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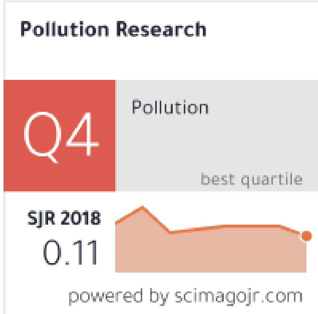

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ADSORPTION OF PB^{2+} ION IN WATER WELL WITH AMBERLITE IR 120 NA RESIN

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ABSTRACT

Some people in the city of Pasuruan, East Java, Indonesia still use wells water to meet the needs of clean water. Some of the well water samples contain Pb^{2+} ion of 0.15-0.23 mg·L^{-1}. This level exceeds the maximum limit of clean air requirements in Indonesia Standard Ministry of Health Regulation No. 416 of 1990, maximum Pb^{2+} ion level 0.05 mg·L^{-1}. The purpose of this research is to know the adsorption efficiency of IR 120 Na amine resin on Pb^{2+} ion; The isotherm condition of Freundlich and Langmuir. The study was conducted in three stages: 1) analyzing the physical properties and chemical content of samples; 2) processing the air in a cation exchanger processing installation; 3) analyze the content of Pb^{2+} ions processed air. The results showed that Pb^{2+} ion adsorption by IR amberlite resin 120 Na was 90.87-99.57%; In the use of resin mass of 20-100 g and feed rate of 0.0208-0.0435 L·s^{-1} showed that the Pb^{2+} content of the processed air has met the standard. Adsorption of Pb^{2+} ions by isotherm with equations of Freundlich and Langmuir equations. Freudlich equation constant is n = 1.6943 and K_f = 6.9984 with result of 0.9715. Langmuir equation constant is A_s = 0.0175 and K_b = 136.8363 with research result of 0.8863.

KEY WORDS : Cation exchanger, Flow rate, Freundlich, Langmuir, Mass

INTRODUCTION

Clean water is a major need in human life. Natural water contains several cations, such as Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}. These ions give a taste to the water and determine the quality of water. In addition, water can also contain some heavy metals, such as Pb^{2+}, Fe^{2+}, Fe^{3+}, Zn^{2+}, Cd^{2+}, Cu^{2+}, Ni^{2+}, Al^{3+}, and others that determine water toxicity (Fardiaz, 1992; Salam *et al.,* 2012; Simonescu *et al.,* 2011; Peng *et al.,* 2009). Pb as one of the heavy metals is very harmful to human health because of its non biodegradable and accumulated in the human body. The toxicity of Pb metal could endanger the life sustainability, activity, growth, metabolism, or reproduction (Chabukdhara and Nema, 2012).

In Pasuruan, East Java, Indonesia, there are several well water containing Pb^{2+} ions between 0.15 to 0.23 mg·L^{-1}. This wells water is used by some people to meet the needs of clean water. The level of Pb^{2+} ions in the well water exceeds the threshold of clean water requirements in Indonesia based on Ministry of Health Regulation No. 416/1990, which is 0.05 mg.L^{-1}. To maintain public health, Then this well water treatment should be done before it is consumed as clean water. One method to decrease the ion content of Pb^{2+} in well water is to use ion exchange resins, such as Amberlite IRC 718, Purolite1 S930, Dowex A 1, and others (Mendes *et al.,* 2005).

Lead (Pb) is an essential and toxic element whose distribution is increased in the environment around humans (Mendes *et al.,* 2005). Exposure to lead in a long time can accumulate in the body and cause side effects on the body organs such as neurologic, reproduction, kidney, and hematology. Children are more vulnarable to exposure to lead than adults. Exposure and lead levels in the blood are

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recommended below 10 mg·dL^{-1} (Lansdown *et al.*, 1986; Goyer, 1990).

One of the methods that can be used to reduce the Pb content is ion exchange (Shi *et al.*, 2013). From many advantages obtained from the method of cation exchanger, among others, resins that have been used can be regenerated, the processing is also flexible, can be done in batch or continuous (Liguori *et al.*, 2015). The resin used can be derived from natural, synthetic, or combination of both materials (Hackbarth *et al.*, 2014; Checinal *et al.*, 2016; Bulgariu and Bulgariu, 2013). The efficiency of resin adsorption can be improved by modification. Amberlite XAD resin modifications produce a surface area of 300-800 m^2·g^{-1} (Ahmad *et al.*, 2015). Several studies have been conducted to determine the ability of Amberlite IR 120 resin to decrease the ion content of Pb^{2+}. The effectiveness of resin adsorption can be increased by potentially modified modification. Research has shown that IR Amberlite 120 resin is good enough to absorb Pb^{2+} ions in waste water, which is about 99% after about 4 hours (Demirbas *et al.*, 2005). Other studies have also shown that IRC 718 Amberlite resin can absorb well the Pb^{2+} ion in artificial water samples containing several heavy metal ions. Amberlite IRC 718 ion exchange resistive capacity reached 3.96 meq·g^{-1} at Pb^{2+} 0.1 M ion concentration (Agrawal *et al.*, 2006).

Research on the adsorption of Pb^{2+} ions by Amberlite resins is indeed interesting, however, in previous studies the samples used were wastewater and artificial samples, not well water (Demirbas *et al.*, 2005; Agrawal *et al.*, 2006). This research refines previous research with novelty of research is the use of Amberlite IR 120 Na resin to adsorb Pb^{2+} ion in well water. The isotermic adsorption performance of Pb^{2+} ions by IR Amberlite 120 NA resin can be known from the Freundlich and Langmuir equations (Stefan *et al.*, 2014). The results of the study are expected to produce the appropriate methods and operating conditions for treating well water into clean water that meets the standards of Minister of Health Regulation No. 416 of 1990. The characteristics of Amberlite IR 120 Na resin are shown in Table 1.

MATERIALS AND METHODS

The materials used are well water, Amberlite IR 120 Na resin, and aquadest. While the tools used are pH meter, thermometer, pump, flow meter, plastic jerry can, water container, porcelain cup, analytical balance, laboratory scale water treatment plant.

Water treatment is done at room temperature and atmospheric pressure. Processing is done by continuous system. In this research, the effect of resin mass and flow rate on the adsorption efficiency of Amberlite IR 120 Na resin to Pb^{2+} ion contained in well water is studied.

The research procedure starts from sampling, initial sample analysis, resin weighing, pH and treated water temperature measurement, well water treatment, analysis of processed water, analysis of data processing, and formulation of Freundlich and Langmuir equations. Weighing resin in 20 g, 60 g, 80 g, and 100 g, each of 3 pieces. In this research the processing system is continuous. The variable used is resin mass and flow rate. The resin mass consists of 4 variables, namely 20 g, 60 g, 80 g, and 100 g. While the flow rate consists of 3 variables, which are 0.0208 L·s^{-1}; 0.0313 L·s^{-1}; And 0.0435 L·s^{-1}. Analysis method of Pb^{2+} ion content used is atomic absorption spectrophotometry (SSA). The processing is carried out in a series of apparatus shown in Figure 1.

Figure 1 shows the installation of a cation exchanger treatment consisting of a well water reservoir, a pump, a cation exchanger reactor, and a processed water container. Two 0.5 inch valves are

Table 1. Properties of Amberlite Resin IR 120 Na

Physical Form	Amber spherical beads
Matrix	Styrene divinylbenzene copolymer
Functional group	Sulfonate
Ionic form as shipped	Na^+
Total exchange capacity	≥ 2.00 eq/L (Na^+ form)
Moisture holding capacity	45 to 50% (Na^+ form)
Shipping weight	840 g/L
Particle Size	
Uniformity coefficient	≤ 1.9
Harmonic mean size	0.600 to 0.800 mm < 0.300 mm 2% max
Maximum reversible swelling	$Na^+ \rightarrow H^+ \leq 11\%$

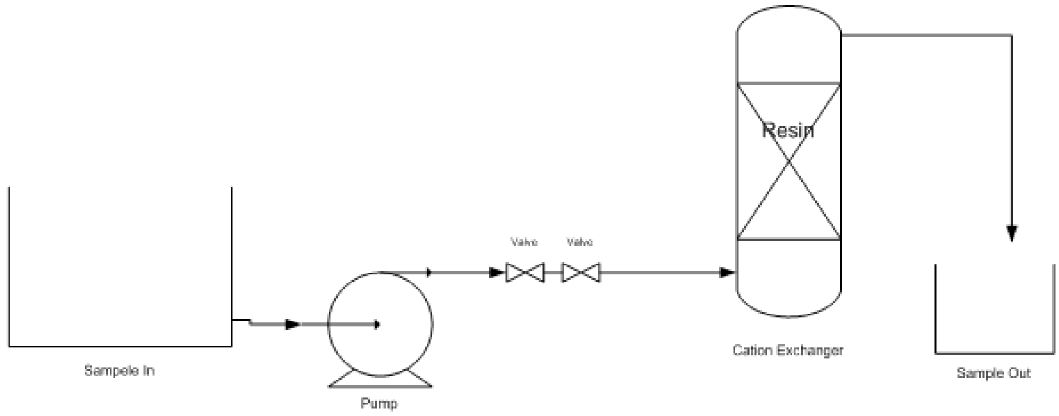

Fig. 1. Installation of cation exchanger processing

installed between the pump and the reactor to adjust the flow rate. While the flow meter is installed between the valve with reactor inlet hole to control the flow rate. The diameter of the reactor is 4 inches , the reactor height is 16 inches and the resin is 3 inches high. Processing starts from pumping the well water to flow to cation exchanger equipment with certain flow rate. The valve opening to the cation exchanger equipment is set to 25% of the full opening for 0.0208 $L \cdot s^{-1}$ flow rate; 50% of full opening for 0.0313 $L \cdot s^{-1}$ flow rate; And full opening for 0.0435 $L \cdot s^{-1}$ flow rate. The flow rate can be seen from the flow meter mounted between the valve and reactor inlet hole. After steady state conditions, sampling is taken at the reactor outlet hole.

RESULT AND DISCUSSION

This study studied the effect of changes in resin mass and flow rate on the efficiency of Amberlite IR 120 Na resin in adsorbing Pb^{2+} ions. In addition, it also studied the process of adsorption of continuous system isotherms using Freundlich and Langmuir equations.

Initial Analysis of The Well Water

The well water that will be processed into clean water is analyzed for its characteristics based on the parameters of clean water requirements in Indonesia. The results of the initial analysis of the well water samples are presented in Table 2. Table 2 shows that the well water contains lead (Pb) above the maximum water requirement.

Analysis of Pb^{2+} ion Content of The Processed Water

The analysis of ion content of Pb^{2+} in treated water using cation exchanger is presented in Table 3. Table 3 contains the data showing the relationship between the resin mass and the flow rate of the Pb^{2+} ion content in treated well water. Table 3 shows that the ion content of Pb^{2+} well water after being treated with Amberlite IR 120 Na resin ranged from 0.001-0.021 mgL^{-1} so that it has met the requirements of

Table 2. Initial Analisys of the well water samples

Parameter	Level	Maximum Limit[a]
Smell	No smell	No smell
Taste	Normal	normal
Temperature	27.5°C	Water temperature ± 3°C
TDS	601 $mg \cdot L^{-1}$	1500 $mg \cdot L^{-1}$
Turbidity	0 NTU	25 NTU
Color	0 $Pt \cdot Co^{-1}$	50 $Pt \cdot Co^{-1}$
pH	8.10	6.5 – 9.0
As	< 0.00004 $mg \cdot L^{-1}$	0.05 $mg \cdot L^{-1}$
Fe	< 0.004 $mg \cdot L^{-1}$	1 $mg \cdot L^{-1}$
F	< 0,02 $mg \cdot L^{-1}$	1,5 $mg \cdot L^{-1}$
Cd	< 0,001 $mg \cdot L^{-1}$	0,005 $mg \cdot L^{-1}$
$CaCO_3$	332 $mg \cdot L^{-1}$	500 $mg \cdot L^{-1}$
Cl^-	29 $mg \cdot L^{-1}$	600 $mg \cdot L^{-1}$
Cr^{6+}	0.01 $mg \cdot L^{-1}$	0.05 $mg \cdot L^{-1}$
Mn	0.23 $mg \cdot L^{-1}$	0.5 $mg \cdot L^{-1}$
Nitrat	0.71 $mg \cdot L^{-1}$	10 $mg \cdot L^{-1}$
Nitrit	0.01 $mg \cdot L^{-1}$	1 $mg \cdot L^{-1}$
Hg	< 0.000002 $mg \cdot L^{-1}$	0.001 $mg \cdot L^{-1}$
Se	< 0.00003 $mg \cdot L^{-1}$	0.01 $mg \cdot L^{-1}$
Zn	0.08 $mg \cdot L^{-1}$	15 $mg \cdot L^{-1}$
CN	< 0.01 $mg \cdot L^{-1}$	0.1 $mg \cdot L^{-1}$
SO_4	4 $mg \cdot L^{-1}$	400 $mg \cdot L^{-1}$
Pb	0.23 $mg \cdot L^{-1}$	0.05 $mg \cdot L^{-1}$
Surfactant	< 0.05 $mg \cdot L^{-1}$	0.5 $mg \cdot L^{-1}$
Organic	< 1.9 $mg \cdot L^{-1}$	10 $mg \cdot L^{-1}$
Coliform	1 $Col \cdot (100\ mL)^{-1}$	10 $Col \cdot (100\ mL)^{-1}$

[a] Minister of Health Regulation No. 416/1990

Table 3. The analysis result of Pb^{2+} ion content in well water after processed using Amberlite IR 120 Na resin.

Mass of resin (g)	Content of Pb^{2+} ion ($mg \cdot L^{-1}$)		
	Q1=0.0208 $L \cdot s^{-1}$	Q2=0.0313 $L \cdot s^{-1}$	Q3=0.0435 $L \cdot s^{-1}$
20	0.011	0.015	0.021
60	0.003	0.0068	0.02
80	0.001	0.0025	0.0058
100	0.001	0.0025	0.0028

clean water in Indonesia. The Pb^{2+} ion content of the processed water is getting smaller at the smaller flow rate and the larger the resin mass. The adsorption efficiency of resin to Pb^{2+} ions in well water is calculated from equation (1).

$$ç = \frac{\text{Pb level (before processed - after processed)}}{\text{Pb level before processed}} \times 100\% \quad .. (1)$$

Adsorption efficiency of Amberlite IR 120 Na resin on Pb^{2+} ion is shown in Figure 2.

Resin Mass and Flow Rate

Figure 2 shows the relationship between the resin mass and flow rate to the adsorption efficiency of Pb^{2+} ions from the Amberlite IR 120 Na resin. It shows that the larger the resin mass and the smaller the flow rate, the greater the adsorption efficiency of the resin to the Pb^{2+} ion. At a flow rate of 0.0208 $L \cdot s^{-1}$ the adsorption efficiency ranges from 0.001 - 0.011 $L \cdot s^{-1}$. At a flow rate of 0.0313 $L \cdot s^{-1}$ the adsorption efficiency ranges from 0.0025 - 0.0150 $L \cdot s^{-1}$. While the flow rate of 0.0435 $L \cdot s^{-1}$ adsorption efficiency ranged from 0.0028 to 0.0210 $L \cdot s^{-1}$. Optimal adsorption efficiency of resin was happened at resin mass of 80 g and 100 g, that is between 97.48-99.57%. Optimal resin adsorption efficiency also occurs in the water flow rate 0.02 $L \cdot s^{-1}$, which is between 95.22- 99.57%. While the highest resin efficiency is on the condition of resin mass 80 g and 100 g with a flow rate of

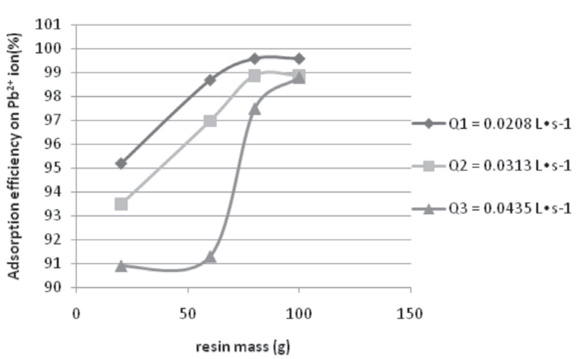

Fig. 2. The effect of mass of Amberlite 120 Na resin and flow rate (Q) on the adsorption efficiency of Pb^{2+} ion

0.0208 $L \cdot s^{-1}$ that is equal to 99.57%. This proves that the efficiency of Amberlite IR 120 Na resin in decreasing the content of Pb^{2+} ions in well water is greater than the resin efficiency in decreasing the ion content of Pb^{2+} in waste water, i.e. 99% (Demirbas *et al.*, 2005).

Isothermic Adsorption

The adsorption process through ion ion reaction mechanism, physical adsorption, adsorption of electrolyte molecules, the formation of complexes between central ions and functional groups, and the formation of hydrates on the surface or in the pores of the adsorbent. Some metals that can be absorbed by resins are a function of both metal concentration and temperature. The amount of Pb adsorbed must be as a function of concentration at constant temperature. This can be explained in the isothermal adsorption equation, such as Freundlich and Langmuir. Freundlich isothermic equations are often used to describe the resin-adsorption characteristics used in solution or wastewater treatment [19,20]. This study included the adsorption characteristics of isothermic resin Amberlite IR 120 Na to Pb^{2+} ion. The isothermal adsorption characteristics is in the Freundlich and Langmuir equations.

Freundlich Equation

The Freundlich equation is shown at equation (2).

$$\frac{x}{m} = K_f\, C_e^{\frac{1}{n}} \quad .. (2)$$

Where is the number of adsorbed Pb per unit of resin mass ($ppm.g^{-1}$), C_e is Pb concentration in in the adsorbate after experiencing the desorption process (ppm), K_f and n are the empirical constants (Naushad *et al.*, 2015; Wolowicz *et al.*, 2016). The constants of K_f and n can be found using equation (3) below.

$$\text{Log}\, \frac{x}{m} = \log K_f + \frac{1}{n} \log C_e \quad .. (3)$$

Graph to represent the Freundlich equation is shown in Figure 3. That Figure is the graph of the relation of log(x/m) and log C_e. Based on the equation (3) and Figure 3, it can be derived (1/n) = 0.5902 and n = 1.6943, while log K_f = 0.845 so K_f = 6.9984. Freundlich equation obtained from isothermal adsorption of Amberlite IR 120 Na resin to Pb^{2+} ion is

$$\frac{x}{m} = K_f\, C_e^{0.5902} \quad .. (4)$$

The correlation coefficient of the Freundlich equation is 0.9715.

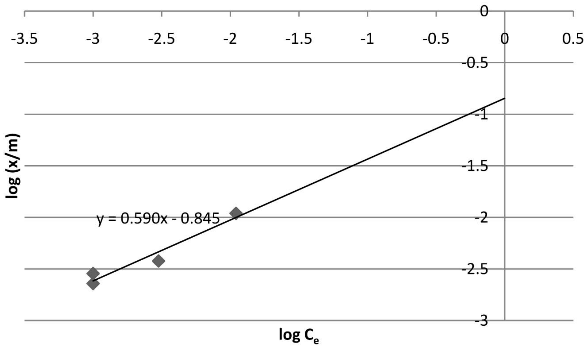

Fig. 3. The Relation of log(x/m) vs log C_e from Freundlich equation.

Langmuir Equation

Langmuir's isothermic equation is shown in the equation (5).

$$\frac{C}{q} = \frac{1}{K_b A_s} + \frac{C}{A_s} \quad .. (5)$$

Where A_s and K_b are coefficients, q is the weight of adsorbed Pb per unit of resin weight (ppm·g^{-1}), and c is the Pb concentration in well water after adsorbed (ppm) (Naushad *et al.*, 2015; Wolowicz *et al.*, 2016). The graph to illustrate the Langmuir equation is presented in Figure 4.

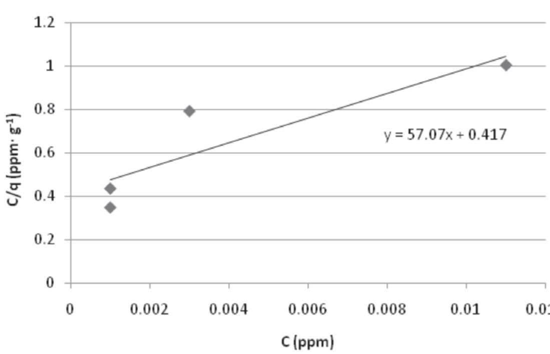

Fig. 4. The Relation of C/q vs C from Langmuir equation

Figure 4 is a graph of the relationship between C/q and C. Based on equation (5) and Figure 4 it is obtained A_s = 0.0175, while K_b = 136.8363. The Langmuir equation obtained from isothermal adsorption of Amberlite IR 120 Na resin to Pb^{2+} ion is:

$$\frac{C}{q} = 0.4176 + \frac{C}{0.0175} \quad .. (6)$$

The correlation coefficient of Langmuir equation is 0.8863.

CONCLUSION

Amberlite IR 120 Na resin is able to adsorb Pb^{2+} ion contained in well water with efficiency between 90.87-99.57%. Processed water has met the requirements of clean water in Indonesia based on Permenkes standard No. 416/Menkes/1990. Adsorption of Pb^{2+} ions under resin mass operating conditions of 20-100 g and a flow rate of 0.02-0.04 L·s^{-1} shows eligible processed water results. The isothermal adsorption test of Amberlite IR 120 Na resin to Pb^{2+} ion in well water using Freundlich equation with constant n = 1.6943 and K_f = 6.9984; Whereas when expressed in the Langmuir Equation with constants A_s = 0.0175 and K_b = 136.8363. Freundlich equation correlation coefficient of 0.9715 while Langmuir equation coefficient of 0.8863. Freundlich's equations and Langmuir's equations are accurate, but Freunlich's equations are more accurate than Langmuir's equations.

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