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# REDUCTION OF $Ni^{2+}$ CONCENTRATIONS IN ELECTROPLATING PROCESS WASTEWATER USING CHITOSAN-ACTIVE CARBON ADSORBENT

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***Abstrak**. Penurunan konsentrasi $Ni^{2+}$ dari air limbah proses elektroplating dapat dilakukan secara efektif menggunakan adsorben kitosan yang dimodifikasi dengan karbon aktif melalui proses adsorpsi. Penelitian ini bertujuan untuk membuat adsorben dengan perbedaan rasio massa antara kitosan dan karbon aktif melalui proses adsorpsi untuk mengetahui pengaruhnya dalam penurunan konsentrasi $Ni^{2+}$ pada limbah elektroplating serta mempelajari pengaruh waktu kontak terhadap penurunan kadar nikel pada limbah elektroplating. Pembuatan adsorben dilakukan dengan mengikat silang kitosan terprotonasi dengan tripolifosfat, setelah itu dilakukan penambahan karbon aktif dengan variasi rasio berikut: 0,5:1,5, 0,75:1,25, 1:1, 1,25:0,75, dan 1,5:0,5 gr/gr. Proses adsorpsi menggunakan air limbah proses elektroplating sebanyak 500 ml dan adsorben sebanyak 2 gr dengan variasi waktu kontak 15 hingga 75 menit. Konsentrasi $Ni^{2+}$ dalam filtrat dianalisis menggunakan Atomic Absorption Spectroscopy (AAS), dan adsorben dikarakterisasi dengan Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy (SEM-EDX). Kondisi optimal untuk penurunan konsentrasi $Ni^{2+}$ terjadi pada rasio massa adsorben kitosan/karbon aktif sebesar 0,5:1,5 gr/gr dan waktu kontak 60 menit, pada sampel ini menghasilkan konsentrasi $Ni^{2+}$ akhir sebesar 2,17 mg/L, efisiensi adsorpsi sebesar 98,92%, dan kapasitas adsorpsi sebesar 49,46 mg/g. Penelitian ini menunjukkan efektivitas adsorben kitosan/karbon aktif dalam menangani kontaminasi $Ni^{2+}$ dalam air limbah proses elektroplating, yang menawarkan solusi lingkungan yang berkelanjutan.*

***Kata kunci**: air limbah, elektroplating, nikel, adsorpsi, kitosan, karbon aktif*

**Abstract**. The removal of $Ni^{2+}$ from electroplating process wastewater can be effectively accomplished using chitosan modified with activated carbon through an adsorption process. This research aims to develop adsorbents with varying mass ratios of chitosan to activated carbon and assess their efficacy in reducing $Ni^{2+}$ concentrations, the impact of contact time on this reduction. Adsorbents were prepared by crosslinking protonated chitosan with tripolyphosphate and incorporating activated carbon in the following ratios: 0.5:1.5, 0.75:1.25, 1:1, 1.25:0.75, and 1.5:0.5 grams per gram. The adsorption process involved contacting 500 milliliters of electroplating process wastewater with 2 grams of adsorbent for various durations of 15 to 75 minutes. $Ni^{2+}$ concentration in the filtrate was analyzed using Atomic Absorption Spectroscopy (AAS), and the adsorbent was characterized with Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy (SEM-EDX). The optimal conditions for $Ni^{2+}$ removal occurred with a chitosan/activated carbon mass ratio of 0.5:1.5 grams per gram and a contact time of 60 minutes, resulting in a final $Ni^{2+}$ concentration of 2.17 mg/L, an adsorption efficiency of 98.92%, and an adsorption capacity of 49.46 mg/g. These findings demonstrate the effectiveness of chitosan/activated carbon composites in treating $Ni^{2+}$ contamination in electroplating wastewater, offering a sustainable environmental solution.

**Keywords:** wastewater, electroplating, nickel, adsorption, chitosan, activated carbon

## 1. Introduction

The electroplating industry is a significant sector that generates hazardous waste throughout production. Many electroplating facilities remain a source of environmental concern within this industry due to their lack of adequate waste treatment systems. The wastewater produced during electroplating operations is particularly concerning, as it contains various heavy metals, including nickel, copper, manganese, chromium, zinc, and iron. Among these, nickel is the most commonly detected heavy metal, often found in alarming concentrations. In general, the concentration of $Ni^{2+}$ in electroplating process wastewater is quite high, above the quality standard, and varies depending on the coating process used. In a study conducted by (Pratika and Widiono, 2020), it was explained that the $Ni^{2+}$ concentration used in the study was 20 mg/L, while according to a study by (Santoso, 2023), the $Ni^{2+}$ concentration in electroplating wastewater was 179.7 mg/L. In this study, the $Ni^{2+}$ concentration in the electroplating process wastewater used was 200 mg/L. In contrast, according to the Regulation of the Governor of East Java No. 52 of 2014, the $Ni^{2+}$ concentration standard in electroplating process wastewater is 1 mg/L. For this reason, processing is needed to reduce the $Ni^{2+}$ concentrations in electroplating process wastewater. The toxicity of nickel and other heavy metals in electroplating process wastewater poses serious environmental and public health risks (Pratiwi, Sunarsih and Dewi, 2019).

The direct disposal of untreated electroplating process wastewater into the environment can lead to severe pollution, disrupting ecosystems and harming beneficial microorganisms essential for maintaining ecological balance. Consequently, it is imperative to establish effective treatment methodologies for this wastewater prior to its discharge into natural water bodies. Reducing heavy metal concentrations can use chemical separation such as precipitation, adsorption, filtration, and coagulation. In addition, it can also use membranes, ion exchange, and flotation (Kosim et al., 2022). The process of reducing $Ni^{2+}$ using the electrocoagulation method has been carried out by et (Djaenudin and Permana, 2017), in this study, the electrocoagulation process was carried out at a voltage of 10 volts, and the percentage of $Ni^{2+}$ reduction effectiveness was obtained at 59.25%. The magnitude of heavy metal reduction in wastewater is influenced by the size of the direct current voltage on the electrode, the narrowness of the electrode contact area and the distance between electrodes, the use of electricity, which may be expensive, and the anode rod, which is easily corroded so that it must always be replaced (Hernaningsih, 2016). One promising approach to reducing heavy metal concentration is adsorption methods. This technique is particularly advantageous due to its operational simplicity and effectiveness, as it allows for repurposing residual biomass derived from natural materials as adsorbents. Such an innovative application not only aids in the treatment process but also promotes sustainability by minimizing waste (Emi and Ahmad, 2022).

Adsorbents incorporating natural polymers, particularly chitosan, play a vital role in effectively adsorbing heavy metal ions in electroplating process wastewater. Chitosan, derived from chitin, is notably proficient in attracting cationic heavy metal ions due to its unique structure, which features a polymer chain enriched with reactive amine and hydroxyl groups. This structural composition facilitates the binding of these harmful ions and contributes to chitosan's impressive chemical stability and its noteworthy selectivity toward various pollutants (Zuhrah et al., 2022). However, one significant limitation of chitosan is its vulnerability to degradation in acidic conditions, which can compromise its effectiveness as an adsorbent. Incorporating crosslinking agents is essential to counter this issue and enhance its stability under such conditions. A prominent example of a crosslinking agent is tripolyphosphate, a versatile polyanionic molecule known for its ability to interact favorably with chitosan, forming a more robust composite material. The combination of chitosan and tripolyphosphate not only bolsters the stability of the chitosan but also allows for the development of an adsorbent that is both biodegradable and non-toxic, making it an environmentally friendly option for reducing pollution (Kurniasih et al., 2018). Despite these advantages, chitosan alone can exhibit limited pore properties, particularly regarding surface area, which constrains its potential for effective adsorption. To maximize its efficacy, modifying chitosan with additional materials that possess larger pore networks and are cost-effective—such as activated carbon—becomes crucial (Wijayanti and Mahatmanti, 2022). Studies conducted by Wijayanti and Mahatmanti demonstrated that the composite material formed by combining chitosan with activated carbon significantly enhances adsorption capacity beyond that of each material when used independently. Specifically, the measured adsorption capacities were found to be 10.3 mg/g for activated carbon, 10 mg/g for pure chitosan, and an impressive 52.63 mg/g for the chitosan/activated carbon composite, illustrating the remarkable potential of this innovative combination in addressing heavy metal contamination. Adsorbent materials other than chitosan and activated carbon can also be used but have lower efficiency and adsorption capacity than chitosan and activated carbon. Research with adsorbent materials other than chitosan and activated carbon was conducted by (Madiabu, Untung and Solihat, 2021) using 60 mesh eggshell adsorbent obtained a decrease in the concentration range of 50 ppm to 75 ppm and an adsorption capacity of 1.99 mg/g was obtained. Therefore, chitosan material is used, which is composited with activated carbon, to obtain a higher reduction in $Ni^{2+}$ through adsorption.

This study was designed to thoroughly investigate the efficiency and capacity of chitosan-activated carbon adsorbents with varying ratios in their ability to reduce $Ni^{2+}$ concentrations in electroplating process wastewater. The $Ni^{2+}$ concentrations were quantified using Atomic Absorption Spectroscopy (AAS), allowing for precise measurements before and after the adsorption process. Furthermore, a detailed analysis was performed using Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX) to identify the specific elements present in the chitosan-activated carbon adsorbent. This analysis also provided insight into the morphological structure of the adsorbent, enhancing our understanding of its properties and effectiveness in $Ni^{2+}$ removal.

## 2. Materials and Methods

### *2.1. Material*

This study aims to investigate the reduction of $Ni^{2+}$ concentrations in electroplating process wastewater generated by a home-based electroplating industry in Surabaya (disguised as “X” ). The methodology involves the application of a tripolyphosphate-modified chitosan adsorbent, which is combined with activated carbon. The raw materials utilized in this research include technical chitosan made from shrimp shells produced by ChiMultiguna, and has a deacetylation degree of 96.9%. In addition, technical activated carbon produced by Cahaya Api Kurnia, which comes from coconut shell cellulose, shows a porosity of 0.8-1 $cm^3$/g. To modify the polycationic characteristics of chitosan, a 100% glacial acetic acid solution (CH3COOH) produced by SmartLab will be used. Technical grade tripolyphosphate produced by PT. Petrocentral will be used as a crosslinking agent. Finally, Aquadest produced by PT. Pash Mitra Mandiri with a purity of >99.9% will function as a universal solvent for the process.

## 2.2. *Activated Carbon Pretreatment*

Activated carbon is initially subjected to a pretreatment process to reduce its particle size, as the commercially available form is typically granular. This process commences with activated carbon grinding using a pestle and mortar. Subsequently, the ground material is sifted through a 60-mesh sieve to obtain a finer particulate. The processed, sieved activated carbon can then be utilized in the manufacturing process of chitosan-activated carbon adsorbents.

## 2.3. *Preparation and Adsorption of $Ni^{2+}$ Concentrations with Chitosan-Activated Carbon Adsorbent*

The manufacturing process and adsorption of $Ni^{2+}$ using chitosan/activated carbon adsorbent were based on (Prehatini and Amaria, 2023) research with modifications: a 1% (m/v) chitosan solution was prepared by dissolving 1 g of chitosan in 100 mL of 2% (v/v) acetic acid. The mixture was stirred at 70 rpm for 90 minutes until evenly combined (Figure 1) . Following this, 1 mL of 25% tripolyphosphate was added to the solution and stirred at the same speed for an additional 60 minutes. Next, activated carbon was incorporated into the solution, varying the ratio between chitosan and activated carbon as needed. The chitosan-activated carbon mixture was stirred using a motor at 70 rpm for 2 hours. After stirring, the mixture was allowed to stand overnight to facilitate an aging process. Finally, the gel was baked at 70°C until it reached a constant weight, which was then crushed into a powder.

The $Ni^{2+}$ concentrations in the electroplating process wastewater sample were first analyzed using Atomic Absorption Spectrophotometry. Next, chitosan-activated carbon adsorbent was added to 500 ml of the electroplating process wastewater sample, with variations in adsorption time. The mixture was stirred at a speed of 150 rpm. Afterward, it was centrifuged at 2000 rpm for 20 minutes to separate the components. The solution was then decanted to separate the filtrate from the residue. Finally, the $Ni^{2+}$ concentrations in the obtained filtrate were analyzed again using Atomic Absorption Spectrophotometry.

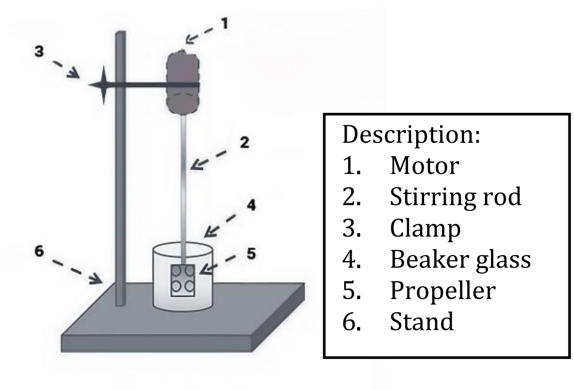



**Figure 1**. A series of chitosan-activated carbon making equipment and adsorption process

In addition, an Atomic Absorption Spectrophotometry (AAS) tool of the brand Thermo Scientific type iCE 3000Series with 6 Hollow Cathode Lamp compartments and Teledyne ASX-560 Autosampler. Background Correction using Deuterium and Zeeman, can determine the analyte concentrations with Flame or Graphite Furnace Analysis so that it can measure ppm and ppb scales. Scanning Electron Microscope-Energy Dispersive X-

Ray Spectroscopy (SEM-EDX) Hitachi SU3500 to determine the elements contained and the morphological structure of the chitosan/activated carbon adsorbent.

### 2.4. *Calculation of Adsorption Capasity and Efficiency*

Calculation of adsorption capacity of chitosan-activated carbon adsorbent can be calculated by the formula Equation (1) by (Choi, 2019).

$$q_e = \frac{(C_O - C_e)V}{m} \tag{1}$$

Description:
qe = adsorption capacity (mg/g)
Co = initial concentration of $Ni^{2+}$ (mg/L)
Ce = final concentration of $Ni^{2+}$ (mg/L)
V = total volume (L)
m = adsorbent mass (g)

Calculation of adsorption efficiency of chitosan-activated carbon adsorbent against $Ni^{2+}$ can be calculated by the formula Equation (2) by (Choi, 2019).

$$Eff\ (\%) = \frac{C_o - C_e}{C_o}\ x\ 100\% \tag{2}$$

## 3. Results and Discussion

### 3.1. *Material Composition in Electroplating Process Wastewater*

The research used electroplating process wastewater from an electroplating home industry in Surabaya. The electroplating process wastewater obtained is liquid and light green. Based on the results of the AAS analysis of the raw materials of the electroplating process, the liquid waste used in this study is obtained in Table 1. From the results of this analysis, it can be seen that the Ni2+ concentrations are quite large, namely 200 mg/L, where, based on the gubernatorial regulation, this amount does not meet the permitted standard because it is 1 mg/L.

**Table 1.** Characteristics of Heavy Metals in Electroplating Waste from Home Industry “X”

| Parameter | Concentrations (mg/L) |
|---|---|
| TSS | 18,5 |
| Total Cyanide (CN) | <0,002 |
| Hexavalent Chrome ($Cr^{6+}$) | <0,0073 |
| Total Chrome (Cr) | <0,0344 |
| Copper (Cu) | 0,0597 |
| Zink (Zn) | 0,0679 |
| Nickel (Ni) | 200 |
| Cadmium (Cd) | <0,0102 |
| Lead (Pb) | <0,0865 |
| pH | 7,0 |

### 3.2. *Color Comparison of Electroplating Process Wastewater before and after the Adsorption Process*

Based on Figure 2, the color comparison of the electroplating process wastewater before and after adsorption can be seen. The color of the electroplating process wastewater, previously light green, became colorless after adsorption. According to

(Djaenudin and Permana, 2017), the decrease in $Ni^{2+}$ ion concentration can be observed directly through changes in wastewater color. Waste that was originally green becomes colorless, or the color fades. The green color contained in wastewater indicates the presence of dissolved $Ni^{2+}$ concentrations. The fading of the green color indicates a decrease in the concentration of dissolved $Ni^{2+}$ (Djaenudin and Permana, 2017). Based on this, the chitosan/activated carbon adsorbent can reduce dissolved $Ni^{2+}$ concentrations in electroplating process wastewater.


**Figure 2**. Color Comparison of Electroplating Process Wastewater Before and After the Adsorption Process (from left to right)

### *3.3. Effect of Chitosan and Activated Carbon Ratio in Adsorbent on $Ni^{2+}$ Adsorption Efficiency Value*

Based on Figure 3 shows that the best adsorption efficiency is in the chitosan: activated carbon ratio of 0.5: 1.5 grams/gram or 0.33 grams/gram. In comparison, the lowest adsorption efficiency is in the chitosan: activated carbon ratio of 1.5: 0.5 grams/gram or 3 grams/gram. This shows that the greater the mass of chitosan and the smaller the mass of activated carbon in the composition of the chitosan/activated carbon adsorbent ratio, the lower the $Ni^{2+}$ adsorption efficiency. Adding activated carbon mass, which is higher than adding chitosan mass in the chitosan/activated carbon adsorbent, can increase the adsorption efficiency. The results of research conducted by (Purnama Sari, Agusnar and Taufik, 2019) showed that in chitosan adsorbent added with activated carbon, the absorption efficiency of $Ni^{2+}$ concentrations reached the highest number, namely 73.43%. In contrast, the lowest absorption efficiency for $Ni^{2+}$ concentrations of 57.71% was obtained in chitosan adsorbent that did not contain activated carbon. According to (Lestari, Rodiah and Asnari, 2024), increasing the amount of chitosan used in the heavy metal ion adsorption process will cause the distance between chitosan particles to become tighter. This could prevent metal ions from binding to the active side of chitosan. As a result, not all metal ions can be adsorbed. According to (Suwazan et al., 2022), cellulose-based activated carbon has a relatively strong ability to absorb metal ions. In this study, the activated carbon comes from cellulose extracted from coconut shells. In addition, the addition of activated carbon to chitosan as a composite adsorbent can enlarge surface pores to increase the absorption efficiency of heavy metal ions in electroplating process wastewater (Suwazan et al., 2022). The less mass addition of activated carbon used, the lower the percentage of effectiveness of $Ni^{2+}$ reduction by chitosan/activated carbon adsorbent.

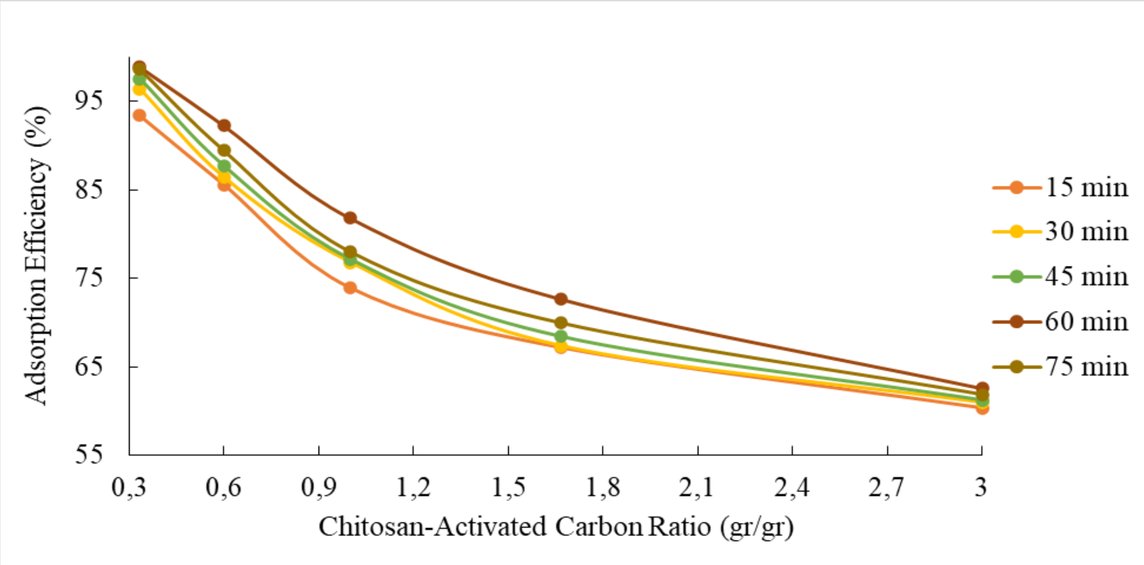



**Figure 3**. Ratio of Chitosan/Active Carbon Relationship with Adsorption Efficiency at Various Contact Times (0,5gr/1,5gr = 0,33 gr/gr ; 0,75gr/1,25gr = 0,6 gr/gr ; 1gr/1gr = 1 gr/gr; 1,25gr/0,75gr = 1,66 gr/gr; 1,5gr/0,5gr = 3 gr/gr)

*3.4. Effect of Chitosan and Activated Carbon Ratio in Adsorbent on $Ni^{2+}$ Adsorption Capacity Value*

Based on Figure 4 shows that the best adsorption capacity is in the chitosan: activated carbon ratio of 0.5: 1.5 grams/gram or 0.33 grams/gram. The lowest adsorption capacity is in the chitosan: activated carbon ratio of 1.5: 0.5 grams/gram or 3 grams/gram. This shows that the greater the mass of chitosan and the smaller the mass of activated carbon in the composition of the chitosan/activated carbon adsorbent ratio, the value of $Ni^{2+}$ adsorption capacity decreases. This statement is supported by (Alves et al., 2021), who revealed that the adsorption capacity of chitosan in the absorption of metal ions is lower than that of activated carbon, where the adsorption capacity of chitosan is 10 mg/g while the adsorption capacity of activated carbon is 10.3 mg/g. According to (Sharififard, Nabavinia and Soleimani, 2016), the adsorption capacity value of chitosan is lower than that of activated carbon. This is due to the smaller surface area and pore volume of chitosan compared to activated carbon. In addition, the increase in the mass of chitosan used can reduce the value of $Ni^{2+}$ adsorption capacity by chitosan/activated carbon adsorbent.

The combination of chitosan and activated carbon produces hydrogen bonds, which indicates that the chitosan-activated carbon adsorbent has a stronger bond so that when applied to heavy metal ions of electroplating process wastewater, it will produce higher adsorption capacity and efficiency (Suhendi, 2023). Based on Figures 3 and 4, it can be concluded that adding activated carbon can increase the value of adsorption efficiency and capacity. The addition of activated carbon can affect the structure of the chitosan film or matrix to become rougher, denser, or layered. This impacts the mechanical stiffness, thermal stability, or flexibility of the chitosan/activated carbon composite. On the surface of activated carbon, there is also an attractive interaction between $Ni^{2+}$ ions and negatively charged carbonyl functional groups (Wijayanti, 2022). Chitosan contains amine groups ($-NH_2$) and hydroxyl groups (-OH), which can form coordination bonds with $Ni^{2+}$ ions. In this process, the free electron pairs from nitrogen or oxygen atoms in chitosan function to form coordination bonds with $Ni^{2+}$ ions so that the adsorption process becomes more optimal. (Ardana, 2014).

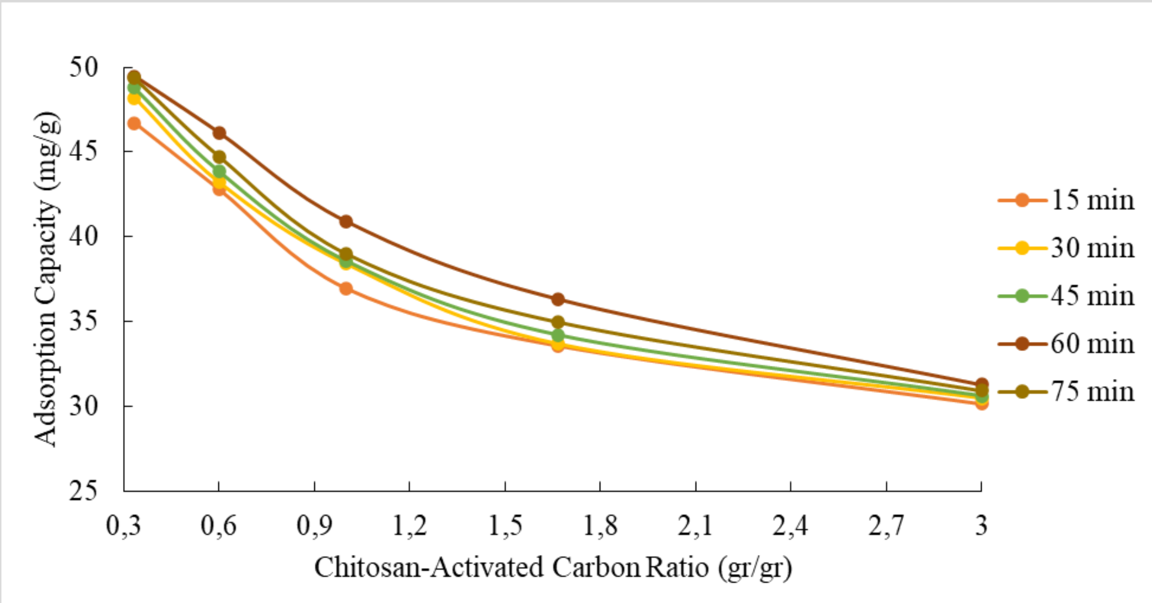



**Figure 4.** Ratio of Chitosan/Active Carbon Relationship with Adsorption Capacity at Various Contact Times (0,5gr/1,5gr = 0,33 gr/gr ; 0,75gr/1,25gr = 0,6 gr/gr ; 1gr/1gr = 1 gr/gr; 1,25gr/0,75gr = 1,66 gr/gr; 1,5gr/0,5gr= 3 gr/gr)

*3.5. Effect of Contact Time on $Ni^{2+}$ Adsorption Efficiency Value*

Based on Figure 5, the adsorption efficiency tends to increase with the increased adsorption process time. The highest adsorption efficiency of 98.92% was obtained in the 60-minute contact time condition with a chitosan/activated carbon ratio of 0.5/1.5 gram/gram. The lowest adsorption efficiency was received at 60.30% in the 15-minute contact time condition with a chitosan/activated carbon ratio of 1.5/0.5 grams/gram. This shows that the longer the adsorption process time, the more $Ni^{2+}$ is absorbed. However, the adsorption efficiency in all ratio variables decreased at 75 minutes of adsorption process time. According to (Fahnur et al., 2024), the efficiency of the adsorption process on the adsorbent increases rapidly when in contact with the adsorbate. It continues to increase until it reaches the equilibrium point. However, after reaching the equilibrium point, the adsorption efficiency decreases. This is because metals that have been adsorbed can be rereleased. After all, they can no longer bind to the adsorbent. Based on this, the 60-minute adsorption process time is the equilibrium point so that when the adsorption process time exceeds 60 minutes, the adsorption efficiency decreases.

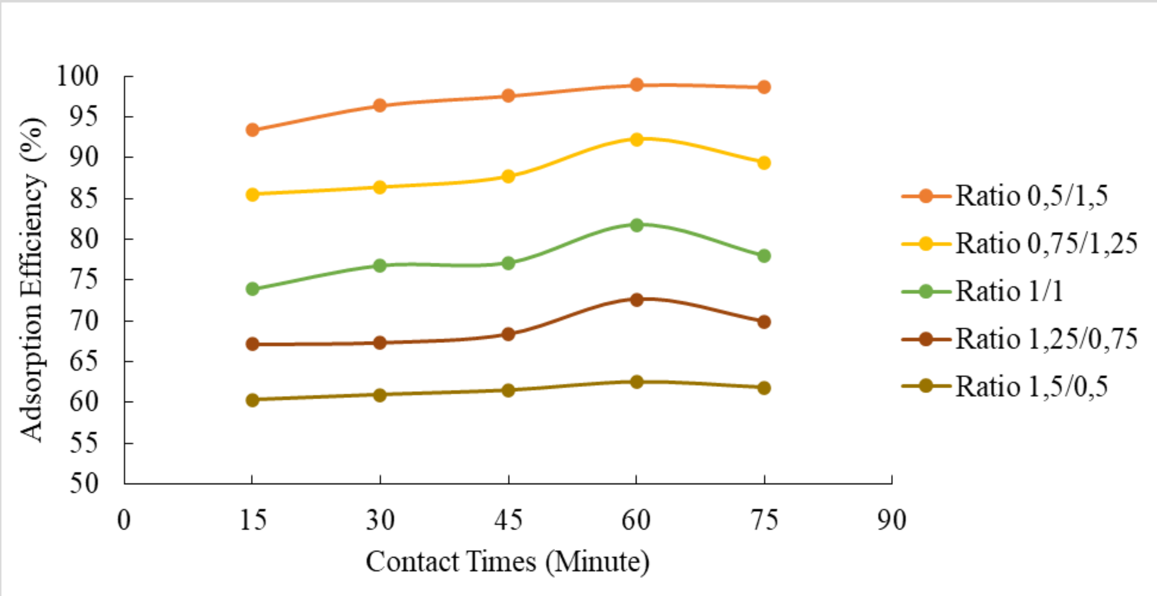



**Figure 5.** Relationship between Contact Time and Adsorption Efficiency at Various Chitosan/Active Carbon Ratios

*3.6. Effect of Contact Time on $Ni^{2+}$ Adsorption Capacity Value*

Based on Figure 6, the adsorption capacity tends to increase with the increased adsorption process time. The highest adsorption capacity of 49.46 mg/g was obtained in the 60-minute contact time condition with a chitosan/activated carbon ratio of 0.5/1.5 gram/gram. Meanwhile, the lowest adsorption capacity was received at 30.15 mg/g in the 15-minute contact time condition with a chitosan/activated carbon ratio of 1.5/0.5 grams/gram. This shows that the longer the adsorption process time, the more $Ni^{2+}$ is absorbed. However, the adsorption capacity in all ratio variables decreased at 75 minutes of adsorption process time. According to (Siswanti, Oktafiana and Putri, 2024), the decrease in adsorption capacity at a contact time of 75 minutes is due to achieving adsorption equilibrium conditions, where the adsorption rate is relatively equivalent to the desorption rate. The longer the adsorption time required to reach the optimum capacity before equilibrium conditions are reached, the more collisions occur between the adsorbate and adsorbent. As the duration of contact time increases, more adsorbate will be adsorbed on the active sites of the adsorbent. However, after the optimum time is reached, there will be a decrease in adsorption capacity. This is due to most of the active sites of the adsorbent being filled and saturated with adsorbate, so only a small number of active sites remain available for the adsorption process. In addition, after saturation conditions, there is also the possibility of the release of adsorbates that have interacted with the adsorbent into the solution.

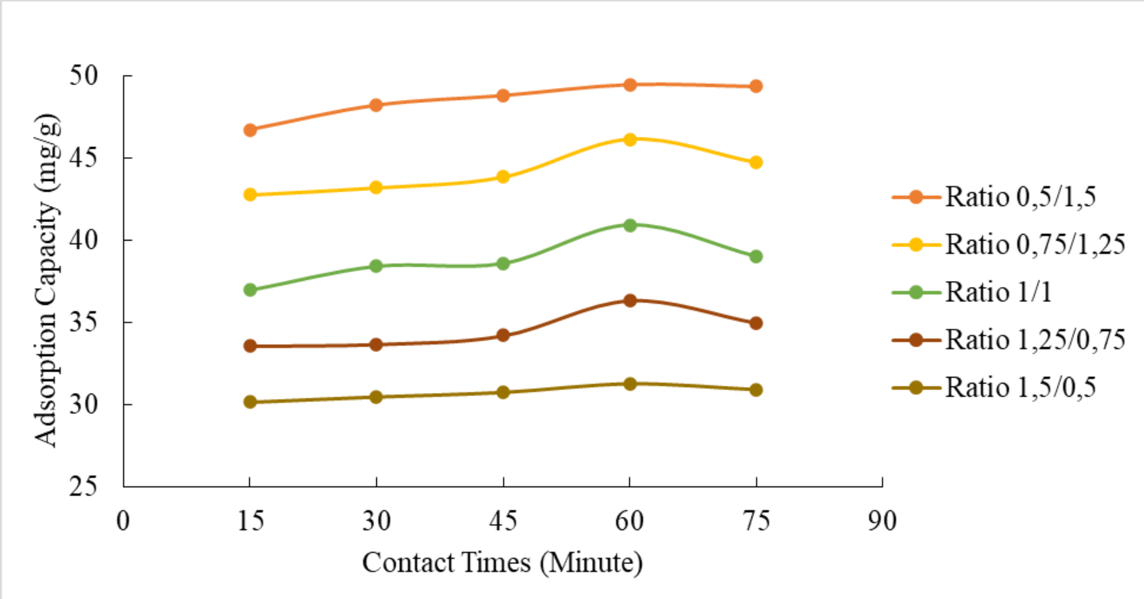



**Figure 6**. Relationship between Contact Time and Adsorption Capacity at Various Chitosan/Active Carbon Ratio

*3.7. Characterization Results of Chitosan/Activated Carbon Adsorbent with Sem-EDX*

SEM-EDX characterization is intended to see the morphology, pore size, and elements of the chitosan/activated carbon adsorbent. The chitosan/activated carbon ratio sample of 0.5/1.5 grams/gram and adsorption time of 60 minutes were used because it produced the highest $Ni^{2+}$ adsorption efficiency and capacity compared to other samples. Characterization using SEM-EDX with a magnification of 1500x can be seen in Figure 7 and Figure 8. Based on Figure 7, it can be seen that the surface morphology of the chitosan/activated carbon adsorbent before adsorption is in the form of coarse flakes that are spread with varying and irregular sizes. Figure 8 shows that the surface morphology of the chitosan/activated carbon adsorbent after adsorption is in the form of chunks with a more even surface. Still, there is accumulation in several parts called agglomeration. Agglomeration occurs due to the formation of imperfect crystals caused by the irregular arrangement and distance between particles. Then, the pore size calculation is carried out using the SEM-EDX analysis image processing method. In the chitosan/activated carbon adsorbent before adsorption, the pore diameter was 117.96 nm, and the pore radius was 58.98 nm. Meanwhile, in the chitosan/activated carbon adsorbent after adsorption, the pore diameter was 7.28 nm, and the pore radius was 3.64 nm. Based on the calculation results, it can be concluded that there is a decrease in pore size before and after adsorption. This is in line with research by (Maharani and Sa'diyah, 2023), which states that after the adsorption process is carried out, the surface of the adsorbent will be covered by metal ions so that the pore size will decrease.

Based on Figure 9, the dominant elements in chitosan/activated carbon adsorbents are C and O atoms. This is because chitosan is a polysaccharide polymer, while coconut shell-activated carbon is a polymer in the form of a cellulose chain. The polymer structure of coconut shell-activated carbon based on cellulose shows a relatively strong chemical adsorption capacity for metal ions and organic bases. Chitosan/activated carbon adsorbents have a $Ni^{2+}$ concentration of 5.99% after adsorption. This shows that chitosan/activated carbon adsorbents can adsorb $Ni^{2+}$ ions in electroplating process wastewater.

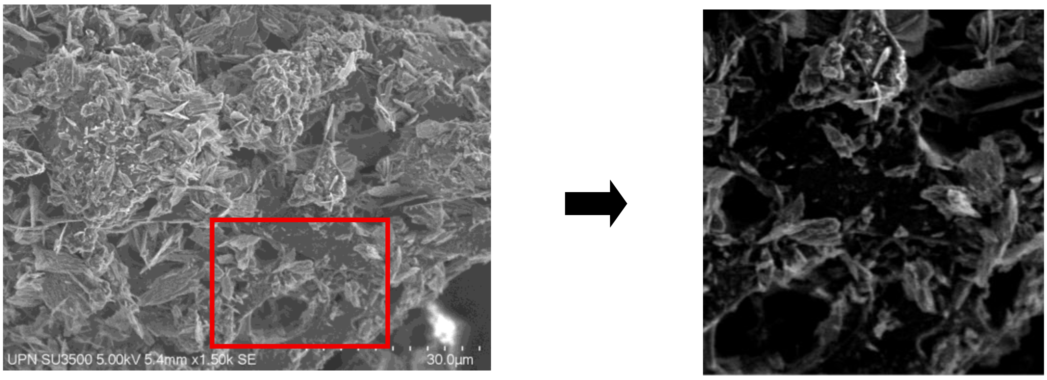



**Figure 7.** Characterization Results and Scale-Up of Chitosan/Activated Carbon Adsorbent Before Adsorption Using SEM-EDX with 1500x magnification

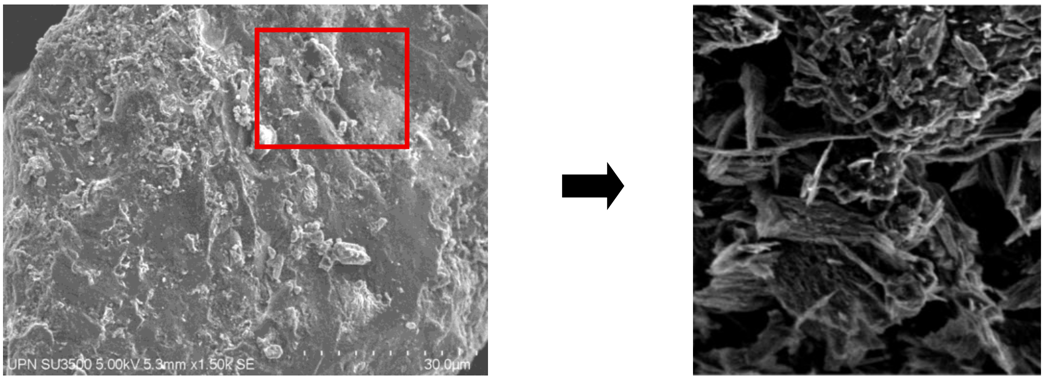
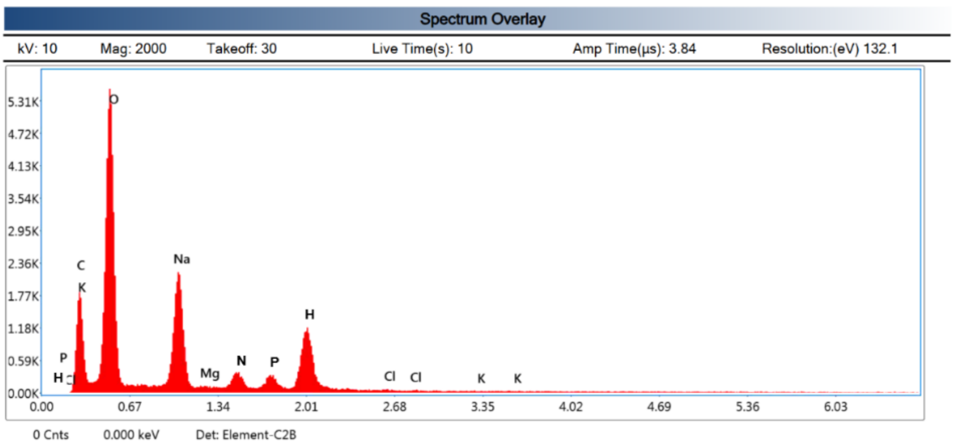
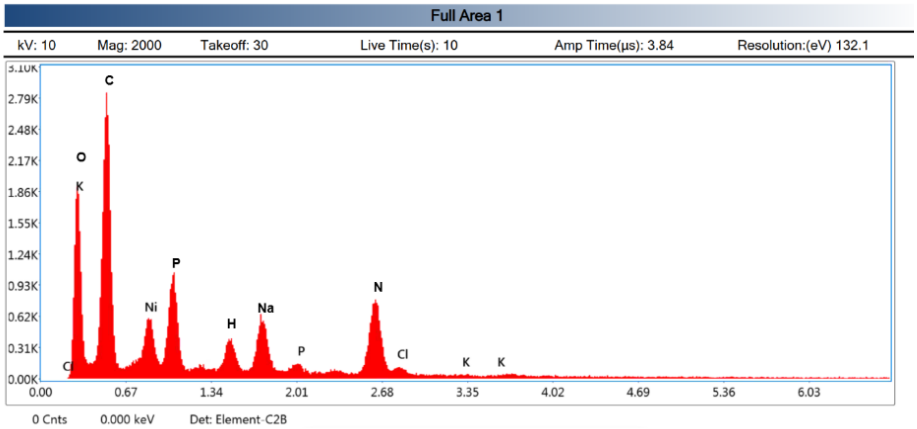



**Figure 8.** Characterization Results and Scale-Up of Chitosan/Activated Carbon Adsorbent After Adsorption Using SEM-EDX with 1500x magnification




(a)




(b)

**Figure 9.** Spectrum of Elements Composing Chitosan/Activated Carbon Adsorbent Using SEM-EDX with magnification (a) Before Adsorption (b) After Adsorption

## 4. Conclusion

The optimal conditions for the chitosan/activated carbon adsorbent were established with a mass ratio of 0.5 grams of chitosan to 1.5 grams of activated carbon, combined with an adsorption contact time of 60 minutes. Under these parameters, the final concentration of $Ni^{2+}$ post-adsorption was measured at 2.17 mg/L, achieving an adsorption efficiency of 98.92% and an adsorption capacity of 49.46 mg/g. An increase in the proportion of chitosan relative to activated carbon was observed, resulting in a decreased capacity for the adsorption of $Ni^{2+}$ from electroplating process wastewater. Furthermore, extending the adsorption contact time significantly enhanced the amount of $Ni^{2+}$ that was effectively adsorbed from the electroplating process wastewater.

## References

Alves, D.C., Healy, B., Pinto, L.A. d. A., Cadaval, T.R.S. and Breslin, C.B., 2021. Recent developments in Chitosan-based adsorbents for the removal of pollutants from aqueous environments. *Molecules*, 26, pp.1–45. https://doi.org/10.3390/molecules26030594.

Choi, H.J., 2019. Applicability of composite beads, spent coffee grounds/chitosan, for the adsorptive removal of pb(Ii) from aqueous solutions. *Applied Chemistry for Engineering*, 30(5), pp.536–545. https://doi.org/10.14478/ace.2019.1039.

Djaenudin, D. and Permana, D., 2017. The Effect of Iron Ion to the Removal of Nickel Ion From Electroplating Wastewater Using Double Chamber Electrodeposition Cell (DCEC) Reactor. *Molekul*, 12(1), pp.14–22. https://doi.org/10.20884/1.jm.2017.12.1.232.

Emi, E. and Ahmad, R.A., 2022. Penentuan Konstanta Penjerapan Logam Nikel Pada Limbah Elektroplating Dengan Metode Adsorpsi Secara Continue Menggunakan Adsorben Eceng Gondok Teraktivasi. *Jurnal Kimia dan Rekayasa*, 2(2), pp.39–49.

Fahnur, H., Mawardi, R., Nurdin, M.I. and Widiyanti, E., 2024. Daya Serap Karbon Aktif Cangkang Kelapa Sawit ( *Elaeis Guineensis* ) Pada Proses Filtrasi Pengolahan Air. *Teknologi Pertanian*, 17(02), pp.195–204.

Hernaningsih, T., 2016. Tinjauan Teknologi Pengolahan Air Limbah Industri dengan Proses Elektrokoagulasi. *Jurnal JRL*, 9(1), pp.31–46.

Kosim, M.E., Siskayanti, R., Prambudi, D. and Rusanti, W.D., 2022. Perbandingan Kapasitas Adsorpsi Karbon Aktif Dari Kulit Singkong Dengan Karbon Aktif Komersil Terhadap Logam Tembaga Dalam Limbah Cair Elektroplating. *Jurnal Redoks*, 7(1), pp.36–47. https://doi.org/10.31851/redoks.v7i1.6637.

Kurniasih, M., Riyani, K., Setyaningtyas, T. and Sufyana, I., 2018. Adsorpsi Ion Ni(II) Menggunakan Crosslink Kitosan Tripolifosfat. *Jurnal Rekayasa Kimia & Lingkungan*, 13(2), pp.174–181. https://doi.org/10.23955/rkl.v13i2.11725.

Lestari, D.W., Rodiah, S. and Asnari, M., 2024. Pemanfaatan Kitosan Sebagai Adsorben untuk Menurunkan Kadar Logam Tembaga (Cu), Besi (Fe), dan Timbal (Pb). *Multidisciplinary Journal Of Sciences and Research*, 2(01), pp.61–68. https://doi.org/10.62668/phenomenon.v2i01.1120.

Madiabu, M.J., Untung, J. and Solihat, I., 2021. Studi Kesetimbangan Isotherm Adsorbsi Logam Nikel(Ii) Pada Limbah Cair Menggunakan Cangkang Telur : Adsorben Berbiaya Murah. *Warta Akab*, 44(2). https://doi.org/10.55075/wa.v44i2.16.

Maharani, D.F. and Sa'diyah, K., 2023. Adsorpsi Logam Nikel Menggunakan Adsorben Serbuk Gergaji Kayu. *DISTILAT: Jurnal Teknologi Separasi*, 7(2), pp.170–178. https://doi.org/10.33795/distilat.v7i2.216.

Pratika, A.R. and Widiono, B., 2020. Studi Literatur Pengolahan Limbah Cair Elektroplating Untuk Mengurangi Kadar Logam Nikel Dan Tss (Total Suspended Solid) Menggunakan Elektrokoagulator. *DISTILAT: Jurnal Teknologi Separasi*, 6(2), pp.346–353. https://doi.org/10.33795/distilat.v6i2.120.

Pratiwi, Y., Sunarsih, S. and Dewi, K.P., 2019. Pengolahan Limbah Cair Industri Elektroplating Dengan Fitoremediasi Menggunakan Azolla Microphylla. *Jurnal Teknologi*, 12(1), pp.54–62.

Prehatini, H.S. and Amaria, A., 2023. Pengaruh Penambahan Kitosan pada Silika Abu Sekam Padi sebagai Adsorben Kitosan-Silika untuk Menurunkan Ion Pb(II). *Unesa Journal of Chemistry*, 12(2), pp.64–72. https://doi.org/10.26740/ujc.v12n2.p64-72.

Purnama Sari, F., Agusnar, H. and Taufik, M., 2019. Preparation and Characterization of Chitosan with Activated Carbon as Adsorbent to Reduce Level Metal Cadmium (Cd) and Nickel (Ni). *ICOCSTI*, pp.280–286. https://doi.org/10.5220/0008921802800286.

Santoso, A.B.T., 2023. Pengaruh Karbon Aktif 60 Mesh Terhadap Kadar Logam Nikel Pada Limbah Industri Elektroplating Alif Bagus Tadji Santoso Bellina Yunitasari. *JTM*, 12(03), pp.83–86.

Sharififard, H., Nabavinia, M. and Soleimani, M., 2016. Evaluation of adsorption efficiency of activated carbon/chitosan composite for removal of Cr (VI) and Cd (II) from single and bi-solute dilute solution. *Advances in Environmental Technology*, (4), pp.215–227. https://doi.org/10.22104/aet.2017.484.

Siswanti, S., Oktafiana, A.H. and Putri, Y., 2024. Adsorpsi Zat Warna Remazol Brilliant Blue R Pada Limbah Industri Batik Menggunakan Adsorben dari Mahkota Buah Nanas. *Eksergi*, 21(1), pp.9–16. https://doi.org/10.31315/e.v21i1.10669.

Suwazan, D., Nurhidayanti, N., Fahmi, A.B. and Riyadi, A., 2022. Pemanfaatan Kitosan Dan Karbon Aktif Dari Ampas Teh Dalam Menurunkan Logam Kadmium Dan Arsen Pada Limbah Industri Pt X. *Jurnal Reka Lingkungan*, 10(2), pp.91–102. https://doi.org/10.26760/rekalingkungan.v10i2.91-102.

Wijayanti, I.L.D. and Mahatmanti, F.W., 2022. Synthesis of Chitosan/Activated Carbon Composite Beads as an Adsorbent of Pb(II) and Cu(II) ions in Aqueous Solution: A Review. *Indonesian Journal of Chemical Science*, 11(2), pp.190–197. https://doi.org/10.15294/ijcs.v11i2.54943.

Zuhrah, P.F., Elystia, S., Zultiniar, Z. and Sari Ermal, D.A., 2022. Penyisihan Logam Cr (Vi) Dari Limbah Cair Elektroplating Menggunakan Adsorben Beads Komposit Chitosan-Clay. *Jurnal Sains dan Teknologi: Jurnal Keilmuan dan Aplikasi Teknologi Industri*, 22(2), pp.252–266. https://doi.org/10.36275/stsp.v22i2.513.