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Studies of Various Adsorbents for the Removal of Copper (II) from Drinking Water: A Review

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ABSTRACT: Copper is a heavy metal that can harm the human's body through water if present in excessive amount. The presence of metal in drinking water is of special concern because of its persistence and toxicity. The elimination of copper from water is important to protect public health. Different low cost adsorbents are used to remove copper from water. The strict environmental regulation and enforcement of discharge limits require effective decontamination and purification methods for copper removal. The adsorbents proved to be beneficial because of cost effectiveness. In present review paper, copper contamination, its toxicity and its removal from drinking water using different adsorbents is depicted.

Keywords: Adsorption, Adsorbents, Copper Water, Toxic.

INTRODUCTION

Copper has fundamental importance for human life and health but it is potentially toxic as well like all other heavy metals. For example, continued inhalation of copper-containing spray is linked with an increase in lung cancer among exposed workers [1-2]. Copper may be found as a contaminant in food, especially shellfish, liver, mushrooms, nuts, and chocolate. Elevated environmental levels of Cu (II) come from variety of sources. Mining, metal cleaning, plating baths, pulp, paper and paper board mills, refineries, fertilizer industries etc., are the potential sources of Cu (II) in industrial effluents [3]. Copper, a widely used metal in industry, is an essential trace element for human health and play an important role in carbohydrate and lipid metabolism & in the maintenance of heart and blood vessel activity. The excessive amount of Cu (II) in the environment can cause serious health issues such as nausea, headache, dizziness, respiratory difficulty, hemolytic anemia, massive gastrointestinal bleeding, liver & kidney failure & even death [4-7].

Level of Copper in Drinking Water: Copper metal contamination exists in aqueous waste streams from many industries such as electronic and electrical, metal plating, mining, manufacture of computer heat sinks, Cu plumbing, as well as biostatic surface, as a component in ceramic glazing and glass coloring. Unfortunately, Cu is a persistent, bioaccumulative and toxic chemical that does not readily break down in the environment and is not easily metabolized. The suggested safe level of Cu in drinking water for humans varies depending on the sources, but tends to be pegged at 1.5 to 2.0 mg/L. Hence, removal of copper from water and wastewater assumes important according to "The Environmental Quality Act 1974, Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979, in Malaysia [8] with selected parameter limits of effluent of heavy metals".

Copper is found in surface water, groundwater, seawater and drinking-water, but it is primarily present in complexes or as particulate matter [9]. Copper concentrations in surface waters ranged from 0.0005 to 1 mg/litre in several studies in the USA; the median value was 0.01 mg/litre. In the United Kingdom, the mean copper concentration in the River Stour was 0.006 mg/litre (range 0.003–0.019 mg/litre). Background levels derived from an upper catchments control site were 0.001 mg/litre. Four-fold increases in copper concentrations were apparent downstream of a sewage treatment plant [10]. In an unpolluted zone of the River Periyar in India, copper concentrations ranged from 0.0008 to 0.010 mg/litre. Copper concentrations in drinking-water vary widely as a result of variations in water characteristics, such as pH, hardness and copper availability in the distribution system. Results from a number of studies from Europe, Canada and the USA indicate that copper levels in drinking-water can range from ≤0.005 to >30 mg/litre, with the primary source most often being the corrosion of interior copper plumbing [11-13] or fully flushed water tend to be low, whereas those of standing or partially flushed water samples are more variable and can be substantially higher. In a study from Sweden, the 10th-percentile copper concentration in 4703 samples of unlashed water from homes in Malmo and Uppsala was 0.17 mg/litre, and the 90th-percentile value was 2.11 mg/litre [14] the median concentration was 0.72 mg/litre. In Berlin, Germany, the median concentrations of two separate composite samples collected from 2944 households were 0.32 mg/litre and 0.45 mg/litre, and the maximum concentrations were 3.5 mg/litre and 4.2 mg/litre, respectively [15]. A recent study in the Czech Republic found that only 1.5% of the samples from the distribution system had copper concentrations greater than 100 μg/litre [16]. Copper concentrations in drinking-water often increase during distribution, especially in systems with an acid pH or high-carbonate waters with an alkaline pH [17]. In 1990–1992, the mean copper content of freshly flushed drinking-water in German households with a central water supply was 182 μg/litre. The mean copper content of tap water from single wells was 134 μg/litre. The highest value measured in freshly flushed, centrally distributed tap water was 4.8 mg/litre, and in tap water from single wells, 2.8 mg/litre [18].The permissible limit of Cu is 2.5 mgL^{-1} in water [19].

Various Adsorbents for Copper adsorption: Removal of heavy metal pollutants at high concentrations from water can be readily accomplished by chemical precipitation or electrochemical methods. At low concentrations, removal of such pollutants is more effective by ion-exchange or adsorption on solid sorbents such as activated carbon [20-21], activated carbon from rice hulls and coal fly ash [22-23]. Some investigators have studied the removal of inorganic metal ions, namely, cadmium (II) *and copper (II).* The activated carbon from rice hulls has been used for separation of air by adsorption [24-29].

At present, there is growing interest in using low-cost, commercially available materials for the adsorption of heavy metals [30]. A wide variety of materials are being used as low-cost alternatives to expensive adsorbents. The aim of the present work is therefore to study the removal of copper (II) using various adsorbents.

1. Saw dust as adsorbent: Sawdust (*Dalbargia sissoo)* as the adsorbent was used for the removal of copper ions from river water. The effects of retention time, pH of the solution, concentration and temperature have also been studied. The probable mechanism of copper (II) adsorption at solid-solution interface has also been worked out. The optimized method has successfully been applied for the removal of copper from river water samples [31].

2. Pine fruit as adsorbent: The pine fruit was used as solid adsorbent for the removal of copper ions from aqueous solutions through batch equilibrium technique. The influence of contact time, pH of the solution and initial concentration of metal ions on adsorbed amount of metal ions were investigated. Adsorption of copper ions was pH dependent and the results indicate the optimum pH for the removal of Cu^{+2} was 7.0, the highest adsorption capacity was found to be 14.1 mg of copper ion per gram of adsorbent at initial concentration of 57.6 mg/L of copper ions. Copper ion was removed by 94.1-96% along the whole range of initial concentrations [32].

3. Rice Husk as adsorbent: Rice husk is less costly adsorbent as compared to activated carbon or synthetic ion-exchanger and is available in abundant quantity. Various modifications on rice husk have been reported in order to enhance adsorption capacities for copper ions removal and other pollutants. Batch studies were conducted to find out the optimum dose of adsorbent, optimal pH and contact time for individual metal solution. It was found that the equilibrium was attained after 40 min for Cu and the maximum removal efficiency was attained at a pH of 7 for Cu [33]. Copper (II) ions adsorbed on rice husk (RH), cellulose extracted from rice husk (RH-cellulose), rice husk heated to 300°C (RHA 300) and rice husk heated to 500°C (RHA 500) were investigated in order to understand their sites of adsorption [34]. The adsorption of copper on rice husk ash was studied by using batch technique. The quantities of copper metal before and after the treatment of their standard solutions with rice husk ash were determined by atomic absorption spectrophotometer. Percentage adsorption was calculated for RHA-Copper solution system. The effects of various parameters, such as pH of solution, contact time, temperature and adsorbate concentration were studied. It was observed that adsorption of copper increased with increasing time, temperature, pH and decreased with increasing adsorbate concentration [35]. The utility of rice husk ash as an adsorbent for copper metal ions from acid mine water was assessed. Study of Chockalingam *et al.* 2006 revealed that about 95% Cu^{2+} uptake was achieved from acid mine water, with increase in pH value by two units using rice husk [36].

4. Cercis siliquastrum L. Leaves as adsorbent: The ability of *Cercis siliquastrum* L. leaves for the adsorption of Cu (II) ions was studied. The effects of different parameters such as contact time of biosorbent and sorbents, pH of metal solution, and initial metal ion concentration on the adsorption were investigated. The maximum adsorption of copper ions was carried out in pH 4. Increasing the initial metal concentration in lower values caused a steep growth in adsorption, which was not observed in higher values [37].

5. Activated Carbon as adsorbent: A series of batch experiments were conducted in order to investigate the feasibility of Elais Guineensis kernel or known as palm kernel shell (PKS)-based activated carbon for the removal of copper from aqueous solution by the adsorption process. Investigation was carried out by studying the influence of initial solution pH, adsorbent dosage and initial concentration of copper. All batch experiments were carried out at a constant temperature of 30°C (±2°C) using mechanical shaker that operated at 100 rpm [38]. It was also investigated that up to 95% copper(II) removal is possible in concentration below 4×10^{-4} M (68.216 mg/L) and about 85% removal was achieved in the concentration range between 4×10^{-4} M to 1×10^{-3} M by *activated carbon* [39].

6. Natural Zeolite as adsorbent: The adsorption behavior of natural (clinoptilolite) zeolites with respect to Cu^{2+} has been studied in order to consider its application to purity metal finishing wastewaters. The batch method has been employed, using metal concentrations in solution ranging from 100 to 400 mg/l. The results show that natural zeolites hold great potential to remove copper ions from industrial wastewater. This naturally occurring material provides a substitute for the use of activated carbon as adsorbent due to its availability and its low cost [40].

***7.* Wheat straw as adsorbent:** Citric acid functionalizing wheat straw was investigated as an adsorbent for copper ions removal from aqueous solution. Maximum removal was observed at pH 4-5. 96% copper ions were removed from solution by using wheat straw [41].

8. Sand as adsorbent: The removal of copper metal from aqueous solutions using ordinary sand as an adsorbent was studied. The amount of metal adsorbed to form monolayer on sand. The heavy metal-sand adsorption phenomena can be illustrated on the basis of the interaction between surface functional group of silicates (sand) and the metal ions. It is deduced that sand can be used as a low cost adsorbent for the removal of heavy metal from wastewater (containing low conc. of metals) especially in the developing countries [42].

9. Peat as adsorbent: Peat is a complex material with lignin and cellulose as major constituents. These constituents, especially lignin and humic acid, bear polar functional groups, such as alcohols, aldehydes, ketones, carboxylic acids, phenolic hydroxides and ethers that can be involved in chemical bonding [43]. 90% of Cu (II) was removed at pH 4 [44].

10. Non-living biomass as adsorbent: Various types of biological materials such as non-living biomass of algae, aquatic ferns and seaweeds, waste biomass originated from plants have been investigated as efficient biosorbents. Claymperes delessertti (moss) was used for the adsorption of copper from aqueous solution [45-59].

11. Orange Peel as adsorbent: The removal of copper was studied by using orange peel as adsorbent. High percentage of removal was observed for lower concentration of copper for all the adsorbents but the uptake of copper by unit weight of the adsorbent was the same. The equilibrium is attained at 7 minutes for the adsorbent [60].

12. Peanut Hulls as adsorbent: The chemical characterization of peanut hulls showed a high cellulose (44.8%) and lignin (36.1%) content, which favors biosorption of metal cations. The sorbent capacity in column was 0.028 and 0.025 mmol g^{-1} for copper, respectively in mono and tri- component systems. A decrease of capacity for copper (50%) was observed when dealing with the real effluent [61].

13. Dehydrated Wheat Bran as Adsorbent: The adsorption of copper (II) ions on to dehydrated wheat bran (DWB), a by-product of the flour process, was investigated as a function of initial pH, temperature, initial metal ion concentration and adsorbent dosage. The percent adsorption of copper (II) ions by dehydrated wheat bran was obtained as 96.4% due to increasing the surface area of the wheat bran resulting in acid treatment while 12% of the copper (II) ions in solution were removed by using the raw wheat bran, at optimum adsorption conditions [62].

Advantages of adsorbents: Adsorption is a useful purification technique most commonly used in industry especially in water and wastewater treatments. The adsorption process has been found advantageous such as: low cost of adsorbent, easy availability, low operational cost, ease in processing as compared to other processes, reuse of adsorbent, environmentally friendly and technically feasible. Adsorbents used are the best way for removal of metals from wastewater because it is simple, time saving and inexpensive involving no sophisticated apparatus [63-67].

CONCLUSION

It is needed to detect the copper concentration in drinking water and also to provide a suitable, environment friendly and cost effective copper removal process to save millions of people all over the world from copper poisoning. It is concluded from the above study that the adsorption is a valuable tool for controlling the level of aqueous copper pollution. The utilization of low cost adsorbents for the treatment of wastewater containing heavy metals is helpful as a simple, effective and economical means of drinking water treatment.

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