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Isotherm Adsorption of Cd(II) Using Surfactant-Modified Activated Carbon-Sodium Lauryl Sulfate (SMAC-SLS)

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ABSTRACT

Heavy metal pollution such as Cd(II) in the environment is a serious issue that requires effective solutions. This study aims to evaluate the ability of sodium lauryl sulfate surfactant modified activated carbon (SMAC-SLS) in adsorbing Cd(II) from solution. SMAC-SLS synthesis was carried out using wet impregnation method with SLS solution. The adsorption process was tested at various concentrations of Cd(II), and the results were analyzed using Langmuir and Freundlich isotherm models. The results showed that the adsorption of Cd(II) on SMAC-SLS followed the Freundlich isotherm model, with R^2 of 0.995, Kf of 1.934 mg/g, and nnn of 5.039, indicating excellent adsorption on the heterogeneous surface. The Langmuir model also gave an R^2 of 0.9767 with a maximum adsorption capacity Qmax of 11.83 mg/g and adsorption energy of 22.517 kJ/mol, indicating a possible chemisorption mechanism. Modification of activated carbon with SLS was shown to increase the adsorption capacity as well as the interaction with Cd(II) ions. This suggests that SMAC-SLS has great potential as an adsorbent in the treatment of wastewater containing heavy metals.

Keywords: Adsorption, Cd(II), SMAC-SLS, Langmuir, Freundlich

I. INTRODUCTION

Research on Cd(II) adsorption using sodium lauryl sulfate surfactant-modified activated carbon (SMAC-SLS) is very important considering that heavy metal pollution, especially cadmium, is a serious problem faced by many countries, including Indonesia. Cadmium is a heavy metal harmful to human health and the environment, which can enter aquatic systems through industrial and agricultural effluents (Es-said, et al., 2021). Previous research shows that activated carbon can serve as an effective adsorbent for removing heavy metals from water, including cadmium, with varying efficiencies depending on the type and characteristics of the activated carbon used . (Moelyaningrum, 2019).

Activated carbon has high adsorption capabilities due to its broad shaft structure, which allows for better interaction with contaminants in solution. Research by Moelyaningrum showed that activated charcoal from coffee grounds can reduce cadmium levels in water significantly, which shows the potential of activated carbon as a solution to address heavy metal pollution (Ko, 2024a). In addition, modification of activated carbon with surfactants such as sodium lauryl sulfate (SLS) can improve its adsorptive properties, thereby increasing its efficiency in adsorbing heavy metal ions such as Cd(II). (Anisyah et al., 2021)..

One of the approaches used in this study is the modification of activated carbon with surfactants, which aims to increase the absorption of activated carbon to metal ions (Jasim & Ajjam, 2024). This modification aims to improve the interaction between activated carbon and metal ions, thereby increasing the adsorption capacity. Previous studies have shown that activated carbon modified with surfactants can increase the adsorption efficiency of various contaminants, including heavy metals and dyes (Anisyah et al., 2021; Lanjar et al., 2018). By using sodium lauryl sulfate, it is expected that the resulting activated carbon has better properties in adsorbing Cd(II) compared to unmodified activated carbon.

In this context, it is important to understand the adsorption mechanism that occurs between activated carbon and Cd(II) ions. The adsorption process can be influenced by various factors, including contact time, pH, and initial concentration of metal ions in solution. Research showed that optimal contact time can increase adsorption efficiency, which is also relevant in this study (Arianti et al., 2023). In addition, the characterization of the resulting activated carbon, both in terms of surface morphology and surface area, is also important to determine the adsorption potential of the material (Anisyah et al., 2021; Lanjar et al., 2018)..

This research also focuses on developing an efficient and environmentally friendly method to address heavy metal pollution. By using renewable raw materials, such as coconut shells, and a simple modification process, it is expected to produce adsorbents that are not only effective but also economical. This is in line with research showing that the use of natural materials as adsorbents can provide a sustainable solution to pollution problems. (Kristianto, 2017).

Overall, this study aims to contribute to the development of better water treatment technologies, particularly in addressing heavy metal pollution (Mandal, et al., 2021). By utilizing sodium lauryl sulfate surfactant-modified activated carbon, it is hoped that a more efficient adsorbent material can be obtained in adsorbing Cd(II) ions from solution, thus helping to reduce the negative impact of heavy metal pollution on the environment and human health. This research is also expected to pave the way for further research on the use of activated carbon in other environmental applications.

Surface modification of activated carbon is necessary to increase its affinity for target pollutants, improve its adsorption capacity, and increase pollutant removal efficiency (Arnelli & Y. Astuti, 2019).(Blanco et al., 2018).. Physical, chemical, and biological methods can be used for activated carbon modification. Surfactants have proven to be very important in chemical modification technologies. By changing the surface charge characteristics of activated carbon and providing more places for ionic adsorption, surfactants can change the hydrophilicity and dispersion of activated carbon in water with lower cost and less effect on the structure of activated carbon. In addition, surfactants can increase the affinity of activated carbon to water and reduce the force of attraction between particles (Hojabri, et al., 2024).

Several previous studies have documented the use of SMAC as an adsorbent. Studies conducted by (Arnelli & Y. Astuti, 2019) used SMAC from rice husk as adsorbent for Ni(II) and Cr(IV) with adsorption efficiency of 95.96% and 99.49%, respectively. In addition, SMAC was also used for methylene blue dye adsorption, which successfully removed 94.30% of the dye (Kuang et al., 2020). Therefore, SMAC combined with SLS can also be used as an adsorben

II. METHODS

Materials used in this study were $ZnCl_2$ (Merck Germany), $CH_3(CH)_{210}CH_2(OCH_2\ CH_2)nOSO_3$ Na (Sodium Lauryl Sulphate, SLS) (Merck), NaOH (Merck), HCl (Emsure), $CdSO_4$ $.8H_2$ O (Merck), Whatman No. 42 filter paper, distilled water, and aluminum foil.

The research procedure consisted of SMAC-SLS synthesis and determination of optimum adsorption conditions. The SMAC-SLS synthesis was carried out by weighing 10 g of activated carbon in 100 mL of 60 mg/L SLS then shaken for 4 hours and then filtered using Whatman paper No. 42. The filtrate obtained was rinsed using distilled water, then dried in an oven at 105ºC for 1 hour and put in a desiccator for 15 minutes (Arnelli et al., 2019).

Determination of optimum concentration, 0.1 g of SMAC-SLS and 50 mL of CdSO solution$_4$ with concentration variations of 5, 10, 15, 20, and 25 mg/L in each erlemeyer. Then the solution was set at Ph 5 according to the optimum pH of the solution using HCl. Each Erlenmeyer was stirred using a shaker at 150 rpm for 60 minutes. Then filtered and the filtrate obtained was measured for concentration using an Atomic Absorption Spectrophotometer (AAS). The results obtained were then analyzed using Freundlich and Langmuir adsorption isotherm calculations.

The Freundlich equation was developed for the homogeneous system shown in equation:

$$log q_e = log K_f + \frac{1}{n} log C_e$$

The Langmuir isotherm model is expressed in the equation:

$$\frac{C_e}{q_e} = \frac{1}{q_{max}K_L} + \frac{q_e}{q_{max}}$$

III. RESULTS AND DISCUSSION

The synthesis of SMAC-SLS was carried out using the wet impregnation method which aims to fill the pores of activated carbon with active components utilizing the principle of diffusion. SLS surfactant is the active component chosen to be impregnated into activated carbon. The selection of SLS surfactant is based on its good chemical stability in various environmental conditions, such as different Ph and temperature. In addition, SLS is an anionic surfactant that has a sulfate group at its hydrophilic end. $(-SO_4^-)$ at its hydrophilic end. SLS impregnation is carried out for 4 hours which aims to allow SLS surfactant to occupy the pores and cavities on activated carbon. The results obtained are then filtered and washed using distilled water to remove excess surfactant residues. The results obtained are then called surfactant-sodium lauryl sulfate modified activated carbon (SMAC-SLS) shown in Figure 1.

Figure 1. Impregnated activated carbon (SMAC-SLS).

Determination of Adsorption Isotherm

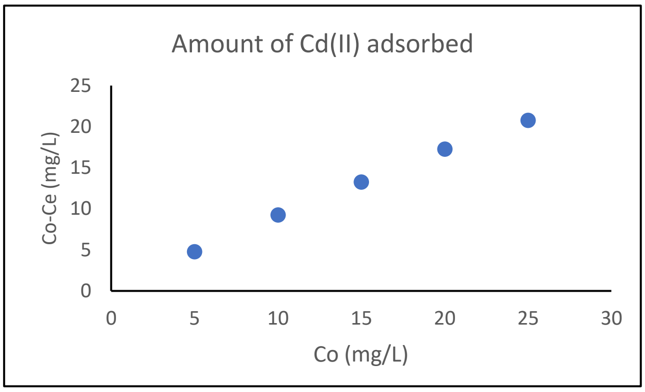

Figure 2 Relationship graph of the initial concentration (Co) of Cd(II) with the concentration of Cd(II) that has been adsorbed (Co-Ce) by SMAC-SLS.

The adsorption isotherm expresses the relationship between the amount of sorbate adsorbed on the adsorbent surface and the concentration of adsorbate in equilibrium. The adsorption isotherm of Cd(II) on SMAC-SLS adsorbent was studied by varying the concentration of Cd(II) on the adsorbent to obtain the following data (Figure 2):

Based on the adsorption results shown in graph 2, it can be seen that the concentration of Cd(II) adsorbed by SMAC-SLS adsorbent increases with the increase of Cd(II) metal concentration in solution. This can be explained that as the initial concentration of Cd(II) increases, the amount of metal ions adsorbed is also greater because Cd(II) ions will occupy active sites on the adsorbent. It has been explained that the greater the metal concentration in the solution, the more active sites on the adsorbent are occupied by metal ions and will reach an optimum condition if all active sites on the adsorbent surface have been filled with metals. However, this study has not found an equilibrium condition in the solution.

Furthermore, the determination of adsorption isotherm was carried out to determine the capacity of Cd(II) metal adsorbed by SMAC-SLS. In this study, adsorption data were analyzed using the Freundlich and Langmuir isotherm models. The Freundlich equation was developed for heterogeneous systems shown in Eq:

$$log q_e = log K_f + \frac{1}{n} log C_e$$

Where q_e is the amount of metal at equilibrium, C_e is the concentration of metal at equilibrium, K_f and $1/n$ is the Freundlich constant.

The Langmuir isotherm model quantitatively describes the formation of a single layer of adsorbate on the adsorbent surface, and no further adsorption occurs when the active side is saturated. This model is expressed in the equation:

$$\frac{C_e}{q_e} = \frac{1}{q_{max} K_L} + \frac{q_e}{q_{max}}$$

Where q_e is the amount of metal at equilibrium, C_e is the metal concentration at equilibrium, q_{max} is the maximum adsorption capacity, and K_L is the Langmuir constant. The Langmuir isotherm model curve is determined by making the relationship C_e/q_e (g/L) and C_e (mg/L) as ordinate and abscissa, respectively. *The slope of* this line equation is $\frac{1}{q_{max}}$ and *the intercept* is $\frac{1}{q_{max} K_L}$. Table 1, and Figure 3 show that the adsorption of Cd(II) using SMAC-SLS follows the Freundlich isotherm model.

Table 1. Adsorption isotherm parameters of Cd(II) metal on SMAC-SLS adsorbent

Adsorbents	Parameters					
	Langmuir			Freundlich		
	R^2	K_L (L mol)$^{-1}$	E (kJ mol)$^{-1}$	R_2	K_f (mg g)$^{-1}$	n
SMAC-SLS	0.9767	11,83	22,517	0.995	1.934	5,039

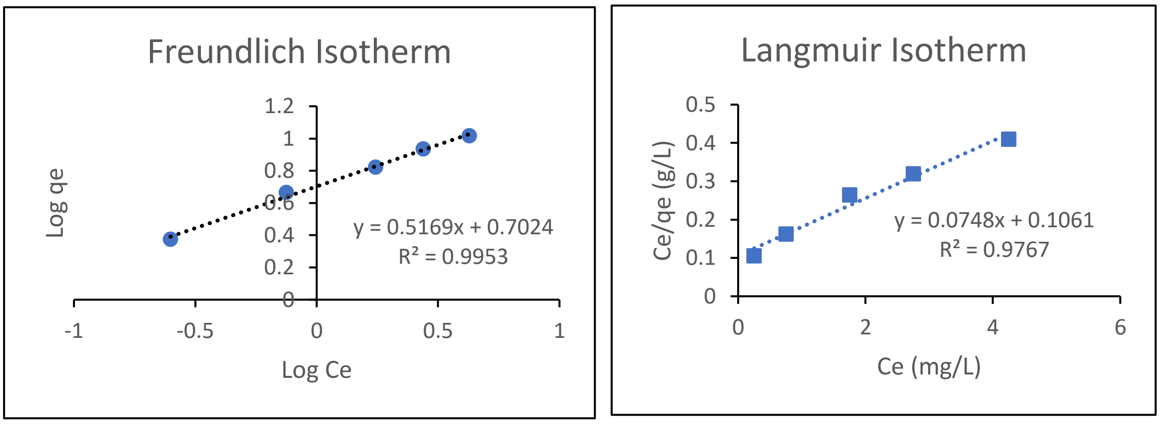

Figure 3 Comparison of Langmuir and Freundlich isotherm models

Based on Table 1 and Figure 3, it can be seen that the adsorption of Cd(II) on SMC-SLS adsorbent follows the Freunlich model so it can be concluded that the adsorption of Cd(II) occurs on heterogeneous surfaces with the possibility of interaction between adsorbate molecules. The large value of n also indicates that the adsorption runs very well, especially at low adsorbate concentrations. In addition, the adsorption process also involves strong interactions between the adsorbate and the adsorbent, with the possibility of a chemisorption mechanism seen from the E value of more than 20 Kj/mol.

Modification of activated carbon with sodium lauryl sulfate surfactant (SMAC-SLS) was shown to improve adsorption ability, both in adsorption capacity and in interaction with Cd(II) ions. This provides great potential in the use of SMAC-SLS as an adsorbent in the treatment of wastewater containing heavy metal ions.

IV. CONCLUSION

The results showed that the adsorption of Cd(II) using SMAC-SLS adsorbent follows the Freundlich adsorption isotherm model indicating that adsorption takes place on a heterogeneous adsorbent surface, with nnn values greater than 1, which indicates adsorption is stronger on the adsorbent and occurs more efficiently.

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