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# Removal of $Zn^{2+}$ From Aqueous Solution Using Chicken Eggshell As Bioflocculant

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## Abstract

*Heavy metals in water resources pose a health and environmental risk because the majority of them cannot be destroyed and may accumulate in the food chain. It may be removed from aqueous solution very easily via adsorption, a well-known approach for reducing heavy metal concentrations. This study explored the suitability and efficacy of waste chicken eggshells as an adsorbent for the removal of the heavy metal zinc (Zn2+) in aqueous solution. Batch experiments were used to examine the effects of initial metal concentration and adsorption capacity. The UV-Spectrophotometer was used to analyze the final concentration of Zinc metal five times. According to the study's findings, up to 83% of the zinc in an aqueous solution could be removed using chicken eggshells as an adsorbent. The maximum adsorption capacity was 7.287 mg/g at room temperature, 1 g of adsorbent dosage, and a starting concentration of 58 mg/L. Isotherm studies with the Langmuir model emerged having a greater coefficient of determination (R2 = 0.9839) than the Freundlich model (R2 = 0.9744), indicating homogeneous adsorption occurred during the process. Overall, the study showed that the enormous amounts of chicken eggshell, which are typically seen as trash, could actually be an economically useful raw material for the removal of zinc from the water body.*

Keywords: egg shells, biosorption, zinc, adsorption isotherms.

## “1. Introduction”

Wastewater treatment in developing nations is a serious issue, and a solution has proven difficult due to a number of adverse circumstances. The greatest necessity for protecting both the environment and human health is access to clean, safe drinking water. Since millennia, developing nations have had greater trouble than industrialized ones with water and sanitation problems [1]. The quality of water supplies is impacted by the quick development of agricultural operations, industrialization, or environmental changes. The presence of heavy metals in wastewater has led to some pollutants. Consequently, the removal of harmful substances from wastewater prior to disposal is necessary for the maintenance of an environment free of pollution [2]. Industries such as metallurgy, electroplating, metal finishing, tanneries, and chemical manufacture are the primary culprits when it comes to heavy metal contamination in the environment. The absorption of heavy metals into living organisms causes severe poisoning. These metals include lead, mercury, arsenic, copper, zinc, and cadmium [3]. One of the heavy metals utilized is zinc, with a bluish-white appearance and an atomic weight of 65.38 g. Zinc is an active metal that reacts with other heavy metals. Zinc compounds and alloys are widely employed in industrial applications. Zinc, a heavy metal, can create toxic hazards such as carcinogenesis and mutagenesis. Teratogenesis is a byproduct of bioaccumulation [4]. Hence there is notable interest regarding zinc elimination from water bodies and its poisoning for human beings at ranges of 100-500 mg/day [5]. The World Health Organization (WHO) suggested the highest permissible concentration of zinc in potable water as 5.0 mg/l [6]. Heavy metals can be removed using several methods, including adsorption, chemical precipitation, ion exchange, electrodialysis, membrane filtration, reverse osmosis, and flotation [7]. The removal of heavy metal ions from industrial waste streams has recently become more challenging because of the introduction of more stringent regulations and laws that limit the quantity of pollutants in effluents that are released into rivers and soils to less than 1 mg/kg. Therefore, it is necessary to look for novel methods that would be effective at low concentrations of contaminants [8]. This potentiality provides biosorption, In the last several decades, the absorption process, which involves immobilizing metal in polluted water, has drawn attention due to its benefits, which include high efficiency, low operating costs, and environmental friendliness in comparison to conventional treatment techniques [9]. The present research used an inexpensive adsorbent called eggshell to try the adsorption approach. The majority of eggshells are frequently

disposed of in landfills without any kind of preparation. They will cause a number of issues, including an unpleasant smell and a breeding ground for bacteria. Eggshells are typically disposed of as garbage, despite their considerable efficacy in some applications. From a physical standpoint, eggshells resemble mostly crystalline calcium carbonate, the partially chicken bone-derived calcium carbonate. The chicken may readily mobilize 10% of its bone when needed for its own purpose. The purpose of this study is to extract $Zn^{2+}$ from artificial wastewater by using eggshells as a low-cost adsorbent material [10].

## "2. Material and Methods"

### Biosorbent

High nutritional contents, including calcium, phosphorus, and magnesium, are found in eggshells. This allows it to be recycled and utilized as a feed ingredient and fertilizer. The shell makes up between 9 and 12 percent of the overall weight, depending on the size of the egg. About 94% of it is composed of CaCO3, with trace quantities of MgCO3, calcium phosphate, and other organic materials, such as protein, present [11]. The majority of high-quality eggshells from commercial layers have 2.2 grams of calcium in the form of 5.5 grams of CaCO3. The typical eggshell has traces of sodium, potassium, zinc, manganese, iron, and copper in addition to 0.3% phosphorus and 0.3% magnesium [12].

### Adsorbent preparation

In this investigation, the adsorbent was chicken eggshells. To get rid of the dirt particles, the chicken eggshells were gathered from kitchen garbage and boiled for ten minutes after being rinsed several times in deionized water. After being air dried, the eggshells were heated to 300ºC for 20 minutes in a hot air oven, then they were allowed to cool to room temperature or 25 °C. Eggshells were crushed by a grinder into powder form, and the resulting particles with a size range of 0.25 to 0.104 mm were sieved through a 60–100 mesh screen.

### Preparation of Stock Solutions

By dissolving a suitable weight of pure salt (ZnCl2) in the required amount of deionized water, stock solutions (1000 mg/L) of Zn(II) ions were created. 0.250 g of zinc chloride was mixed with 250 ml of water in a volumetric flask to produce 1000 ppm Zn (II), after which Zn (II) ion concentration was determined using a UV spectrophotometer.

### Batch Adsorption Experiment

In conical flasks, a weighed sample of eggshell powder was combined with 250 ml of the metal solution Zn (II), after which the mixture was swirled for a predetermined amount of time at room temperature using a magnetic stirrer. After this process, the mixture was allowed to settle down for some time. Then it was separated from the adsorbent by filtering using a Whatman filter. To overcome the metal's mass transfer barrier between the aqueous and solid phases, the initial metal concentration is crucial. Five different concentration solutions ranging from 50 mg/L to 54 mg/L were prepared in the same manner. Afterwards, these samples were go for testing in a UV spectrophotometer (DR 6000). Using the following formula, the amount of Zn (II) eliminated at equilibrium ($q_e$) was calculated:

$$q_e = \frac{(C_o - C_e)V}{W} \tag{1}$$

The formula for calculating the effectiveness of adsorption (%) was

$$R = \frac{C_o - C_e}{C_o} \times 100\% \tag{2}$$

In this equation,
W (g)= mass of the adsorbent.
V (L)= volume of the aqueous solution containing metal ions.
Co (mg/L) =the initial amount of metal ion loaded.
$C_e$ (mg/L) = the amount of metal ions at equilibrium.
$q_e$ (mg/g) = amount of metal ion removed per gram of adsorbent.
R (%)=percentage removal efficiency.

## "3. Adsorption isotherms"

### Langmuir isotherm model

The underlying premise of this model is that adsorption diffuses at a location on the adsorbent's surface with a homogeneous energy level. There won't be any more space for adsorption. This suggests that the adsorption model

is monolayer in nature if that is the case. The Langmuir isotherm design cab's linear form is represented by the equation that follows:

$$\frac{C_e}{q_e} = \frac{1}{q_m \times K_L} + \frac{C_e}{q_m} \quad (3)$$

where $q_e$ is the amount amount of metal ions removed per gram of adsorbent (mg/g) and Ce is the number of metal ions at equilibrium (mg/L). The Langmuir isotherm constants are $a_L$ (L/mg) and $K_L$ (L/g). The value of $a_L$ from the route and the value of $K_L$ from the curve were estimated using linear charts; the linear charts that were obtained were utilized [13].

**Freundlich isotherm model**

This approach, which has the fundamental premise that adsorption occurs on non-uniform power levels across diverse sites, looks to be the exact opposite of the Langmuir model. Unlike the Langmuir template, it is not of the monolayer kind. This equation may be used to show the linear form of the Freundlich isotherm model:

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e \quad (4)$$

where the heterogeneity variable for the bond distribution is denoted by $K_F$. A graph of ln$q_e$ vs lnCe was obtained as straight rows. The curve and curve were used to compute the constants $K_F$ and 1/n [13].

**Temkin Isotherm model**

The Temkin isotherm can only be used with ion concentrations that are in the middle of the spectrum. The following equation provides the Temkin isotherm model's linear form.

$$q_e = \frac{RT}{b} \ln K_T + \frac{RT}{b} \ln C_e \quad (5)$$

Where, $K_T$ is the Temkin Isotherm Constant (L/g) .b is the Temkin constant (J/mol).

## "4. Data Collection and Analysis"

Table 1. summarizes the values for all batch adsorption parameters.

**Table 1.** Initial and equilibrium concentration of Zn(II) ion

| Sample | $C_o$ (mg/L) | $C_e$ (mg/L) | Adsorption Efficiency | Removed Capacity(mg/g) |
|---|---|---|---|---|
| 1 | 50 | 2.15 | 83 | 5.15 |
| 2 | 52 | 2.5 | 80.769 | 5.75 |
| 3 | 54 | 2.75 | 79.629 | 6.4 |
| 4 | 56 | 3.10 | 77.85 | 6.95 |
| 5 | 58 | 3.5 | 75.86 | 7.287 |

**Effect of initial Zn (II) ion concentration**

One important element in the adsorption process is concentration. From 50 mg/L to 58 mg/L was the initial concentration range. Fig. 1. illustrates the percentile of the adsorption efficiency method. It demonstrates how quickly the adsorption process happened at low concentrations. At 50 mg/L, the greatest adsorption efficiency is 83%. The high percentage of adsorption effectiveness suggested that zinc (II) ions mass transfer migration from bulk to eggshell surface occurs quickly. Additionally, the percentage of adsorption efficiency marginally decreases as the concentration rises. Zinc (II) ions diffused to the eggshell's surface at increasing concentrations, after which the intraparticle diffusion model took place. During the first adsorption step, zinc (II) ions quickly saturated the surface active sites. Following that, though, the adsorption process slowed down because of competition amongst zinc (II) ions for attachment to the eggshell surface. The graph in Fig. 2. illustrates the connection between the removal capacity (mg/g) and the initial metal concentration (mg/L). The data points exhibit a rising trend, suggesting that the removal capacity grows in tandem with the starting concentration of the metal ions. This pattern is in line with the theory that better adsorption efficacy is achieved at higher adsorbate concentrations due to increased mass transfer to the absorbent surface.

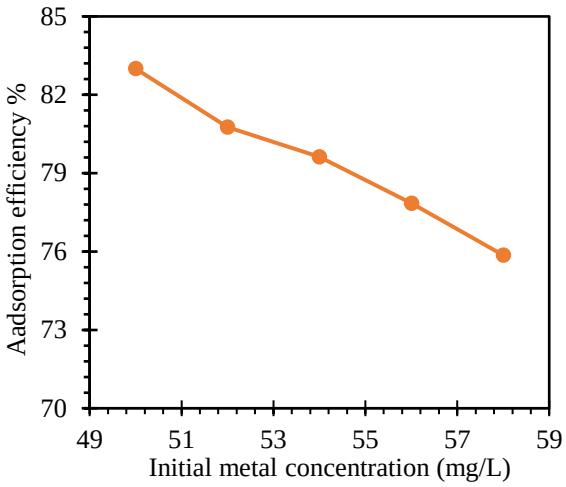



**Fig. 1.** Percentage Adsorption Comparison (R)

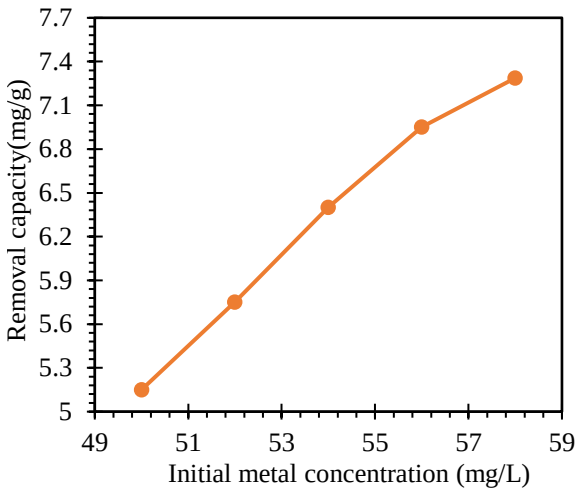



**Fig. 2.** Removal Capacity Comparison ($q_e$)

## "5. Adsorption equilibrium"

Understanding the process of biosorption, or how the adsorbed ions are distributed between the liquid phase and the solid phase composed of the adsorbent, requires an understanding of the equilibrium adsorption isotherms. Several models are fitted to the experimental data and analyzed. The Langmuir, Freundlich, and Temkin isotherm models are used in this work to identify the best model for design purposes. Figures 3,4, and 5 show the plots of the Langmuir, Freundlich and Temkin model equations illustrating Zn (II) biosorption by eggshell powder.

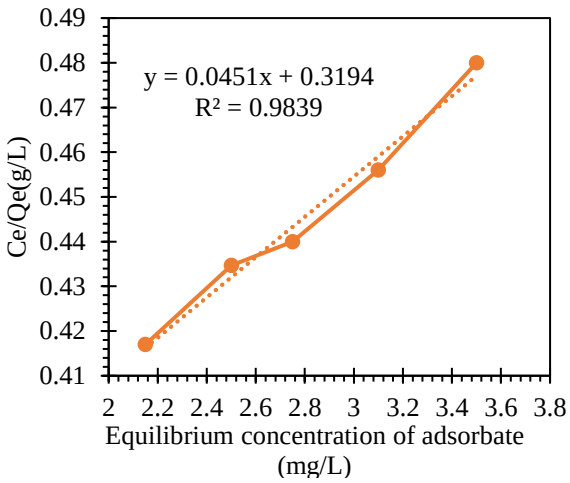



**Fig. 3.** Langmuir Isotherm

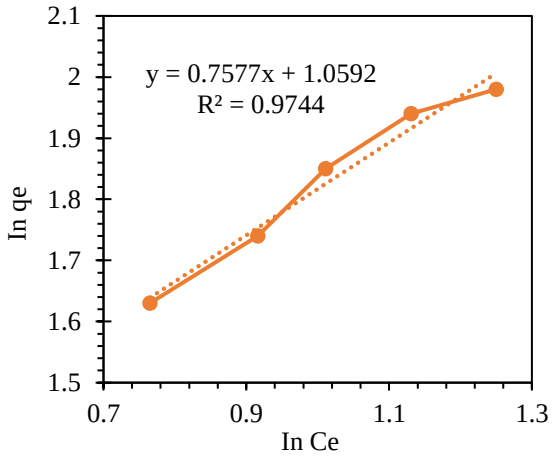



**Fig. 4**. Freundlich Isotherm

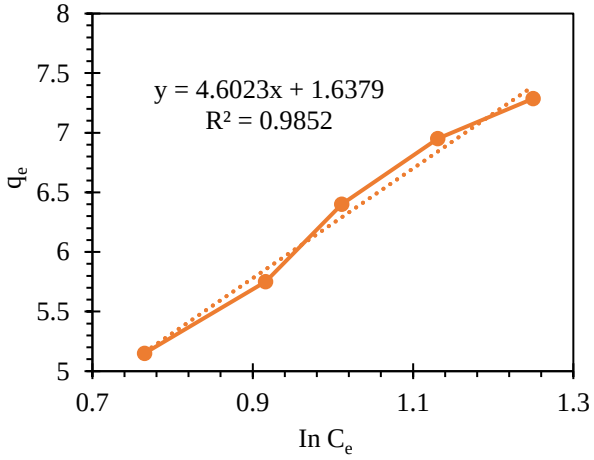



**Fig. 5.** Temkin Isotherm

In addition to the Temkin model, the Langmuir and Freundlich models are frequently utilized to characterize equilibrium sorption isotherms. Table 1, 2, 3. displays the findings of the calculations for the Temkin, Freundlich, and Langmuir isotherm constants.

**Table 2.** Langmuir Isotherm Parameter

| Langmuir Isotherm | | |
|---|---|---|
| $q_m$ (mg/g) | $K_L$(L/mg) | $R^2$ |
| 3.65446395 | 1.097 | 0.9839 |

**Table 3.** Freundlich Isotherm Parameter

| Freundlich Isotherm | | |
|---|---|---|
| $1/n$ | $K_F$ | $R^2$ |
| 0.2735 | 1.5657 | 0.9744 |

**Table 4.** Temkin Isotherm Parameter

| Tempkin Isotherm | | |
|---|---|---|
| b (J/mol) | $K_p$ | $R^2$ |
| 0.89675 | 13.6758 | 0.9852 |

Within the concentration range studied, there was a strong correlation found between the Freundlich and Langmuir equations and the zinc adsorption on egg shell powder when compared to Temkin equations alone. This isotherm's prediction accuracy is lower throughout the examined concentration range, according to the Temkin data analysis.

## "6. Discussion"

The main outcomes 5of the study shows that when Zn (II) ion concentration initially increased, the proportion of Zn (II) ions eliminated dropped. The greatest value of 83% was achieved in Zn (II) ion removal at a starting concentration of 50 mg/L. Conversely, the removal capacity at equilibrium increased as the initial Zn (II) ion concentration rose. The correlation coefficient (R2) values derived from the two adsorption isotherms utilized indicate that the Zn (II) biosorption fits in better with Langmuir than with Freundlich. The Langmuir constant (K) indicates the degree of interaction between the adsorbate and the surface. The $K_L$ value of 1.097 from this investigation indicates how efficiently a certain surface may adsorb a particular solute from a combination with a particular solvent. A higher value of K denotes a strong contact between the adsorbent and the adsorbate, whereas a lower value denotes a weaker relationship in the case of adsorption in the liquid-solid system. The K values that are used to describe the distribution of components between the gas and liquid phases in equilibrium are analogous to this constant. In both cases, K's value can be greater than or equal to one.

## "7. Conclusion"

According to the current study, zinc ions from aqueous solution were effectively adsorbed by the powdered egg shell. Because egg shell powder contains more carbonate groups than other materials, it has a higher capability for biosorption. When 1 g of eggshell powder is added to a 50 mg/L zinc (II) solution and agitated for 20 minutes, the ideal conditions are reached. The adsorption of zinc (II) by eggshells in this study complies with the Langmuir isotherm for adsorption (R2 = 0.9839). It is assumed that monolayer zinc (II) ions develop on eggshell outer surface active sites. There is a direct relationship between the quantity of active sites on eggshell surfaces and the removal capability of zinc (II) ions.

## "8. Acknowledgment"

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