Comparative Analysis of Greenly Manufactured Copper Oxide (CuO) Nanoparticles over Filtration Method for Bioremediation Application

Kullu Sai Kumar Yadav[1], Manikandan S[2*]
[1]Research Scholar, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India, Pincode:602105.
[2*]Project Guide, Corresponding Author, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences,Saveetha University, Chennai, Tamil Nadu, India, Pincode: 602105.

ABSTRACT
Aim: Industrial wastewater effluent is commonly treated with sand bed based filtration to remove suspended particles and colloids. A solo system, on the other hand, will leave behind soluble organic molecules in industrial effluent as a novel filtration bed. The adsorption affinity and capability of nanoparticles toward the removal of suspensions from a locally provided industrial wastewater sample were investigated in a batch mode through adsorption studies. **Material and methods:** It is our goal in this current application not only to raise the effectiveness of suspended solids removal but also to increase sand surface area by integrating functionalized green produced copper oxide-based nanoparticles into it. At the macro-level, these types of nanoparticles are made of eco-friendly, naturally occurring materials. There are two groups, each with six samples with G power 80% and coincidence interval of 95%. **Results and Discussion:** The results showed that employing functionalized sand with copper oxide nanoparticles at a modest mass fraction (5 wt %) improved suspension removal efficiency by 66 %. After that, the filter bed column was run in continuous mode with functionalized and non-functionalized sands, $p=0.05$. **Conclusions:** Unexpectedly, the breakthrough time of the functionalized sand using in-house generated copper oxide-based nanoparticles was 50 times greater than that of the un-functionalized sand in this study. According to the researchers, these promising innovative discoveries will improve current traditional methods of wastewater treatment both in the lab and in industry as novel filtration beds.

Keywords: Nanoparticles, Green Synthesis, Wastewater Treatment, Novel Filtration Bed, Adsorption, Copper Oxide.

INTRODUCTION

The worldwide freshwater scarcity and water pollution problems have gotten worse in recent years. Currently, hazardous and unreliable water sources are to blame for about 1.5 million deaths per year, or 5 % of all deaths worldwide. It is anticipated that by 2050, more than half of the world's population would have restricted access to clean drinking water at all times . Lack of sufficient drinking water supplies is primarily caused by water contamination. Due to the priority placed on industry and agricultural development in every developing country, the quality of water becomes contaminated with dangerous metal residues and organic pollutants such as mercury, cadmium, nickel and arsenic (Briffa, Sinagra, and Blundell 2020) Other contaminants include copper, lead, zinc, and cobalt Waterborne pathogens such *Salmonella typhosa*, *Escherichia coli*, and *Vibrio cholerae* cause typhoid, diarrhea, and cholera, respectively . There is a pressing need for speedy and efficient removal of contaminants from aquatic habitats through the use of new technology. Wastewater may be cleaned using a number of methods, including biological, chemical, and physical purification. (Dey and Devasena 2015; Dey, Devasena, and Sivalingam 2018). For the removal of both inorganic and organic contaminants from wastewater, the adsorption method is the most extensively employed physical technique. So far, a wide variety of adsorbents derived from both natural and synthetic sources have been discovered. In a well-established novel filtration bed the materials include copper oxide nanoparticles, sand, activated carbon, carbon nanotubes, rice husk, mesoporous silica, and cucurbiturils

In the past five years, the total number of articles published related to this study are as follows; Science direct contained 3666 articles and Pubmed contained 146 articles. Nanoparticles have evolved in the recent several decades as a versatile tool for a variety of applications, including catalysis , fuel cells, biosensors , cell labeling, pharmaceuticals, solar cells, and photonic band gap materials. The surface area of nanoparticles (NPs) is very high in volume ratio. That is why they can attach various compounds more effectively. Copper oxide nanoparticles have an edge over other materials because of their exceptional ability to adsorb. In sewage sludge, copper oxide nanoparticles can also regulate the proliferation of microbes by inhibiting their growth (Zhang et al. 2017). The cleaning of wastewater with copper oxide nanoparticles has recently been reported (Ighalo et al. 2021). The purification process is simplified, cost-effective, and safe when copper oxide nanoparticles are used to remove metal ions. The co-precipitation method is the most popular and widespread method for synthesizing copper oxide nanoparticles (Rangel, Antunes Boca Santa, and Riella 2020). Nanoparticle aggregation is a major problem since stabilizing chemicals are lacking in nanoparticles. A variety of applications such as phototherapeutic and theranostic treatment for heavy metal ions removal from groundwater can benefit from surface alterations that allow them to be generated in a changeable nanosize range . In order to alter the size, stability from aggregation, and biocompatibility of green synthesized copper oxide nanoparticles, a variety of surface modifying agents, such as PEG-polyethylene glycol copper oxide (CuO), ions, and plant extracts, have been utilized. Copper oxide nanoparticles can be easily made in a more environmentally friendly and cost-effective manner. The copper oxide nanoparticles' multimodal features have been put to good use in a variety of applications.Previously our team has a rich experience in working on various research projects across multiple disciplines(Sathish et al. 2020; Arivazhagan et al. 2020; Pandurangan, Veeraiyan, and Nesappan 2020; Saravanan et al. 2021)

The leaves of the Indian tree *Azadirachta indica* (Neem) are known for their antioxidant and antibacterial qualities, and *Jatropha curcas* latex has comparable effects. Several multifunctional nanoparticles have been created using natural product extracts such as neem, curcumin, and bhringraj, and are used as nanoparticle capping and stabilizing agents. Antibacterial, antioxidant, and anti-cancer activities are some of the most commonly investigated qualities in all cases. We present copper oxide nanoparticles coated with *Azadirachta indica* (Neem) leaf extract as an unique green synthesis nanoparticle. To date, no green syntheses of *Azadirachta indica* (Neem) natural extract-based multifunctional CuO nanoparticles have been documented in the literature. CuO nanoparticles are further described, and their metal ions adsorbent properties, as well as their potential in wastewater treatment, are investigated as potential novel filtration beds.

MATERIALS AND METHODS

This study was conducted in the Microbiology Lab of Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. The total sample size of the experiment is 12 ((Javed et al. 2020)). In this Group 1 is conventionally treated waste water and Group 2 is nanoparticles treated wastewater. The G power value is 80% and Coincidence Interval (CI) is 95%. The sample preparation is done as given below,

Part 1: Green synthesis of CuO nanoparticles

Azadirachta indica (Neem) extract preparation:

Fresh *Azadirachta indica* (Neem) leaves were washed thoroughly with clean water before being rinsed thoroughly with double distilled water. Boil 10 g *Azadirachta indica* (Neem) leaves in 100 mL double-distilled water for 20 minutes at 60 ℃. The leaf extract of *Azadirachta indica* (Neem) has been obtained.

Green synthesis of Copper oxide (CuO) nanoparticles :

In 50 mL of double distilled water,1 wt% copper chloride was dissolved. To the copper chloride solution mixture, 5 mL of *Azadirachta indica* extract was added. Incubate solution mixture to 70 ℃ to 80 ℃ for 30 mins. NaOH (1M) solution was used to adjust the pH of the solution mixture to 9. The formation of CuO nanoparticles is indicated by the solution mixture turning green to greenish brown. Filtered and dried to obtain powdered CuO nanoparticles. Figure 1 represents the schematic flowchart of the preparation of Copper Oxide Nanoparticles.

Part 2: Construction of a typical wastewater residue adsorption and filtration bed

The fluidized bed has been currently divided into multiple cells; each was measuring 3 cm to 5 cm and the total filtration bed sized around 2 feet. The cells were sized so that in a normal loading cycle, one or two beds had been filled. After locating a suitable source of crushed rock, and sorted. This is achieved by sifting crushed rock material through a succession of sieves. In sieves, metal wire screens are often linked to a wooden frame. Gravel and sand are filtered through successively finer screens before being divided into heaps based on size. Each size of material in the biosand filter's structure serves a distinct purpose. The coarse sand particles had been filled to the bottom above the filter ,and the sieved sand particles had been filled in decreasing order. Coconut coir is interspersed in the middle of the gravel sand bed. The coir itself retains moisture, preventing rapid drainage and soil drying. Coir's dual drainage and retention properties help it manage moisture in both heavy clay and dry sandy soils. The CuO nanoparticles bed has been spreaded in the second top next to the activated charcoal, and above that very fine sand has been filled and sludge has been flooded over it for waste residue filtration and adsorption. The filtrate was collected , and the absorbance was measured at 369 nm (using UV spectrometer) to determine the residue suspension. Figure 2 represents the Schematic diagram of the sand filtration bed.

STATISTICAL ANALYSIS

To compare results such as mean, standard deviation, and standard deviation error, IBM SPSS software Version 26 is used. Conventionally treated wastewater and copper oxide nanoparticles treated wastewater are the dependent variables. There are no independent variables in this equation. To determine statistical significance, an independent samples-t-test was performed.

RESULTS

CuO nanoparticles enhanced sand bed based wastewater treatment was performed on collected industrial effluent, and the filtrate quality was compared to conventionally treated water samples. Table 1 shows the physicochemical parameters (turbidity and color) of conventionally treated wastewater and wastewater treated with copper oxide nanoparticles.

When compared to conventionally treated wastewater (0.9737), a significant reduction in suspension was found in nanoparticles treated wastewater (0.8797). Table 2 shows the mean, standard deviation and standard error comparison of conventionally treated wastewater and wastewater treated with copper oxide nanoparticles.

The independent sample T test reveals no statistical difference between conventionally and nanoparticles-treated water, but there is a mean difference between water treated with nanoparticles and water treated with conventional methods. Table 3 compares the Independent sample T test values between groups and reveals a significant value of P=0.05. Figure 3 depicts the differences between the mean bar graphs of conventionally treated wastewater and CuO nanoparticles-treated wastewater.

DISCUSSION

According to this study, using nanoparticles for wastewater reduces the percentage of suspended solids in the wastewater. The degradation rate of dyes and textile effluent using copper oxide nanoparticles is 91 % and 92 %, respectively(Obodo et al. 2019). Copper oxide nanoparticles provide specific benefits in the removal of suspensions and other heavy compounds prevalent in wastewater.

Akintelu et al proved that copper oxide nanoparticles interact with bacterial cells in wastewater and serve as an antibacterial agent . The use of copper oxide nanoparticles promotes heavy metal adsorption from wastewater, such as lead and cadmium . There are no contradictory findings for the green synthesized ZnO nanoparticles for wastewater treatment. The restriction contains the following elements: Due to the high cost of obtaining precursors, nanotechnology is currently very expensive (Pandey and Jain 2020) and developing it can be as well. Furthermore, nanotechnology-based products are more expensive because they are more difficult to manufacture. Nanotechnology has improved the quality of life , but it has also resulted in more pollution, both in the water and the air. Nanotechnology pollution, on the other hand, is pollution at the nanoscale. Biological life is in grave danger as a result of this type of pollution. Nanoparticle hazards have gotten scant attention. As a result, only a few more are centered around water purification.

Studies related to characterization and the activity of copper should be performed in future. Opportunities are available for studying metal oxides for wastewater treatment, as well as antimicrobial and antibacterial properties.

CONCLUSION

According to the findings, wastewater treated with nanoparticles (0.87) has significantly less suspension than wastewater treated conventionally (0.90). The turbidity of the wastewater is reduced by copper oxide nanoparticles with a statistical significance of $p= 0.05$.

DECLARATIONS

Conflict of Interest

No conflict of interest in the manuscript.

Author's contribution

Author SKY was involved in data collection, data analysis, and manuscript writing. Author SM was involved in the conceptualization, data validation, and critical review of the manuscript.

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TABLE AND FIGURES

Table 1. The physicochemical parameters (turbidity and color) of conventionally treated wastewater and wastewater treated with copper oxide nanoparticles.

GROUP	TURBIDITY	COLOR
CONVENTIONALLY TREATED	0.90	Pale yellow
COPPER OXIDE NANOPARTICLES TREATED	0.87	Color less

Table 2. The mean, standard deviation and standard error comparison of conventionally treated wastewater and wastewater treated with copper oxide nanoparticles. Wastewater treated with nanoparticles (0.87) has significantly less suspension than wastewater treated conventionally (0.90)

	GROUP	N	MEAN	Std.Deviation	Std.Error Mean
ABSORBANCE	CONVENTIONALLY TREATED	6	0.9737	0.00216	0.00088
	COPPER OXIDE NANOPARTICLES TREATED	6	0.8797	0.00216	0.00088

Table 3. Comparative analysis of Independent sample T test values between groups reveals a significant value of P=1.000. Wastewater treated with nanoparticles (0.87) has significantly less suspension than wastewater treated conventionally (0.90)

		Independent Sample Test								
		Levene's Test for Equality of variances		**T-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig(2.tailed)**	**Mean diff**	**Std. diff error**	**5%confidence interval of the difference**	
									Lower	**Upper**
Absorbance	**Equal variances assumed**	0.000	0.05	174.198	12	0.05	0.17000	0.00098	0.16787	0.17213
	Equal			174.98	12.0	0.05	0.1700	.000	0.1678	0.1721

	variances not assumed						0	98	7	3

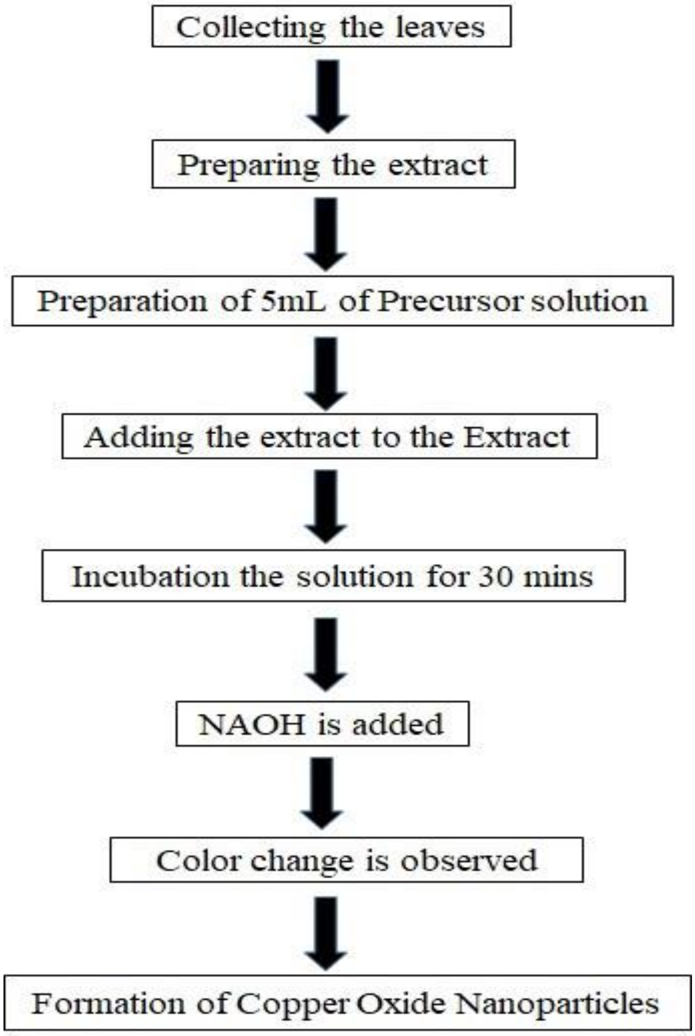

Fig. 1. Schematic flowchart of the preparation of Copper Oxide Nanoparticles.

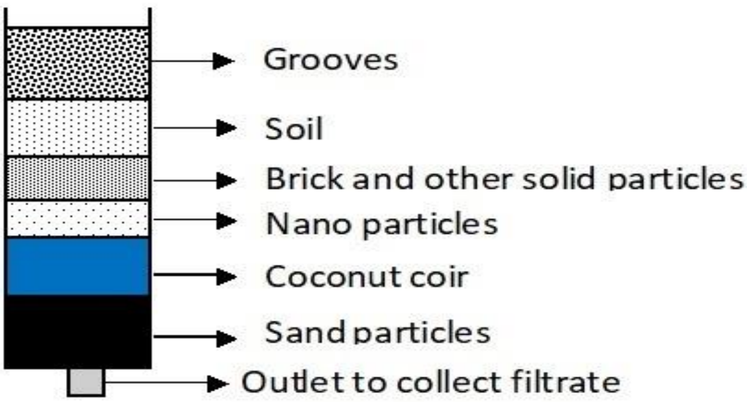

Fig. 2. Schematic diagram of the sand filtration bed.

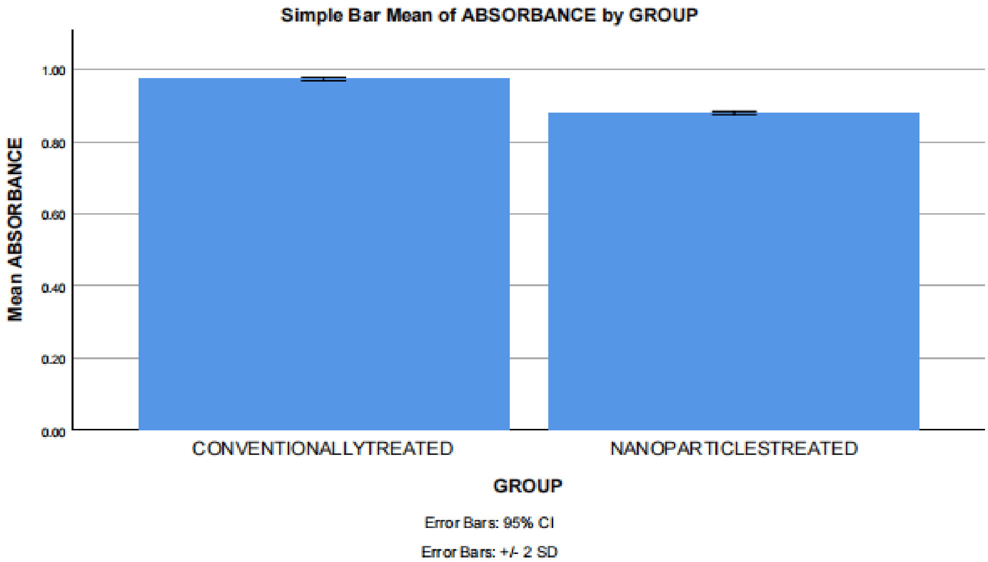

Fig. 3. Depicts the differences between the mean bar graphs of conventionally treated wastewater and CuO nanoparticles-treated wastewater. X axis: Conventionally Treated Groups; Y axis: Mean absorbance. SD+-2.