013). According to Shayan & Xu (2004), the glass content of SiO_2 is varies i.e. clear glass is 72.24%, chocolate glass is 72.21% and green glass is 72.38%. Glass waste itself is often used to manufacture the silica gel because of the major content of silicon dioxide. Silica gel is one of synthetic amorphous silica compounds. Silica is a solid material used as an adsorbent. Silica gel has the properties as a snare called adsorptive because it has active site on the surface of silanol (-SiOH) and siloksan (Si-O-Si). Silica gel that is used as water vaporizer is added cobalt as an indicator to determine the capacity of water vapor absorbed (Sulastri and Kristianingrum, 2010).

This study uses silica gel from a dark-colored glass household waste obtained by reacting glass waste with sodium hydroxide to form sodium silicate solution. Then, the acid solution is added to sodium silicate solution by dropping until gel is formed. That liquid is allowed to remain at over night, then filtered and washed it until it is free from chloride ions. The obtained residue is dried by heating at 110 ^{0}C from neutral water waste for 2 hours and finally weighed it. This obtained residue is silica gel.

2. RESEARCH METHOD

The subject of this research was silica xerogel powder that is from glass waste (dried silica gel). Metal ions such as Cu^{2+} and Zn^{2+} which are in electroplating waste by silica gel from glass waste are the object of this research.

Initial phase of this study was sample preparation. Cleaned samples of glass waste were as obtained in waste source in Sleman, Yogyakarta. Then, the cleaned glass waste was dried. Cleaned and dried glass waste was subsequently destructed, then the result was filtered with the size is 100 mesh.

The next step was making Na_2SiO_3 sodium silicate solution from waste. The preparation of sodium silicate solution was initiated by reacting 6 grams powdered glass waste with 180 mL 3 M NaOH solution in the heating tin. Then, the mixture was heated and stirred with a magnetic stirrer until boiling. After that, put the mixture for overnight until the temperature was drop and cool. Finally, the mixture was filtered with a Buchner filter. The obtained filtrate is a solution of sodium silicate (Na_2SiO_3).

Then, it was continued by making synthesis of silica gel from glass waste. Making silica gel could be carried out by adding HCl dropwise into sodium silicate (Na_2SO_3) solution while continuously stirring constantly. Adding the HCl until gel was formed. Then, the mixture was sterilized overnight. After that, that mixture was filtered and washed until free from chloride ions and neutral waste water. The obtained residue was dried with a heated at 110 ° C for two hours and then weighed it. That residue obtained is named silica gel. After the mass of silica gel obtained from synthesis result can be determined the yield of silica gel from the synthesis of glass waste.

Then, determining the optimum pH on adsorption of Cu(II) and Zn(II) ions in electroplating waste by silica gel from glass waste. Initial levels of Cu(II) and Zn(II) on electroplating waste were analyzed using Atomic Absorption Spectroscopy. After that, about 100 mL of electroplating waste was inserted into beaker glass to be added 0.1 gram of silica gel. The pH of the mixture was adjusted on a scale of two by adding dilute nitric acid solution. Next step was stirred the mixture using a magnetic stirrer at low speed for 10 minutes, then allowed to stand for 1 hour and measure the temperature. The mixture was then filtered and the filtrate was analyzed using AAS. This activity was performed on pH 2 until 9.

The last step was adsorption of Cu(II) and Zn(II) ions in electroplating waste at various contact time. After getting the optimum pH, then made the variation of contact time. This contact time variation was made with 4 samples (1, 2, 3, and 4 hours). Poured 100 ml of electroplating waste and 0.1 gram of silica gel in to a glass beaker. Make sure the waste was at optimum pH. Then stirred it using a low-speed magnetic stirrer for 10 minutes. Stand that compound for 1 hour and

measure the temperature. Now, filtered the compound then analyzed using atomic absorption spectrophotometry. Then determined adsorption on Cu(II) and Zn(II) ions.

Qualitative analysis was performed using infrared spectra test, while quantitative analysis used effectiveness test of Cu(II) and Zn(II) ions by silica gel through adsorption study.

3. RESULTS AND ANALYSIS

Sample of glass waste used is in the form of black sheets. Then, the glass sheets are smoothedto powder. Figure 1 shows the glass waste in the form of powder sieved by 100 mesh of sieves

The aim of using synthesis of silica gel from glass waste is to synthesize the gel composed dark glass waste. This research method used sol gel method, where this sol gel method of dark glass waste powder is reacted with sodium hydroxide solution to form sodium silicate which then reacted with hydrochloric acid to form silica gel.

Table 2. The result of silica gel powder synthesized with a various concentration hydrochloric acid.

Mass of glass waste (g)	Concentration HCl (M)	Silica Gel (g)	Silica Gel (%)
6.0000	1	0.4751	7.92
6.0000	3	2.0350	33.92

Adding the acid is intended for condensation and polymerization reaction to take place. The mechanism reaction that is on the surface of silica gel from acidification process of the sodium silicate solution can be seen in Figure 1.

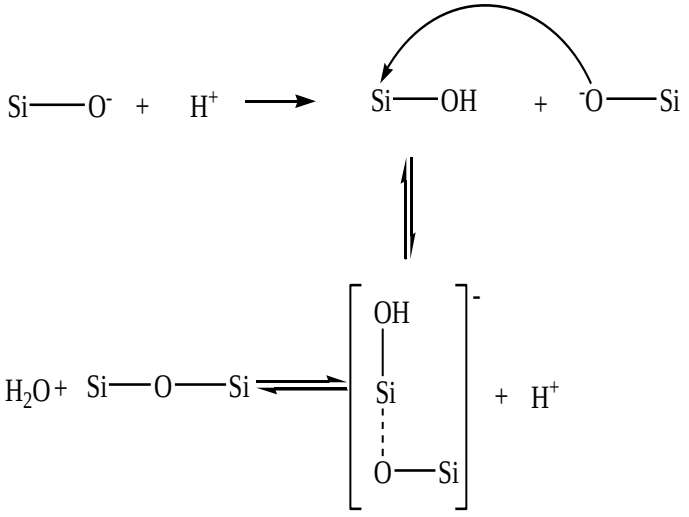

Figure 1. The chemical reaction mechanism to form siloxane bond

Adding the acid to the sodium silicate solution causes silicate anion turn into silanol. When silanol reacts with silicone anion again, it will form siloxane. This reaction continues until silica gel is formed. The Silanol itself can condense to form siloksan bridge (Si-O-Si) (Sudiarta, Diantariani, & Suarya, 2013).

The reaction mechanism shows that orthosilicate acid occurs due to the interaction between sodium silicate solution and acid. Orthosilicate acid is intermediary process of hydrolysis. The orthosilicate acid is a highly unstable substance that readily condenses and forms a silica sol polymer (Ali, Chunghtai, & Sttar, 2009: 2)

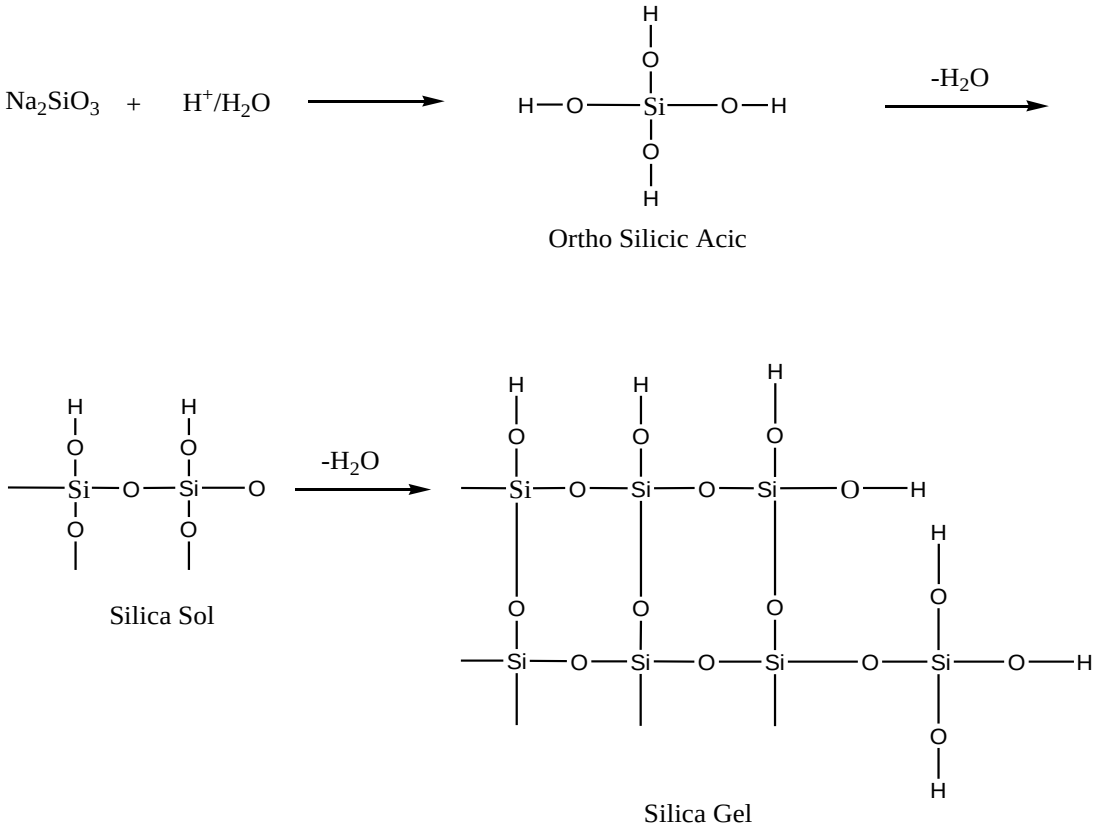

Figure 2. Silica Gel Formation Mechanism

The characterization of silica gel using infrared spectrophotometry aims to know the functional group of silica gel through infrared spectra. To ensure the success of synthesis process need to be tested using infrared spectroscopy.

Table 2. The band in the spectrum of silica gel characterized using infrared spectrophotometry

Interpretation of Functions	Wave Numbers (cm^{-1})
stretch vibration of -OH from Si-OH	3425,58
asymmetric stretch vibration of Si-O from Si-O-Si	1087,85
symmetric stretch vibration of Si-O from Si-O-Si	802,39
bend vibrationof –OH from Si-OH	1635,64
symmetric stretch vibration of Si-O from Si-OH	956,69
bend vibration of Si-O-Si	470,63

The silica gel characterization of glass waste shows that there are silanol (Si-O-Si), siloxane (Si-O-Si) and siloxy (Si-O-) groups. The presence of silanol, siloxane and siloxy groups shows that the synthetic gel silica has a bonding characterization that is similar to kisel gel as a comparison.

The silica gel which was synthesized from glass waste is used to adsorb of Cu(II) and Zn(II) from electroplating waste. The waste is from Kotagede silver handicraft industry center. The characteristics of the electroplating waste can be seen in Table 3.

Table 3. Characteristics of electroplating waste from the central of Kotagede silver handicraft industry.

Parameter	Observation Results	Description
Color	Green	-
Smelt	Sting of acid	-
pH	2.3	Exceeded threshold
Metal ion content:		
Cu^{2+} (ppm)	255.4800	Exceeded threshold
Zn^{2+} (ppm)	12.0120	Exceeded threshold

The adsorption of Cu(II) and Zn(II) metal ions were performed on various pH of solution and contact time variation. The following are graphs of the adsorption content of Cu (II) and Zn (II) metal ions by silica gel on various pH variations.

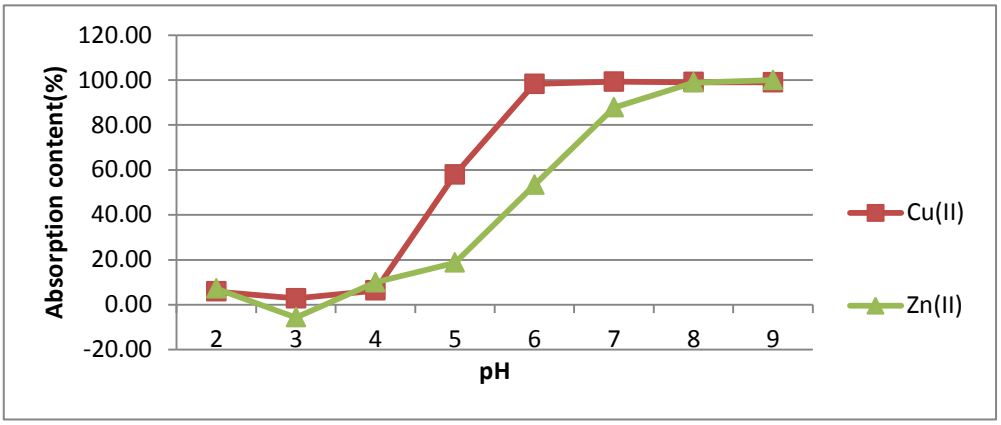

Figure 3. The graph of adsorption rate of Cu(II) and Zn(II) ion on various pH

When the pH is low, the absorption process of Cu(II) and Zn(II) metal ions by silica gel occurs slower. This is possible because the adsorbed Cu(II) and Zn(II) ions are released due to the interaction. This interaction occurs electrostatically and make the bond is weak. However, starting at pH 5 occurs a significant absorption and becomes maximum at pH 7. While the pH is above 7, the adsorption process tends to decrease. This is because pH of Cu (II) and Zn(II) metal ions begin to precipitate in the form of hydroxide, which prevents them from interacting with the silica gel (Cahyaningrum, 2011).

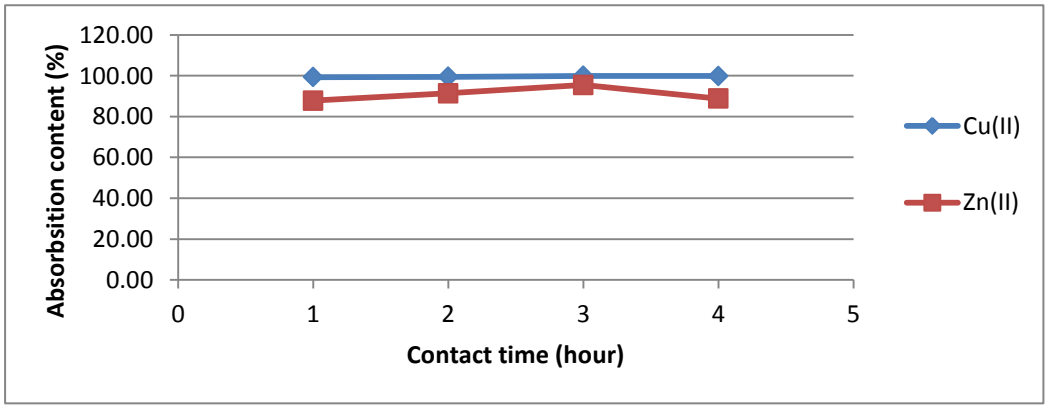

Figure 4. The graph of adsorption rate of Cu(II) and Zn(II) ions at various contact times

While the contact time of Cu(II) and Zn(II) metal ions are 3 hours, those metals are adsorbed by silica gel optimally. This is because the adsorbent of silica gel interacting with Cu(II) and Zn(II) metal ions reaches equilibrium at 3 hours.

The adsorption of Cu(II) metal ions is greater than Zn(II) metal ions. This is influenced by the radius of each metal ion. The magnitude of metal radius of Cu(II) and Zn(II) are 73 pm and 74 pm (Sugiarto, 2003). This affects the value of ionization energy where the smaller the radius of a metal atom, the greater the value of its ionization energy. This ionization value can affect the ability of metal ions to release electrons, the value of ionization energy is greater, the more difficult it is to remove the electrons. If the metal ions are difficult to release electrons, the bonding strength of the metal ions is getting smaller and easily absorbed (Tanindya & Dina, 2014).

4. CONCLUSION

Silica gel was obtained by syntesis of glass waste using sol gel methods. The research shows that (1) the optimum pH and the optimum contact time for Cu(II) adsorption was 7 and 3 hours, therefore the optimum pH and the optimum contact time for Zn(II) was 8 and 3 hours, (2) the adsorption effectiveness of Cu(II) and Zn(II) in liquid waste of electroplating by silica from glass waste occurred in pH 7 for 3 hours were 99.9300% and 95.4200%.

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