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The Effect of Selenium Nanoparticles in Removing Heavy Metals from Some Types of Water

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ABSTRACT

Given the critical need to remove heavy metals from contaminated water due to their toxic effect even when at low concentrations on both living organisms and humans, Alginate encapsulated SeNPs and commercial SeNPs were employed for the removal of these pollutants. The treatment process involved adding the nanoparticles to the contaminated water at a concentration of 100 µg/cm^3 and allowing them to interact for 24 hours, The removal efficiency was assessed using an atomic absorption spectroscopy to quantify the extent of heavy metals removal, specifically targeting copper, lead, chromium, and nickel. The results demonstrated that Alginate encapsulated SeNPs were more effective than commercial SeNPs in removing three metals: copper, lead, and chromium. While the Commercial SeNPs showed superior performance in removing nickel. these finding highlight the potential of alginate encapsulated SeNPs as a promising material for heavy metal removal with efficiency comparable to or even surpassing that of commercial SeNPs. Alginate serves as a support material for the nanoparticles, enhancing their capacity to absorb heavy metals due to its high affinity for these metals and its intrinsic non-toxic nature.

Keywords: alginate encapsulated SeNPs, commercial SeNPs, copper (Cu), lead (Pb), chromium (Cr)

INTRODUCTION

Heavy metal pollution is one of the most dangerous types of pollution, particularly in developing countries, especially in industries such as metal paint factories, fertilizer production, and many other factories. The wastewater from these industries and as well as areas where pesticides are used contains heavy metals that are discharged directly or indirectly into the environment. Sewage from refineries also contains a high level of heavy metals (e.g., Lead (Pb), mercury (Hg), cadmium (Cd), nickel (Ni), etc.) which seep into groundwater, making it toxic. This metal can also contaminate bodies of water, threatening aquatic life, furthermore, irrigating agricultural land with wastewater introduces these toxic metals into the food chain posing a serious threat to human health (Kumar *et al*., 2020).

Nanoparticles have played significant role in various applications, including treatment bacterial infections (Selah and Mohammad, 2024) and elimination agricultural pests (Burhan *et al*., 2025). And the treatment of cancerous diseases (Selah and Mohammad, 2025) In the field of wastewater treatment, nanoparticles demonstrate higher efficiency compared to conventional method such as absorption, filtration and sedimentation, which tend to be less effective and more energy-intensive (Hao *et al*., 2022). Nanotechnology-based methods can be divided into three categories: processes that involve the use of nanomaterial's, processes that use Nano-membranes, and hybrid processes (Hartshorn *et al*., 2018). Algae also used to remove heavy metal (Saeed *et al*., 2020) Processes that use nanomaterial's include absorption and catalysis. methods that using nano-membranes rely on reverse osmosis and Nano filtration to remove pollutants, while hybrid methods combine nanotechnology with other treatment techniques to achieve greater efficiency and effectiveness (Hasan *et al*., 2021).

Nano-membranes have garnered significant attention among researchers due to their numerous advantages over traditional filtration membranes. Carbon nanotubes are distinguished by their membranes porous structure with thin layers as well as their impermeability to microorganisms and heavy metals (Rasaki *et al*., 2019). this contributes to effective water treatment. the most commonly used polymers for these membranes include polysaccharides such as alginate, cellulose, chitosan, starch, and others. Alginate in particular has been the focus in many applications, including the removal of heavy metals due to its high affinity for heavy metal ions (Samrot *et al*., 2022).

MATERIALS AND METHODS

Heavy metals are among the most dangerous water pollutants and pose a major concern because they are non-biodegradable and toxic even at low concentrations. Accordingly, the ability of alginate SeNP encapsulated s and commercial SeNPs to remove heavy metals, including copper (Cu), lead (Pb), chromium (Cr), and nickel (Ni), was investigated, based on the research conducted by (Challab *et al*., 2024), using the following steps:

1. Twelve samples of water collected from local generators in various residential (the water used is tap water and water is taken from the generator and from different location in the city) areas of Mosul city /Iraq. Each sample was measured at 1 liter and collected in sterile bottles.
2. Each water sample was divided into three parts. Alginate encapsulated SeNPs were added to one part and commercial SeNPs to the other, achieving a final concentration of 100 $\mu g/cm^3$. The final part was kept for measurement and served as a control sample.
3. The samples (water and selenium nanoparticles) were incubated for 24 hours at 25°C in a shaking incubator. (to increase the adsorption heavy metals on the surface of selenium nanoparticles)
4. The tubes were centrifuged at 4,000 rpm for 5 minutes, and the filtrate was collected.
5. The absorbance was measured at the College of Agriculture and Forestry using a flame atomic absorption spectrometer (AAS) for samples treated with both types of SeNPs and untreated samples. Cathode tubes specific to each element were used.
6. After taking the readings, they were plotted in the standard curve(the equation is prepared in advance by specialists working on the device located in the central laboratory at the College of Agriculture and forestry ,University of Mosul)for each heavy metal, which had been prepared in

advance from the concentrations (0.5, 1, 3, 5, 10, 20, 40 parts per million), the wavelength used were: Cu = 373 nm, Cr = 580 nm, Pb = 283.3 nm, Ni = 337.8, the concentration of each metal in the sample was then determined.

7. A statistical analysis of the results was conducted using a simple experimental design and a completely randomized design. Comparisons between treatments were made using Duncan's multiple range test at a significance level of 0.01.
8. The percentages of heavy metal removal by the two types of SeNPs were also calculated according to the following equation:
   E = C0 - Ce/C0 x 100

Where E = percentage, C0 = concentration before removal, Ce = concentration after removal

RESULTS AND DISCUSSION

Given the importance of removing heavy metals from contaminated water, due to their toxic effects on living organisms and humans, even at low concentrations, alginate encapsulated SeNPs and commercial SeNPs were used to remove these contaminants. After adding them to the water to be treated at a concentration of 100 µg/cm^3, and leave it for 24 hours and measure it with an atomic absorption spectrometer to investigate the extent of removal of these metals, including copper, lead, chromium, and nickel, due to this nanomaterial. The results showed significant differences between the treatments included in the experiment in their effect on the studied elements, as shown in (Table 1).

Table (1): Effect of alginate encapsulated SeNPs and commercial SeNPs on heavy metal removal from some water

Material		heavy metals			
		Cu ppm	Pb ppm	Cr ppm	Ni ppm
control	Mean	.2659 a	.3428 a	.4074 a	3.0645 a
	Std. Deviation	±.02889	±.08286	±.08505	±.35004
SeNPs commercial	Mean	.1612 b	.1896 b	.3250 ab	1.8386 b
	Std. Deviation	±.04294	±.06656	±.12265	±.50675
SeNPs encapsulated	Mean	.1507 b	.1827 b	.2920 b	2.1615 b
	Std. Deviation	±.05813	±.08493	±.10372	±.67922

The treatment with encapsulated SeNPs did not differ significantly from the commercial SeNPs, but it was shown that both treatments were superior to the control treatment in removing heavy metals. (Table 2) shows the superiority of encapsulated SeNPs over commercial SeNPs in removing copper, lead, and chromium, with removal percentage reached 43.3%, 46.7%, and 28.2%, respectively. In contrast, the removal rates for commercial SeNPs were 39.2%, 44.7% and 20.1% respectively, as for the nickel element, commercial SeNPs excelled in its removal, with removal rate 40.1%, while the removal rate of encapsulated SeNPs was (29.4%). To clarify the results, a graph was prepared in Fig. (1).

Table (2) Percentage of heavy metal from some water removal using encapsulated SeNPs and commercial SeNPs

Material	Percentage of heavy metal removal			
	Cu	Pb	Cr	Ni
commercial SeNPs	39.2	44.7	20.1	40.1
encapsulated SeNPs	43.3	46.7	28.2	29.4

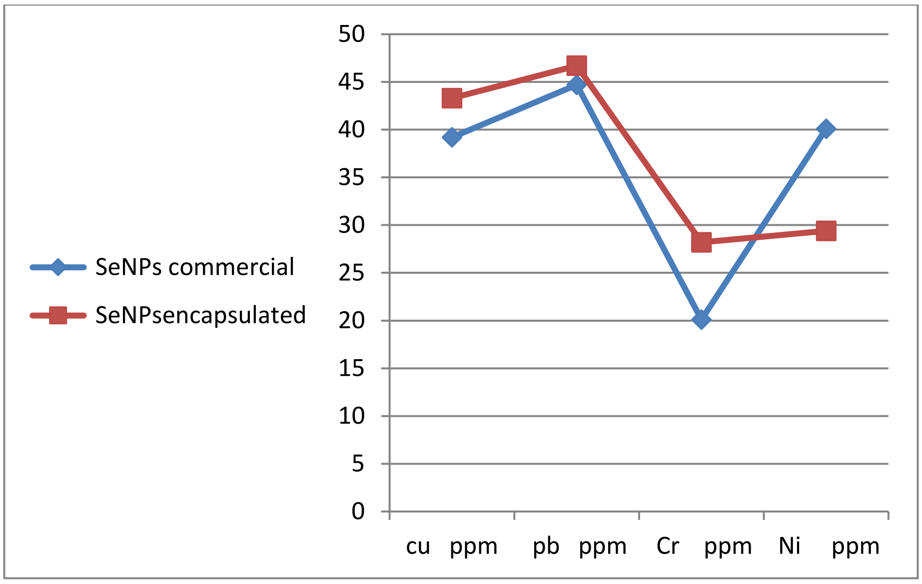

Fig. 1: Removal of heavy metals from some water using encapsulated SeNPs and commercial SeNPs.

Current study indicates that alginate encapsulated SeNPs were superior in removing heavy metals for three metals: copper, lead, and chromium. Commercial SeNPs were more effective at removing nickel than encapsulated SeNPs. This demonstrates the efficiency of encapsulated SeNPs in removing heavy metals, making them comparable to commercial SeNPs, as alginate acts as a supporting material for nanoparticles enhancing their ability to absorb heavy metals due to its high affinity for these metals and its inherent non-toxicity (de Mello Ferreira *et al*., 2021).

Our results in removing heavy metals were lower than those reported by other researchers, for example (Aziz *et al*., 2022) were able to use SeNPs at a concentration of (20, 15, 10, 5 mg/cm^3) to remove lead and chromium by 98.3%, 95.9%, respectively. Similarity (Jain *et al*., 2015) used of SeNPs at a concentration of (0.22 g/L) to remove zinc at a concentration of 60 mg for each of the polluted water.

Additionally, (El-Shehawy *et al*., 2023) used silver nanoparticles at a concentration of (0.2 g/L) to removing iron, zinc, manganese and copper at a rate of 97.1%, 43.3%, 65.6% and 2.4% respectively.

(Khoso *et al*., 2021) included that using nickel and iron nanoparticles at concentrations of 50, 40, 30, 20, 10, and 5 mg/50 ml played a significant role in removing chromium, lead, and cadmium, with removal rates of 89%, 79%, and 87%, respectively. (Al-Allaf *et al*., 2023) utilized nano-iron oxide in wastewater treatment. Additionally (Selah and Mohammad, 2021) employed iron nanoparticles to inhibition of bacterial growth

The lower removal rate of heavy metals in our study may be due to the difference in the concentrations of the nanomaterial's used, as our concentrations were in micrograms. Another possible reason is the lower pollution level of the water used in our experiment, which led to less absorption to heavy metals by nanomaterial's. Additionally, temperature and pH also affect the extent

CONCLUSIONS

The treatment with encapsulated SeNPs did not show a statistically significant difference compared to commercial SeNPs in overall heavy metal removal. However, both treatments were significantly more effective than control. Notably, encapsulated SeNPs demonstrated superior efficacy in the removal of copper, lead, and chromium. whereas commercial SeNPs exhibited greater effectiveness in removing nikel.

RECOMMENDATIONS

We recommend the use of encapsulated SeNPs in the treatment of water contamination with heavy metals

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تأثير دقائق السلينيوم النانوية في إزالة المعادن الثقيلة من بعض انواع المياه

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الملخص

نظراً لأهمية ازالة المعادن الثقيلة من المياه الملوثة، لتأثيرها السام حتى عند وجودها بتراكيز قليلة على الكائنات الحية والانسان، استُخدمت دقائق السلينيوم النانوية المُغلفة بالألجينات، بالإضافة إلى دقائق السلينيوم النانوية التجارية، لإزالة هذه الملوثات. فبعد إضافة الدقائق النانوية إلى المياه الملوثة بتركيز 100 ميكروغرام/سم^3 وتركها لمدة 24 ساعة. قُيّمت كفاءة الإزالة باستخدام مطيافية الامتصاص الذري لتحديد مدى إزالة المعادن الثقيلة، كالنحاس والرصاص والكروم والنيكل. أظهرت النتائج أن دقائق السيلينيوم المُغلَّفة بالألجينات كانت أكثر فعالية من دقائق السيلينيوم التجارية في إزالة ثلاثة معادن: النحاس والرصاص والكروم. في حين تفوقت دقائق السيلينيوم التجارية في إزالة النيكل، تشير النتائج الى إمكانية استخدام دقائق السيلينيوم المُغلّفة بالألجينات كمواد واعدة لإزالة المعادن الثقيلة بكفاءة تُضاهي، بل وتتفوق، على كفاءة دقائق السيلينيوم التجارية. يعمل الألجينات كمادة داعمة للجسيمات النانوية، مُعززًا قدرتها على امتصاص المعادن الثقيلة بسبب تقاربه العالي مع هذه المعادن وطبيعته غير السامة.

الكلمات الدالة: SeNPs المغلف بالالجنيت، SeNPs التجاري، نحاس، رصاص، كروم.