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Review Article

Using Sustainable Natural Filters to Remove Cadmium from Polluted Water

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Abstract

In the current study, two types of filters made from sustainable natural materials—one containing natural cellulose and the other having natural nanocellulose—were used to remove cadmium from contaminated water. Polyethylene containers were used to gather samples of contaminated water from the Hilla River. Three separation columns (250 ml) and (5 cm diameter) were used to conduct the first and second experiments filled with natural cellulose and nanocellulose, respectively, and the third filled with a mixture of both. In two stages, the first, three separation columns were filled to a height of 6 cm and at flow rates of 100 ml and 250 ml per minute. In the second stage, the height of the materials was 12 cm and at the same flow rates. The study›s findings demonstrated cellulose and nanocellulose may remove cadmium, their efficacy varies. In both stages, the maximum percentage of pollutant removal was seen in the second separation column. The findings of the present investigation also shown a correlation between the velocity at which contaminated water passes through the filters in the separation column and the clearance rate. The statistical analysis results at the probability level of P≤0.05 clearly indicate the existence of a substantial inverse association between the flow rate and the removal rate.

Keywords: Cadmium, Cellulose, Nanocellulose, Separation Columns and Removal Rate.

1. Introduction

The modern global society is in front of numerous problems, and the lack of water supply and the environmental degradation problems are among the most severe [1]. Water sources are becoming more essential as the population of the world increases and more people move into the urban areas. Parallel to the process of urbanization and industrialization, detrimental pollutants have been released in to the waters thus degrading the general quality of water bodies and posing dangers to life forms and people [2]. As described earlier, there are challenges that face water treatment and purification process and therefore it is more crucial now than before to enhance quality and permanent process of water treatment. The water resource is scarce and irreplenishable, closely related with life and significant to all the industrial and agricultural production. Nonetheless, there are quite strict limitations regarding the access to clean water for drinking and everyday use [3].

The factors that are making sustainable materials to become a source of hope amidst these enormous barriers include; those materials that can satisfy present needs without compromising the future generation's ability to satisfy their needs are sustainable materials. This ethical viewpoint is especially well aligned with the notion of finding balance in the provision and use of water as well as aimed at attaining ecological equilibrium [4].

As of the present time, heavy metal ions have become the most severe problem in the aquatic environment which is hazardous to humans and leads to adverse effects on the environment [5]. In their naturally occurring form, heavy metals are substances whose densities are high compared to that of water. Most of the companies that use heavy metals are those companies which engage in manufacture of; tanneries, medicines, chemicals, electroplating, mining, alloys, fertilizer and the likes [6].

Cadmium (Cd) is a powerful metal that is usually harmful at extremely low doses. Even short-term exposure to elevated Cd levels can have detrimental consequences on health. Owing to cellular and molecular alterations, the harmful consequences of intentional exposure to Cd in the forms of oxide, chloride, and sulfide also cause serious health problems [7].

The application of sophisticated nanomaterials—materials that are purposefully created at the Nanoscale—has greatly increased the range of applications possible in the water treatment industry [8]. The capacity to create a material with desired properties that differ from the bulk material has drawn a lot of interest lately to the field of nanotechnology. Applying nanotechnology simply means scaling down to a nano level where the special quantum and surface phenomena may be utilized, improving the current processes and materials [9]. The capacity of the nanomaterial to support biochemical processes further is significantly influenced by the characteristics of nanoparticles, which include their uniform shape and high surface area to volume ratio [10]

The most common biopolymer found in the world is cellulose. This biomaterial is made up of parallel arrays of β-1, 4-linked glucose chains and is a highly organized crystalline polysaccharide [11]. Numerous investigations indicate that basic dimer repetitions, or cellobiose, are the cause of the distinctive high order structure of cellulose, Moreover, the literature characterizes these dimer repetitions as two D-glucopyranose units connected by β-1,4-glycosidic linkages, Furthermore, the intermolecular hydrogen bonding by the extensive number of hydroxyl groups in cellulose chains are responsible for the physico-chemical characteristics such as hydrophobicity, chirality, crystallinity or biodegradability of the material [12-14]. Additionally, this natural polymer's exceptionally dense OH-groups on its surface structure make it easy to functionalize and change it utilizing a range of functional groups and other chemical techniques, hence enhancing and modifying its physicochemical features. Because of this, cellulose is a flexible and adaptable substance [15]. Because of its low cost, availability, flexibility, safe processing, nontoxic, and biodegradable qualities, cellulose has drawn special attention and is now one of the most promising alternatives to synthetic and fuel-based products [16].

Adsorbents based on nanocellulose are becoming more and more common these days. This is due to the fact that nanocellulose high specific surface area, excellent mechanical properties, and robust biocompatibility make it especially suitable for heavy metal ion adsorbent construction [17].

The current research aims to find the best way to remove cadmium from polluted water by comparing the ability of natural cellulose and nanocellulose to remove.

2. Materials and Methods

2.1. Experimental Work

Five-liter plastic bottles were used to collect contaminated water from the Hilla River in Hilla City, central Iraq, and were properly cleaned using acid and deionized water. Subsequently, 0.45 mm filter paper was used to extract dissolved metals from the contaminated water samples. To finish the experiment, three 250 ml separation columns with a 5 cm diameter were employed. Cellulose was used in the first column, nanocellulose in the second, and a 1:1 blend of the two earlier components in the third. For every content, there were three replicates.

The experiment included two stages. The first, three separation columns were filled to a height of 6 cm and at flow rates of 100 ml and 250 ml per minute. In the second stage, the height of the materials was 12 cm and at the same flow rates [18].

2.2. Heavy Metals Analysis

50 milliliters of water were acquired in a beaker, and to this was added 2 milliliters of concentrated nitric acid and 5 milliliters of concentrated hydrochloric acid. The sample was then heated to a temperature of 90 to 100 °C for two hours, or until it had dried completely. The sample was allowed to cool before being filtered and having distilled water added to get the amount up to 50 ml. The heavy metals were subsequently measured by atomic absorption spectrometry (AAS) [19].

2.3. Statistical Analysis

For least significant differences (LSD < 0.05), SPSS 17.0 programs were utilized. ANOVA, or analysis of variance, was used to compare the columns.

3. Results and Discussion

Figure 1 and 2 shows the cadmium concentration rate in separation columns at a height of 6 cm and 12 cm respectively. According to the present findings, the second column filled Nanocellulose removed the cadmium ions more effectively in both stages. Additionally, because the adsorbent surface and adsorbing time were increased, the efficiency of the second column with a high of 12 cm was better than that of a high of 6 cm [20].

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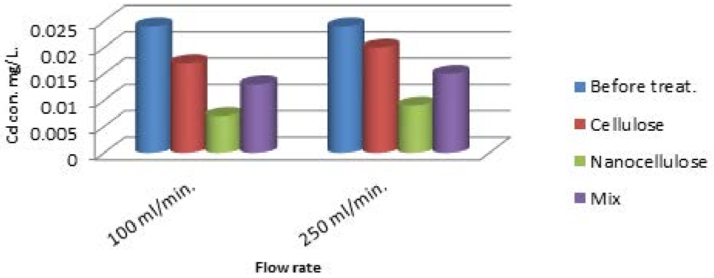

Figure 1: Cadmium Concentration Rate in Separation Columns at a Height of 6 cm

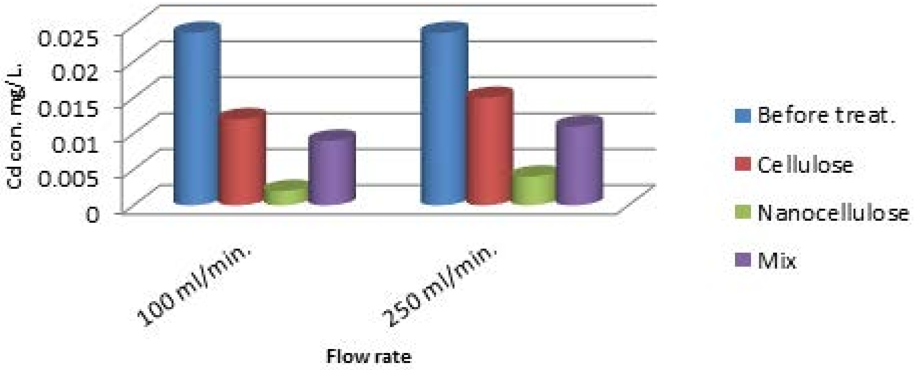

Figure 2: Cadmium Concentration Rate in Separation Columns at a Height of 12 cm

Cellulose interacts with water molecules more readily due to its innate hydrophilicity, which makes it a good material to utilize in water treatment processes. Furthermore, because to their plentiful supply, low energy needs, affordability, sustainability, and renewable nature, cellulose-based materials provide a wider range of applications in water treatment [21]. It is noted from the above figures that the ability of nanocellulose to remove cadmium is higher than natural cellulose, and this is due to the variations in the specific surface area/volume (S/V) ratio have been a major factor in explaining these disparities. For example, cellulose perform significantly worse than nanocellulose because they have a lower S/V ratio, which affects their adsorption capabilities. It follows that the percentage of water pollution adsorption decreases with decreasing S/V ratio. Furthermore, a comparison of cellulose and nanocellulose suspensions revealed that the latter has greater stability, which is important for a longer exposure to the pollutant that has to be absorbed [22].

Through the results of the statistical analysis, which showed a positive correlation between the removal rate and the amount of material used for removal, the more material, the higher the removal rate. The results also showed an inverse correlation between the removal rate and the speed of water flow in the separation column; the lower the flow rate, the higher the removal rate, as in Figures 3 and 4.

Figure 3: Removal Rate in Separation Columns with a Height of 6 cm

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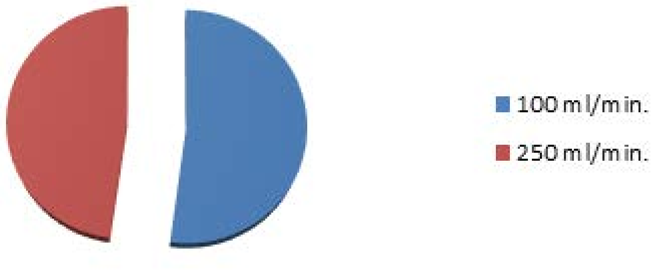

Figure 4: Removal Rate in Separation Columns with a Height of 12 cm

The adsorption capacity of native cellulose is lower than that of nanocellulose. Since the adsorption capacity is unstable in the presence of hydrophobic polymer matrices and is prone to aggregation formation during composite processing, it has not changed much over the years. Its employment in polymer reinforcement is limited by its short-lived nature and inconsistent performance, nevertheless, this may be addressed by Nanocellulose, a simple cellulose-building unit. According to recent study, nanocellulose is a material of the subsequent generation that has great promise for a wide range of technological applications [23, 24].

4. Conclusion

Over time, a multitude of remediation approaches have been developed to remediate the contamination caused by heavy metals from both industrial and human activities. Nano bioremediation has shown to be a game-changer because of the generated substance's high remediation efficiency and non-toxicity. Reducing the overall cost and cleanup time, as well as the toxic impacts of heavy metal pollution, has been accomplished by employing a greener approach.

The results of the current study showed that various materials derived from natural materials are able to remove cadmium from the polluted Hillah River to a greater extent than the natural materials themselves. The results also showed that increasing the amount of materials used in removing pollution and reducing the speed of water flow has better results in removal through the period of increased contact between the polluted water and the material.

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