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Prof. Dr Ana Radojević

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Original Research

CHANGE IN METAL REMOVAL DEGREE DURING COPPER ION BIOSORPTION
ONTO RAW AND CALCINED CHICKEN EGGSHELLS

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Abstract

Copper ion biosorption using raw and calcined chicken eggshells as biosorbents was conducted. The change in metal removal degree over time was monitored. Biosorption experiments were carried out in batch conditions for 90 minutes, as this duration is considered sufficient to reach equilibrium between phases. The experiments were conducted at three temperatures: 25 °C, 30 °C, and 35 °C. The results showed that the Cu²⁺ removal degree increased with time for both raw and calcined chicken eggshells. The results also indicated that system temperature significantly affects the efficiency of the biosorption process. Copper ion biosorption onto raw eggshells was considerably faster and more efficient, with a higher copper removal degree at higher temperatures. Biosorption onto calcined eggshells was less dependent on temperature, with Cu²⁺ removal being slightly faster at 35 °C, but the overall efficiency remained the same at all temperatures.

Keywords: biosorption, metal removal degree, raw chicken eggshells, calcined chicken eggshells.

INTRODUCTION

Heavy metal water pollution is considered a serious problem due to its toxic effects on the environment. Many industries, including mining and metallurgy, generate significant amounts of wastewater and contribute to environmental pollution [1]. Various conventional methods are employed at the industrial level to treat wastewater, including adsorption, ion exchange, precipitation, cementation, and others. However, these methods have certain disadvantages, such as insufficient metal removal, toxic sludge generation, and high economic cost. In this context, adsorption of heavy metals using natural biosorbents, or biosorption, represents a potential method for wastewater treatment. Figure 1 shows the operational ranges of selected wastewater treatment technologies. It can be seen that biosorption is a potential alternative to conventional methods in the low concentration range, between 0.001 and 100 mg dm⁻³ [2–5].

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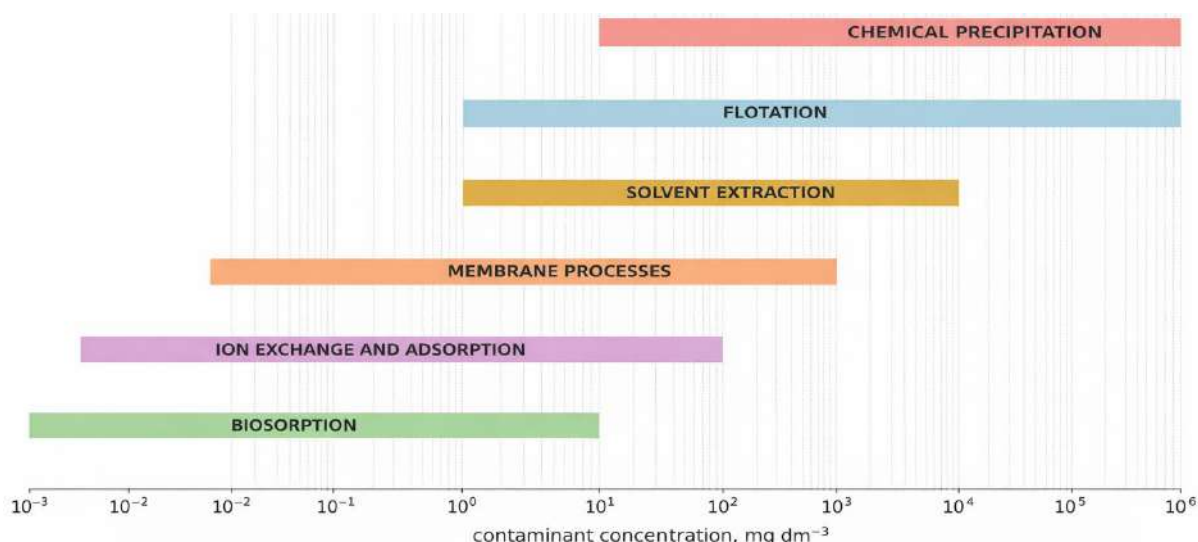


Figure 1 Operational ranges of certain wastewater treatment methods [5]

Biosorption is a physicochemical process for removing substances from a solution using biological materials as adsorbents. It relies on the ability of certain biomass to bind ions or molecules from aqueous solutions through various physicochemical and metabolic mechanisms [4,6].

The biosorption process offers several advantages over conventional wastewater treatment methods, including [7]:

- Low cost,
- Ability to remove heavy metals from wastewater at low concentrations,
- Ability to remove multiple heavy metals simultaneously,
- Capacity to treat large volumes of wastewater,
- No need to add chemicals,
- Functionality across a wide range of operational conditions, including process temperature, solution pH, and the presence of other metals,
- Low amounts of generated waste and toxic materials.

However, this process also has certain disadvantages, including [7]:

- Saturation of active sites within biosorbents,
- In some cases, reversible sorption of metal ions on the biomass.

MATERIALS AND METHODS

Chicken eggshells used for biosorbent preparation were collected from households in eastern Serbia. The collected raw chicken eggshells (RCE) were ground and sieved using laboratory sieves, and the (-1+0.4 mm) fraction was used for biosorption experiments. Calcined chicken eggshells (CCE) were prepared by calcining the raw chicken eggshells at 900 °C in a chamber furnace. Figures 2 and 3 show the raw and calcined chicken eggshell samples.



Figure 2 Raw chicken eggshells (RCE)

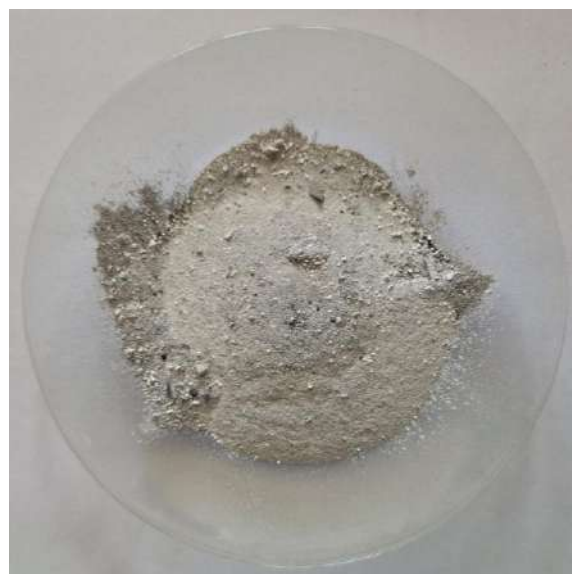


Figure 3 Calcined chicken eggshells (CCE)

Synthetic Cu^{2+} ion solutions were used for the biosorption experiments. The RCE and CCE samples were rinsed with distilled water before the biosorption experiments. Cu^{2+} concentrations in the solutions were determined using a Spectroquant Pharo 300 (Merck) spectrophotometer. The degree of copper removal was calculated based on the material balance using the following equation:

$$RD \% = \left(1 - \frac{C_{(t)}}{C_i} \right) \cdot 100 \quad (1)$$

where: C_i and $C_{(t)}$ – are the initial and current copper ion concentrations, at time t (g dm^{-3});
 RD % – is the metal removal degree (%).

RESULTS AND DISCUSSION

To determine the copper removal degree using RCE as a biosorbent, 0.05 dm^3 of the solution (initial concentration 0.5 g dm^{-3}) was brought into contact with 1 g of the biosorbent sample for various process times, ranging from 1 to 90 minutes. The biosorption experiments were conducted at three different temperatures: 25°C , 30°C , and 35°C . After the biosorption experiments, the suspension was filtered, and the filtrate was analyzed for Cu^{2+} content. The Cu^{2+} removal degree was calculated using Equation (1). The results are shown in Figure 4.

The copper removal degree onto CCE was determined performing the same experiments, with the only different process parameter being the initial Cu^{2+} concentration of 5 g dm^{-3} in this case. The obtained results are shown on Figure 5.

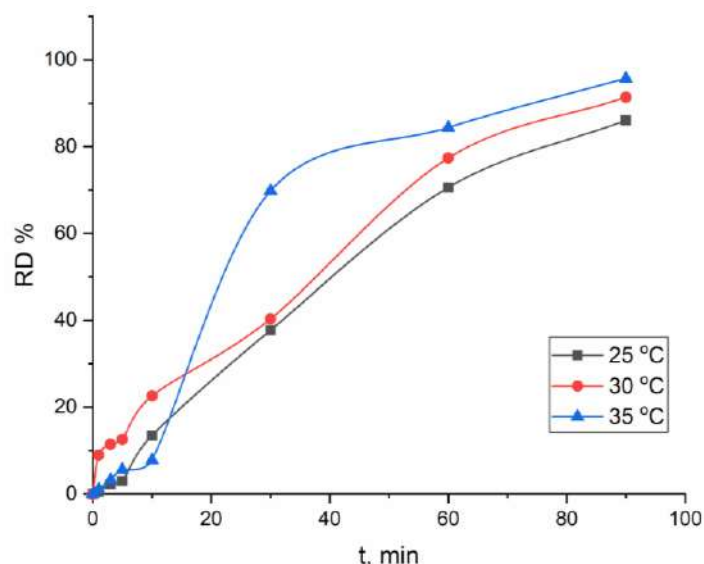


Figure 4 Change in the removal degree with time during copper ions biosorption onto RCE, on different temperatures

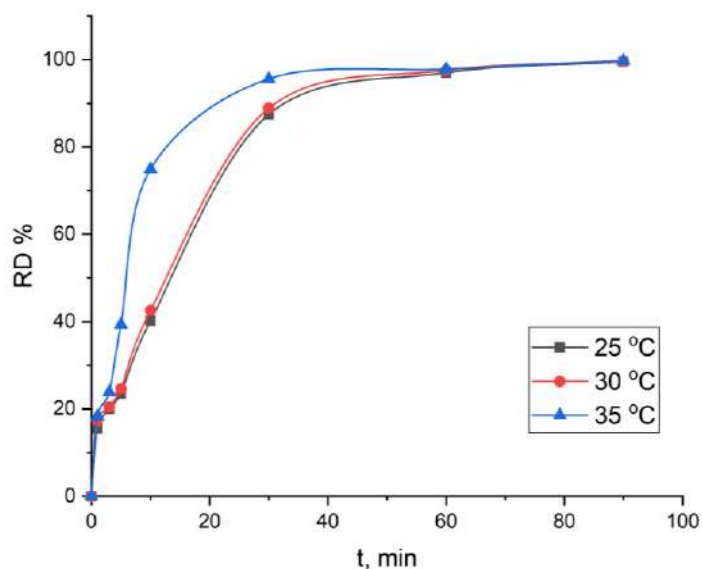


Figure 5 Change in the removal degree with time during copper ions biosorption onto CCE, on different temperatures

The obtained results show that the degree of metal removal increases with time during the biosorption of copper ions onto RCE (Figure 4) at all analyzed temperatures. It is also evident that system temperature is an important process parameter influencing the biosorption rate and efficiency. The degree of copper removal increased more rapidly at 35 °C, suggesting that the process is faster at higher temperatures. The recorded removal degree at 35 °C after 90 minutes was significantly higher (96%) than those at 30 °C (91%) and 25 °C (86%), indicating that system temperature plays a key role in biosorption efficiency in this case.

The results shown in Figure 5 indicate that the biosorption of Cu^{2+} ions onto CCE is less dependent on temperature. The degree of metal removal increases with time at all analyzed temperatures. The removal degree increased slightly faster at 35 °C compared to other

temperatures, with the final removal degree (after 90 minutes) reaching nearly 100% at all three temperatures.

CONCLUSION

Environmental protection is a crucial topic in the 21st century. Heavy metal wastewater pollution, including copper contamination, is a major environmental problem today. Recently, the scientific community has focused on investigating the use of various "living" and "non-living" biomass for removing pollutants from aqueous solutions and wastewater. This work demonstrates the potential of raw and calcined chicken eggshells for copper ion biosorption from aqueous solutions.

The results showed that both raw and calcined chicken eggshells are efficient biosorbents for copper ion removal, achieving high removal rates. In both cases, a metal removal rate of over 90% was recorded at all analyzed temperatures. However, the results also indicate that system temperature affects the process rate in both cases. Higher metal removal rates were observed at higher temperatures during the biosorption of copper ions onto raw chicken eggshells. Biosorption onto calcined chicken eggshells was shown to be less dependent on system temperature.

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