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FACTORS AFFECTING BIOSORPTION OF Cu (II) IONS FROM INDUSTRIAL WASTEWATER

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ABSTRACT

Biosorption is considered a potential alternative for the removal of heavy metals from waste solutions to other conventional processes. The existence of copper in industrial waste water is normally in the structure of bivalent Cu(II) as a hydrolysis product or as $CuCO_3$ in the form of organic complexes and its concentration may reach up to 0.1-0.12g.l^{-1}, which according to the world health organisation water quality standard has to be reduced to 0.0010-0.0015g.l^{-1} to render it non-toxic in the industrial waste water. This study clearly indicates the effect of contact time, particle size, pH, metal concentration as well as biosorbent concentrations on Cu(II) ions removal from industrial effluents.

1. INTRODUCTION

Copper, is among the heavy toxic metal that can be found in the surrounding environment due to industrial processes such as production of electricity appliances, battery manufacturing, production of brass and metallurgical processes [1]. Copper can naturally be exposed through volcanic eruption; fires arising from forest, in the process of vegetation been decayed as well as dust blown by the wind. Likewise, anthropogenic ally, power plants, incinerators and iron foundries can all be a source of copper emission [2]. The existence of copper in industrial waste water is normally in the structure of bivalent Cu(II) as a hydrolysis product or as $CuCO_3$ in the form of organic complexes and its concentration may reach up to 0.1-0.12g.l^{-1}, which according to the world health organisation water quality standard has to be reduced to 0.0010-0.0015g.l^{-1} to render it non-toxic in the industrial waste water [3]. When Cu(II) is been ingested too much into the body more than the limit of > 0.002 g.l^{-1} it result in the increase in the liver thereby leading to anaemia, kidney and gastrointestinal problems [4]. Industrial waste water that contains heavy metals beyond the threshold concentration must undergo treatment before been discharge into the environment. Many treatment processes exist for the treatment of heavy metal found in waste water and the kind of treatment to be applied depends on the concentration of the heavy metals in the effluent. The table below shows concentration of heavy metal in metal finishing wastewater that is not treated [5].

Table1 Concentration of heavy metal in metal finishing wastewater that is not treated.

Heavy metal	Concentration (mg/l)
Cyanide	1-5
Zinc	3-5
Copper	3-5
Nickel	5-10
Chromium	5-10

The treatment methods generally used for heavy metal found in the wastewater comprise: chemical precipitation, adsorption, ion exchange, chemical oxidation [6], and recently biosorption. The aim of this review is to highlight the major factors that affect biosorption of copper from aqueous solution.

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2. BIOSORPTION

The ability of materials (biological) to adsorb heavy metals found in waste water through physical or chemical pathways is termed biosorption [7]. Simply it can be referred as the concentration or binding of heavy metals from wastewater stream by either dead, inactive or plant based biomass. Biosorption have several applications in different industries especially the heavy metals processing ones, which include metal plating, metal processing, mining, battery manufacturing and metal finishing operations. Biosorption is a new alternative to other methods of heavy metal ions removal from wastewater especially industrial wastewater, due to their numerous disadvantages like high cost, partial metal removal and generation of sludge. Low cost, minimisation of sludge production, metal recovery, ability to regenerate the biosorbent and non-requirement of additional chemicals is what makes biosorption to have more advantages over other conventional methods [8]. Biosorbents for metal removal comes under different types of categories such as fungi, bacteria, industrial wastes, algae and agricultural waste [9]. Hence, biosorption is a good applicant for the removal of toxic metals from large volume and lower concentration of aqueous solutions. Copper metal removal by biosorption has so far been investigated throughout the last decades using different biosorbents [10].

2.1 Adsorption Mechanism

For adsorption to occur there must be forces that attract the absorbate to the solid surface in a solution. This mechanism or forces which attract the absorbate to the solution of the solid interface can either be physical or chemical [11]. We can also say it is by donor-acceptor complexion mechanism where atoms of the surface functional group donate electrons to the adsorbate molecules. The position of these functional groups determines the type of adsorbate/adsorbent bond and therefore, decides whether the process is chemical or physical [12].

2.1.1. Physical Adsorption

Physical adsorption (physiosorption) is a reversible method in which there is the attraction of molecules by mechanical forces when the molecules come in contact with the adsorbent. The reversible process depends basically on the force of attraction between the adsorbate and adsorbent. This type of adsorption is multilayer which means that each molecule layer forms on the top of previous with the number layers being proportional to the contaminate concentration [13].

2.1.2. Chemical adsorption

In comparison to physical adsorption, chemical adsorption is an irreversible process which is caused as a result of the reaction taking place between molecules of the adsorbed substance and the adsorbate. It involves the formation of covalent or ionic bonds, consumes high energy and it can occur over wide range of temperature. “Due to its irreversibility, monolayer is expected to form chemisorptions while multilayer is encountered in physiosorption” [11].

2.2 Factors Affecting Biosorption Cu(II) ions

2.2.1. Effect of pH

One of the most important parameter that affects biosorption process is pH. “At low pH, concentration of protons is high and the ion exchange sites become solidly protonated”[14]. Solution chemistry of the metals, metallic ions competition and functional groups activity are all influenced by pH[15]. Studies have shown that the pH solution has an important effect on the biosorption of metal and as the pH solution increases, there is an increase in cation biosorption [16]. Biosorption of Cu(II) ions on biomass is mainly due to ionic attraction and at lower pH values the ionic metals are in competition with the H^+ in the solution [17].

Studies on the effect of pH on the biosorption of copper have been carried out by the use of different types of biomass. For example, the biosorption of copper using wheat-shell was pH dependent, where it is seen that biosorption efficiencies increases from 33% at pH 2 to 95% at pH 5 [18].

Another study by [16] on the biosorption of copper using *Spirogyra species* reveals that an increase in pH from 2.5 to 5, the biosorption capacity increases at all the selected Cu(II) ions concentrations. Further studies by [19] using red alga (*Palmaria palmata*) and beer draff found that at a low pH value of 1.0 almost no adsorption happened, but when pH is raised between 5.0 - 6.0, there was an optimum adsorption on both the materials.

2.2.2. Effect of Temperature

Temperatures have a substantial influence on biosorption. Temperature influence has more effect in a situation where by metal uptake increases within a temperature range of about 20-30^{0}C, but decreases with an increase of temperature above a critical value. An increase of temperature might increase the metal ions kinetic energy which makes it easier for the metal ions to be attached to the biosorbent surface [20]. Different research have shown that the binding of metal ions to the surface of the biosorbent at a low temperature is more rapidly, easily and reversible because of low requirement of energy [21].

Studies by [22], on biosorption of Cu(II) ions using teak leaves at different temperatures show that biosorption decreases with an increase in temperature between 20°C to 40°C, and also the capacity of the sorption (q) decreases thereby making biosorption affinity to decrease at high temperature. Another study by [17] shows that biosorption capacities decreased as the temperature increases from 20 to 50 °C. 20°C and was found to be the optimum between the studied temperature ranges.

Batch biosorption experiments carried out by [23] at a temperature range of 30°C and 50°C shows the variation of first and second order rate constants with temperature. Both rates increased as the temperature increases from 30°C - 50°C due to high frequency of contact between the Cu(II) ions and adsorbent particles.

2.2.3. Effect of Biosorbent Concentration

Biosorbent concentration is one of the factors affecting biosorption. Studies have shown in several researches that as biosorbent dosage increases, the metal uptake decreases. This is as a result of an increase in the surface area of the adsorbent which in turn increases the number of sites available for binding [24]. In a study of Cu(II) removal using teak leaves, the biosorption efficiency was found to increase when the biosorbent concentration was increased [22].

Because of the decrease in surface area per unit of adsorbent [25] found that the equilibrium concentration of copper increases when adsorbent concentration increases. Due to the increased of pre-treated powder waste biosorbent concentration, the first order rate and second order rate constants also increased, this is due to the increased of binding sites of the biosorbent available [23].

2.2.4. Effect of Metal Concentration

Metal concentration is another factor that affects biosorption process. Studies have verified that at higher concentration of metal ions the amount of adsorbed ions is greater than the amount at lower concentration since there are more binding sites for interaction [26]. There is a greater driving force at higher concentration between the solid and liquid interface thus enabling mass transfer.

The biosorption of Cu(II) ions by wheat shell was studied at several different initial copper concentrations ranging from 10 to 250 mg/l.

Biosorption efficiencies decreased with the increasing of initial metal concentrations. The initial metal concentration provides a driving force that overcomes mass transfer resistance of metal ion between the adsorbent and the biosorbent solution [27].

The biosorption percentage decrease may be due to lack of enough surface area to absorb the available metal in the solution [28]. Studies by [17] indicated that initial Cu(II) ion concentration is an important parameter for biosorption of Cu(II) ions by dried activated sludge biomass.

2.2.5. Effect of Particle Size

Particle size of adsorbent is another vital factor that needs consideration in biosorption research. The surface of contact with the biosorbent and metal ions in solution plays a significant role for biosorption processes. [17] studied the effect of particle size for the removal of Cu(II) ions using dried activated sludge. <0.063; 0.63–1.25; 1.25–2.50 mm range of particle size were used and the results shows that biosorption capacity of Cu(II) ions at equilibrium increase with decrease of particle sizes.

The pseudo-first order and second order kinetic models were determined by [23] for various sizes of particle pre-treated with powdered waste sludge**,** the rate constants for both models increased with decreasing particle size due to larger total surface area of particles at small particle sizes.

2.2.6. Effect of Contact Time

Studies have shown that biosorption efficiency of Cu (II) ions increases by increasing contact time. In copper adsorption using cone biomass, adsorption occurs in two steps and equilibrium was reached after 60 minutes. Further increase in time do not show any increase in biosorption [25].

Rate of biosorption is normally faster and the removal of the biosorbate normally takes place at the initial contact time. In Cu(II) ions biosorption using Spirogyra species, biosorption increases with increase of contact time from 0- 120 minutes [16].

3. CONCLUSION

Pollution of the environment by toxic heavy metals discharge from industrial wastewater is a widespread phenomenon. Considering the methods for removal of these metals must be given strategies to high removal efficiency and at the same time keeping to the minimum. Biosorption readily provides an efficient option to other physiochemical process of removing toxic metals. But never the less, factors such as the contact time, particle size, pH, metal concentration as well as biosorbent concentration have a great effect on biosorption. This study clearly indicates the effect of these factors on Cu(II) ions removal from industrial effluents.

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