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# Enhanced Heavy Metal Removal from Wastewater Using Optimized Graphene Oxide: A Comparative Assessment with Coagulation Methods

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**Abstract -** Wastewater containing heavy metals has the potential to be hazardous to human health and the environment. Heavy metals must so be eliminated from wastewater. These days, coagulation-based techniques are widely employed and have demonstrated results. There are now additional opportunities to improve the removal effects of specific heavy metals thanks to new techniques like the use of nanomaterial's. Because of its high surface area and distinctive structure, grapheme oxide has attracted a lot of attention among these nanomaterials. Additionally, grapheme oxide is an eco-friendly substance. However, the majority of the published studies used lab-prepared simulated wastewater samples rather than actual wastewater samples. Therefore, actual wastewater samples must be used to empirically demonstrate the removal effects. In this experiment, I used wastewater collected from the Fill an wastewater treatment plant in Sundsvall to investigate the removal effects of pure and modified graphene oxide. Additionally, I have researched the impacts of using graphene oxide in conjunction with the coagulation process to remove heavy metals. The huge potential of graphene oxide in wastewater treatment is demonstrated by the results, which reveal that it has removal effects comparable to those of the coagulation method.

***Key Words*:** Graphene oxide, wastewater, heavy metals, and removal efficiency.

## 1.INTRODUCTION

Heavy metal contamination from industrial and agricultural activities poses severe health risks. Traditional treatment methods face inefficiencies and high costs. Graphene oxide (GO), with its large surface area and functional groups, offers effective heavy metal adsorption, making it a promising wastewater treatment material.

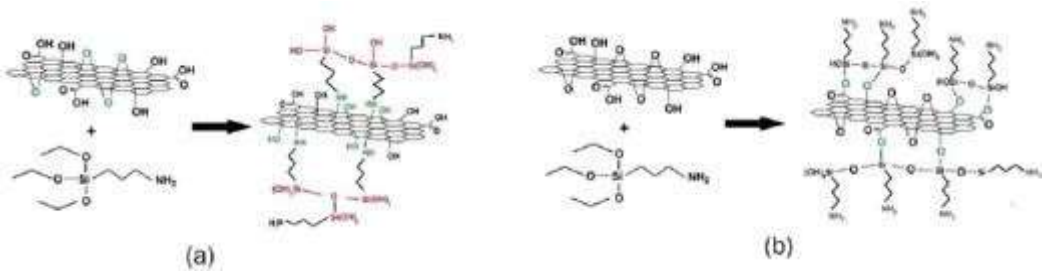
## 3. Materials

Lab-made graphene oxide was produced by the Materials Group at the Department Of Natural Sciences, Mid Sweden University. Commercial graphene oxide was purchase from GOOGRAPHENE. Poly aluminum chloride (PAX-15) was purchased from UPONOR. All other chemicals mentioned in this thesis were purchased from SIGMAALDRICH without further purification. Wastewater samples were collected at Fillan (Sundsvalls' wastewater treatment plant).

### 3.1. Synthesis of graphene oxide

Lab-made graphene oxide was synthesized using a modified Hummer's method. Graphite (1.0 g) was mixed with 70 ml of 98% $H_2SO_4$ in an ice bath, then 9.0 g $KMnO_4$ was added while keeping the temperature below 30°C. The mixture was heated to 40°C for 30 min, then to 95°C for 15 min after adding 150 ml water. After dilution with 500 ml water, 15 ml of 30% $H_2O_2$ was added, turning the suspension dark brown. GO was rinsed with 500 ml of 1:10 HCl, vacuum-filtered, and dried at 60°C overnight.

### 3.2. Modification of graphene oxide




In order to alter the graphene oxide, I employed 3-Aminopropyl triethoxysilane (APTES). In short, 10 milliliters of graphene oxide suspensions containing 1 milliliter of APT ES were mixed for IO minutes. After that, modified graphene oxide was gathered using vacuum filtering and washed with water. The obtained sample was then re-dispersed in 10 milliliters of water. The reaction between graphene oxide and APTES is depicted in Figure 2 [15].

*Figure 1.* Schematic representation of the two reaction routes commonly described for the functionalization of GO with APTES: opening of epoxy groups by the APTES amines (a); and OH reacting with

the ethoxy silane groups of the APTES (b). The figure is from ref [15].

### 3.3. FTIR of graphene oxide

A Nicolet 6700 spectrometer was used to perform the Fourier-transform infrared spectroscopy. The range of wavenumbers is 400–4000 cm.

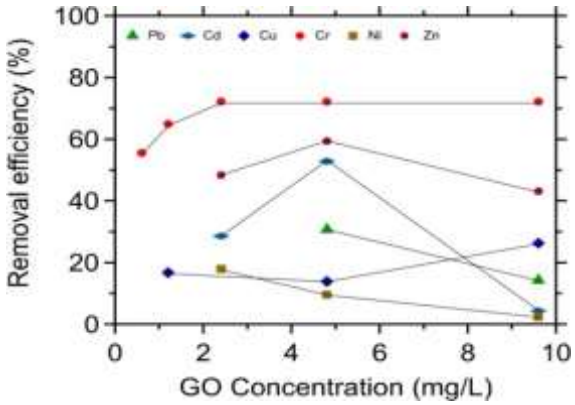
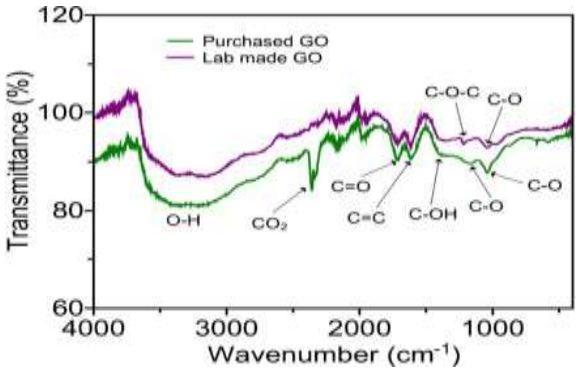



**Chart 1**




## 4. RESULTS AND DISCUSSION

I have researched the effects of treatment duration on the effectiveness of heavy metal removal from wastewater. Figure 8 displays the study's findings. The results showed that the concentration of Cd after treatment is below the instrument's detection limit and that a 10-minute treatment period would be sufficient to eliminate the majority of the metal ions. After 10 minutes of treatment, the removal efficiency for Pb can reach 70%, which is a very good result when compared to the 80% removal efficiency utilizing PAX-15 for 25 minutes of treatment. After IO min treatment, the elimination efficiency for Cr was 68.2%, whereas for PAX-15 treated sample, it was 77.3%. Following IO min treatment, the elimination efficiency for Ni was 20.6%. This time, it appears that the samples are contaminated with zinc. Consequently, the outcomes were not displayed. Appendix Table A4 contains the analytical+ data, which is provided below. The findings indicate that for all three tested doses, a longer treatment period will result in a lower removal effectiveness of lead. There have been no discernible differences for Cd. It appears that a longer treatment period may have a stronger elimination impact for Cr and Ni.

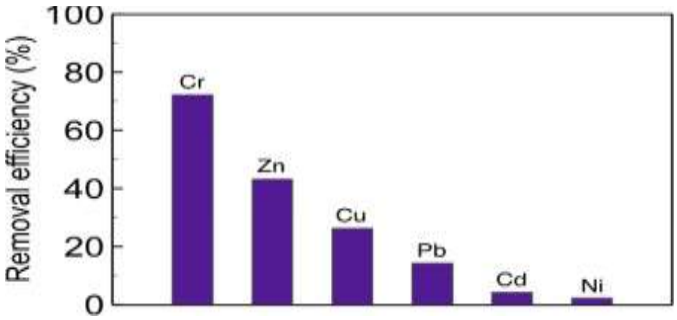



*Figure 2.The removal efficiency of lab-made GO to different heavy metals at the concentration of 9.6 mg/l.*

The effectiveness of the lab-made graphene oxide in removing various heavy metals is displayed in Figure

The elimination of Cd, Ni, and Pb was significantly inhibited at a concentration of 9.6 mg/l. This allows for the selective removal of Cr from effluent. It was discovered that the purchased graphene oxide's selectivity was less noticeable than that of the lab-made graphene oxide. The removal efficiencies for the metals are concentrated between 40% and 60%, particularly at the concentration of 9.6 mg/l. The removal efficiencies showed a wider range at the purchased graphene oxide concentration of 2.4 mg/l. The selectivity is difficult to observe, though. At a concentration of 2.4 mg/l, I have discovered that the modified graphene oxide can remove Cr, Pb, and Cd selectively. At this concentration, the removal actions on Zn and Cu were inhibited.

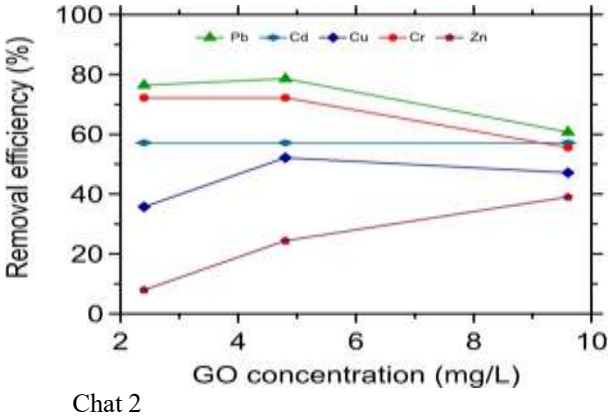

**Fig -3**: Figure

### 4.1 Synergistic effect

Sadly, after experimenting with two distinct concentration ratios, I was unable to discover the synergistic effect of the graphene oxide and PAX-15 combo. However, modifying the experimental methodology could result in a superior effect. I combined the PAX-15 and graphene oxide simultaneously. Nevertheless, the graphene oxide and PAX-15 interaction resulted in aggregates that diminished the synergistic impact. The two reagents can be added in the following order: graphene oxide at a low concentration initially, followed by PAX-15 10 minutes later (because graphene oxide works after 10 minutes, and time could be even shorter). One may anticipate better outcomes in this situation.

## 5. CONCLUSIONS

This study examined the effectiveness of different graphene oxides in removing heavy metals from wastewater. Lab-made GO is the cheapest and highly effective for Zn, with some selectivity for Cr at high concentrations. Purchased GO achieves the best removal but has lower selectivity. Modified GO performs similarly to purchased GO but requires less material. Compared to PAX-15, GO offers similar removal efficiency but works faster (10 minutes vs. longer for PAX-15) and at a much lower concentration (9.6 mg/l vs. 52 mg/l). However, factors like mass production and cost must be considered.




Chat 2

To fully utilize GO for heavy metal removal, key improvements are needed. Cost-effective, sustainable synthesis methods should replace toxic, energy-intensive processes like Hummers' method. Green synthesis using biomass or agricultural waste can lower costs and support sustainability. Simplifying purification steps can enhance scalability. Functionalizing GO with thiol groups, Fe3O4, or biopolymers like chitosan can improve adsorption, selectivity, and reusability. Integrating GO into hybrid treatment systems, such as membrane filtration or electrochemical processes, can enhance efficiency and mitigate issues like aggregation and competing ions, maximizing its potential for large-scale wastewater treatment.

Pilot-scale studies and field trials are crucial to assess GO's real-world performance, as lab conditions do not fully reflect industrial wastewater complexities. Large-scale trials will help identify challenges like material regeneration, environmental safety, and long-term efficiency. Additionally, studying GO's environmental impact and toxicity is essential for safe implementation. Addressing these factors will enhance GO's effectiveness, scalability, and sustainability, making it a viable solution for heavy metal removal and tackling global water pollution.

## ACKNOWLEDGEMENT

Future research should focus on cost-effective, eco-friendly GO synthesis, avoiding hazardous chemicals and enhancing scalability. Functionalizing GO with thiol groups, polymers, or nanoparticles can improve adsorption efficiency and selectivity. Multi-functional GO composites could address heavy metals, organic pollutants, and pathogens, broadening wastewater treatment applications. Pilot-scale studies and field testing are essential to assess GO's real-world performance, stability, and environmental safety. Integrating GO with existing treatment technologies may further optimize wastewater purification, making it a viable, sustainable solution for heavy metal removal.

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