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USING SUSTAINABLE GREEN ORGANIC NANOMATERIALS AS NANOCELLULOSE TO REMOVAL OF HEAVY METAL LEAD (PB) FROM AQUEOUS SOLUTIONS

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Abstract

The issue of removing heavy metals from various water sources is currently a serious challenge due to their hazardous bioaccumulation, as it necessitates a sustainable green treatment technology to remove them.

A Fourier-Transform Infrared Spectroscopy was used to identify the nanocellulose, which detected many functional groups such as (-OH) wide (3100-3600 cm^{-1}), (C-H) (2800-3000 cm^{-1}), and primary distinctive peaks were found in fingerprint region of band (856 cm^{-1}), which is attributed to stretching (C-O-C) group at β-(1→4)-glycosidic connections.

When using lab starch-based nanocellulose, weighing (0.5 g), the highest removal of (91%) was obtained within (6 hours) of stirring with lowest concentration (5 ppm), while the removal of (62%) decreased, when highest concentration of (Pb) used in (60 ppm) during the same time.

Whereas, the removal was increased when the amount of nanocellulose was doubled to be (1.0 g), where the removal was complete (100%) at (5 ppm), and removal was (74 %) at (60 ppm) with same reaction time.

From the results, the (Pb) removal depends on many factors like duration of reaction time, amount of nanocellulose, degree of saturation, and free space available of highly catalytic oxidative sites on surface area.

This paper aims to use prepared nanocellulose from lab starch to use in removal of lead (Pb) from aqueous solutions cleanly and efficiently.

Keywords: Sustainability Development, Green Nanomaterial, Nanocellulose, Aqueous Lead (Pb)

1. Introduction

Environmental and health issues are major concerns in today's world, where one of these issues is chemical pollution by heavy metal in water.[1] The term Heavy Metal can refer to any hazardous metal, regardless of its atomic mass or density.[2]

According to sources, a heavy metal is one of the typical transition metals, like lead, cadmium, nickel, silver and mercury. These metals contribute to environmental pollution from sources like leaded gasoline, industrial waste, and acid rain, which leaches metal ions from the soil into lakes and rivers.[3] Elements like Hg, Ag, Pb, and Ni are extremely hazardous elements.

These heavy metals are persistent, bioaccumulative, and difficult to break down or metabolize in the environment. Such metals are absorbed at the primary producer level and initially consumed at the consumer level, accumulating in the ecological food chain, aided by urbanization and traffic, industrial and agricultural operations, waste incineration, and mining.[4]

Heavy metal contamination nearly often occurs in a periodically, starting with industry and ending with humans. It is well known that chronic exposure to heavy metals and metalloids at relatively low levels can have negative effects according to both of an Agency for Toxic Substance and Disease Registry [ATSDR] and Material Safety Data Sheets [MSDS] for each chemicals that prepared and registered in an organic compounds dictionary, The concentration of heavy metals has a significant role in toxicity parameters lethal concentration (LC_{50}), lethal dose (LD_{50}), and impact on human health and their environment.[5]

Lead causes multiple changes in the organisms body and there are often general symptoms such as decreased appetite, weight loss and growth disturbances.[6]

Some of the traditional techniques that are it is used for water treatment which includes adsorption, ion exchange, coagulation, flocculation and sedimentation processes. However, these traditional methods are harmful to the environment. On the one hand, it does not achieve the required level and some of it is not economical.[7]

Recently, cellulose has gain attractiveness for its use in bioremediation methods because of its numerous distinct qualities and potentials, nanocellulose, like many other sustainable nanostructure materials Figure (1), when the cellulose dimension is lowered to nanometric levels, the adsorption of heavy metals from wastewaters is considerably improved.[8,9]

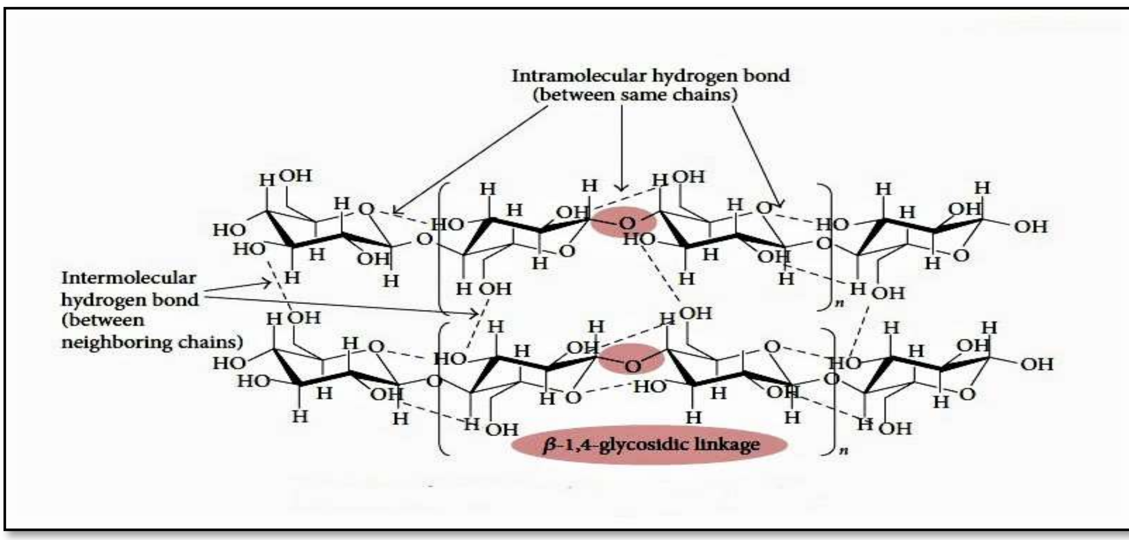

Figure 1. Chemical structure of cellulose chains.[10]

2. Methods Procedures

1. Preparation procedure of nanocellulose [11]

It can be use lab-starch after filtration step can be taken to dry it. Heated to 50 Cº for (1 hour) after making a solution from starch and (50 ml) de-ionized distilled water. Add 3 drops from citric acid (extract of lemon juice) were added to the extracted sample Figure (2). Isolate the powder by centrifugation step (10 minutes) at (6000 rpm), and then filtered through Whitman filter paper 42 (2.5 µm). Evaporation and washed with de-ionized distilled water to get dry nanocellulose at room temperature.

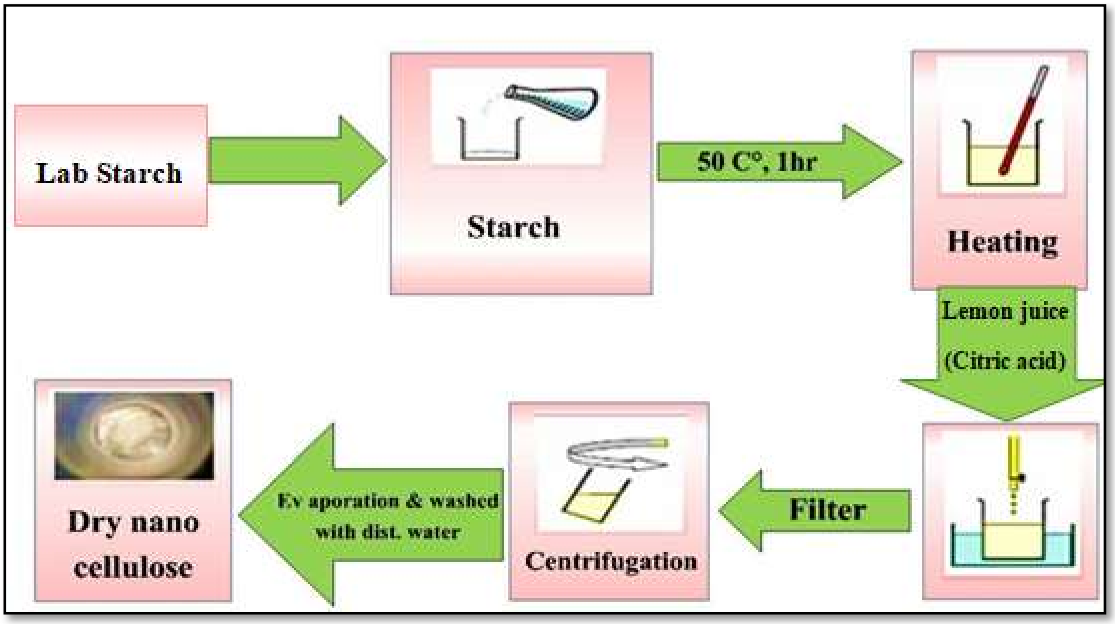

Figure 2: Scheme for preparation of cellulose nanocrystals [12]

2. Preparation of the heavy metal (Pb) in aqueous solution

Five different solutions of concentrations (5, 10, 20, 40, 60 ppm) have been prepared by using the following equation: $\mathbf{ppm_1} \times \mathbf{v_1} = \mathbf{ppm_2} \times \mathbf{v_2}$ in (100 ml) of distilled water for each.

3. Procedure for the heavy metal (Pb) removal by using prepared nanocellulose from lab starch

Using weights (0.5 and 1.0 g) separately from lab starch-based nanocellulose and it was added to the prepared aqueous solutions (5, 10, 20, 40, 60 ppm), then stirred at (700 rpm) by an electromagnetic stirrer at different scheduled intervals of times (1, 3, 6 hours) to monitor the highest removal rate during all reactions. The mixtures were filtered using (filter paper) where the filtrated solutions were measured using atomic absorption technique after treatment by prepared nanocellulose.

3. Results and Discussion

The stretching of the (-OH) group caused an absorption peak to appear in the range of (3600-3100 cm^{-1}) on the FTIR spectrum, and the stretching of the (C-H) group caused a peak to occur at (3000-2800 cm^{-1}). The band was seen at (1651 cm^{-1}) across from the water absorptions bending (H-O-H) at (1400 cm^{-1}), the (C-H) group underwent symmetric bending.

The primary distinctive peaks were found in the fingerprint region of the absorption band (856 cm^{-1}), which is attributed to the stretching of the (C-O-C) group at β-(1→4)-glycosidic

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connections. Figure (3 and 4), FTIR spectra that supported the existence of nanoscale of the cellulose.

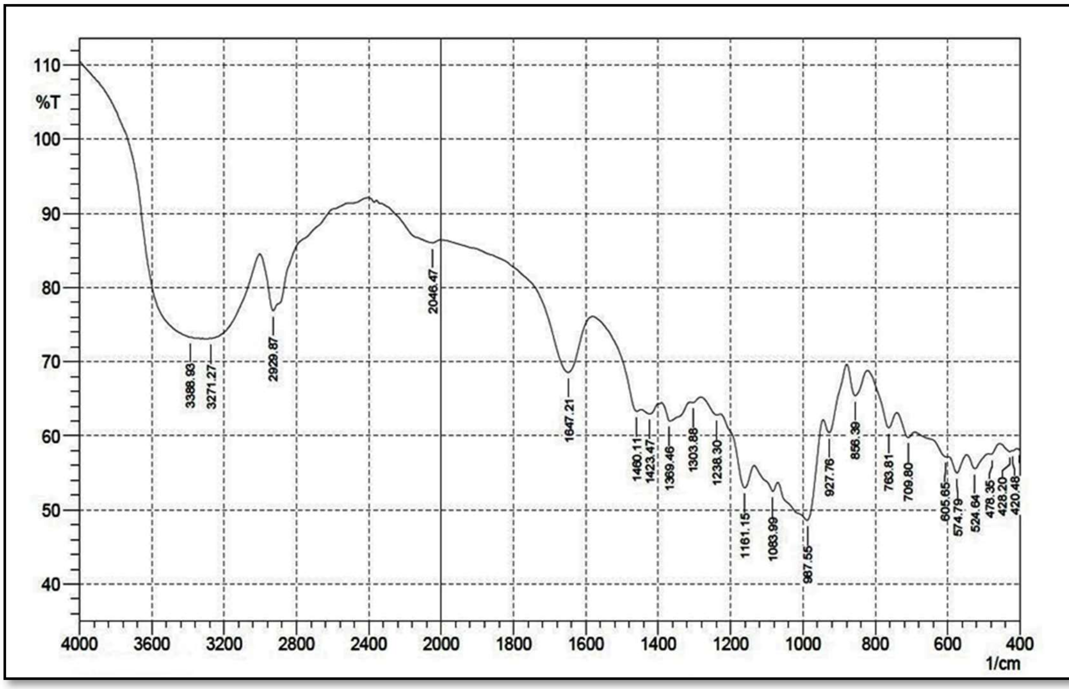

Figure 3: FT-IR spectra for lab starch.

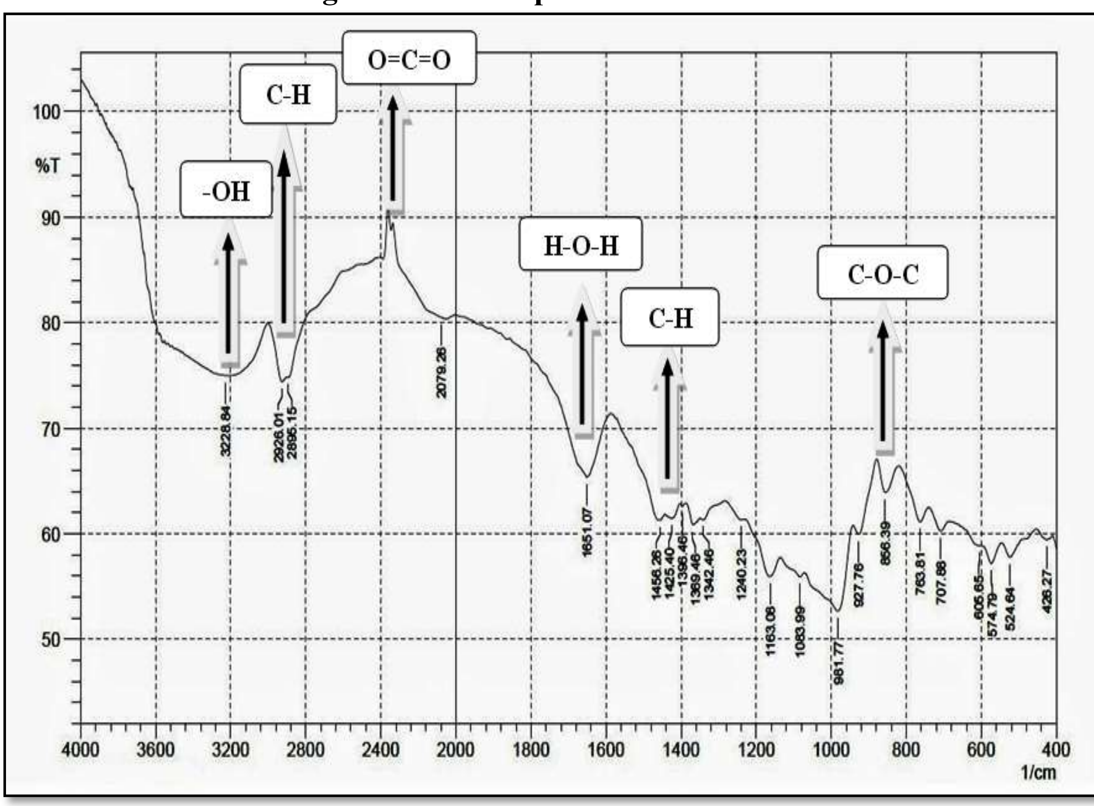

Figure 4. FT-IR spectra for lab starch-based nanocellulose.

It was clear the explanation of the role of nanocellulose in the adsorption of (Pb) from its aqueous solutions with green removal reactions through the use of high exchangeable protons on the hydroxyl groups(-OH) spread on the surface and thus high possibility of chemical bonding to be occur between negative oxygen atoms (H-O-Glucose-O-Glucose-O^-) with positive (Pb^{2+}) ions to form formula (H-O-Glucose-O-Pb-O-Glucose-O-H).

From the results, the (Pb) removal depends on the factors of the duration of reaction time, amount and source nature of nanocellulose, degree of saturation and free space availability of surface area.

It can be seen, when using lab starch-based nanocellulose, weighing (0.5 g), the highest removal of (91%) was obtained within (6 hours) of stirring with the lowest concentration (5 ppm), while the removal of (62%) decreased, when the highest concentration of (Pb) used in its aqueous solution was (60 ppm) during the same time.

The results clearly indicate that the ability of nanocellulose to remove lead is gradually decreasing due to the increase in its concentrations, which corresponds to the lack of its sufficient quantity for removal.

Whereas, the removal was increased when the amount of nanocellulose used was doubled to be (1.0 g), where the removal was complete (100%) at a concentration of (5 ppm) at a reaction time of (6 hours), and the removal was (74 %) at (60 ppm) during the same time, as shown in Tables (1.and 2.).

Table 1. Treatment of (Pb) using (0.5 g) lab starch-based nanocellulose

Solutions Pb (C_0 ppm)	1 hour Pb (C_t ppm)	3 hours Pb (C_t ppm)	6 hours Pb (C_t ppm)	1 hour Pb Removal %	3 hours Pb Removal %	6 hours Pb Removal %
5	1.4130	1.2914	0.4083	71.74	74.172	91.834
10	6.0098	5.8910	2.6166	39.902	41.09	73.834
20	13.3114	11.5745	12.1046	33.443	42.127	39.477
40	22.7213	18.9216	20.1405	43.196	52.696	49.648
60	34.7376	28.2202	22.5952	42.104	52.966	62.341

Table 2. Treatment of (Pb) using (1.0 g) lab starch-based nanocellulose

Solutions Pb (C_0 ppm)	1 hour Pb (C_t ppm)	3 hours Pb (C_t ppm)	6 hours Pb (C_t ppm)	1 hour Pb Removal %	3 hours Pb Removal %	6 hours Pb Removal %
5	1.2086	0.7787	0.000	75.828	84.426	100
10	4.3365	2.6507	0.6693	56.635	73.493	93.307
20	10.0022	11.1773	9.2817	49.989	44.113	53.591
40	18.5428	15.8936	20.5870	53.643	60.266	48.532

60	23.8004	18.7100	15.3765	60.332	68.816	74.372

In general, properties that make nanocellulose consider as an ideal tool for water treatment applications from chemical pollution by heavy elements such as lead are high surface area, superior mechanical strength, superior surface chemistry factors with anionic surface groups, and high dispersion in water.[13-14]

Recently, there are several studies regarding achieving a high removal of lead from the aqueous solutions by following unique removal methods using sustainable green nanomaterials such as Nano bentonite clay, Nano carbon, Silica, and Hydrogel, that are friendly to human and the environment.[15-19]

4. Conclusions

1. Production of nanocellulose from laboratory starch using an efficient sustainable green analytical method.
2. The prepared nanocellulose has a high ability to remove toxic lead element from its aqueous solutions with high removal rates compared to the amount used.
3. The conditions of the removal reaction were done in an environmentally friendly way so that no chemical substance or harsh conditions such as high temperature and pressure were entered into it, but it was only through stirring with very short reaction times.

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Conflicts of Interest: The authors declare no conflict of interest.

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