Received: 02 October 2023 | Revised: 25 November 2023 | Accepted: 04 December 2023

https://doi.org/10.56946/jce.v2i2.280

Journal of Chemistry and Environment

Research Article

Plant Extract Mediated Biogenic Synthesis and Characterization of Nickel Oxide Nanoparticles and its Environmental and Antibacterial Applications

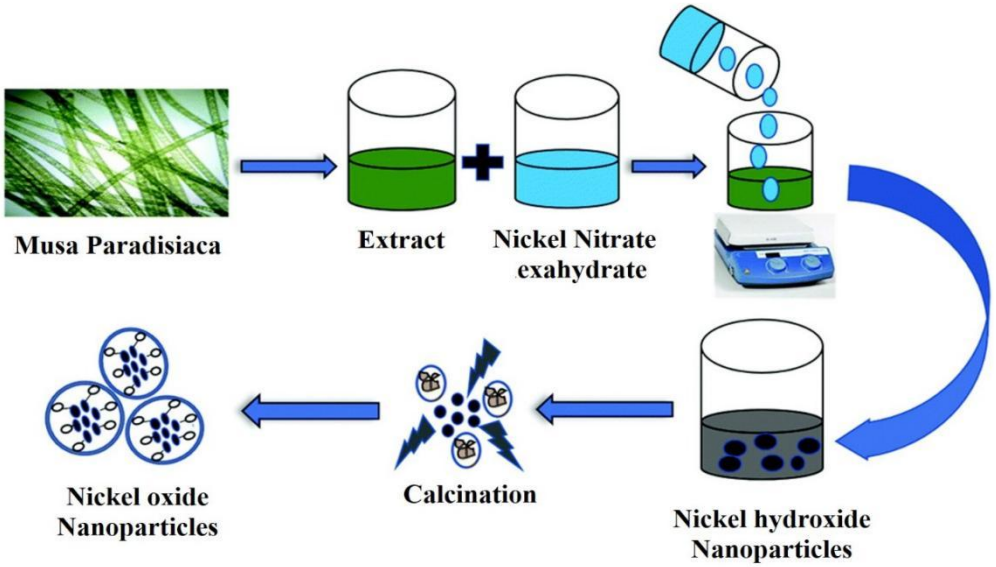
Muhammad Faizan[1], Mariyam Fatima[1], Faryal Shams[2], Muhammad Ibrahim[*3], Shabab Hussain[4], Kehkashan Sabir[5], Syed Salman[6], Ihtisham Ahmed[*7], Muhammad Muzamil Arshad[5], Immad Khan[7], Mahboob Subhani[8]

[1]Department of Chemical and Material Engineering, Chang Gung University, Taoyuan 33302, Taiwan.
[2]Institute of Chemical Sciences, University of Peshawar, 25120 Pakistan.
[3]Department of Biosciences, Comsats University Islamabad, 45550, Pakistan.
[4]Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, Università Degli Studi di Messina, Piazza Pugliatti, 1, 98122 Messina ME, Italy
[5]Sarhad Institute of Allied Health Sciences, Sarhad University of Science and Information Technology, 25120 Peshawar, Pakistan.
[6]Department of Chemistry and Biology "A. Zambelli" Università Degli Studi di Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano SA, Italy.
[7]Department of Chemistry, Islamia College University Peshawar, 25120 Pakistan.
[8]College of Chemistry and Chemical Engineering, Central South University, South Lushan Road, Changsha 410083, China
Corresponding Authors:
ibrahimattaullah2347@gmail.com
ihtishamahmed6@gmail.com

Abstract

This research focuses on the green synthesis of Nickel Oxide nanoparticles (NiO NPs) using Musa paradisiaca, commonly known as banana plant, as a cost-effective and eco-friendly approach. Musa paradisiaca, utilized in traditional medicine, possesses various medicinal properties, including antioxidant, antibiotic, allogeneic, and hypoglycemic antimicrobial attributes. The peduncle extract of Musa paradisiaca serves as a reducing and capping agent for NiO nanoparticle synthesis. Characterization techniques such as XRD, EDX, and UV-vis spectroscopy were employed to analyze the properties of the synthesized NiO nanoparticles. XRD analysis confirmed an average grain size of 15.26nm, while SEM images revealed round cubic-shaped nanoparticles with a highly crystalline structure. The antibacterial activity of NiO nanoparticles was investigated against bacterial strains, including Escherichia coli, Staphylococcus aureus, Bordetella bronchiectasis, and Bacillus subtilis, demonstrating effective antibacterial properties. Furthermore, the catalytic power of the synthesized nanoparticles was evaluated through the degradation of methyl blue and methyl orange dyes under sunlight and UV light. The results indicated superior degradation efficiency under sunlight compared to UV light for both dyes. Additionally, the study explored the adsorption activity of NiO nanoparticles for chromium (VI) at various concentrations, with the best adsorption percentage recorded at 17.23% under pH 4.

Keywords:
NiO NPs, Nanoparticles, Musa paradisiaca, antibacterial activity, chromium adsorption, MO degradation, MB degradation.



Graphical abstract

1. Introduction

Nanotechnology with its wide applications and unique properties acquired remarkable incentive in emerging science and technology for creating new ideas in the field of research to compete with daily challenges. Not only in the field of science but also in field of engineering nanotechnology is getting fame and growing rapidly. This is the reason that researcher have researches on nanotechnology all around the globe [1].

Nickel oxide nanoparticles considered as significant nanoparticles as they are vital transition metal oxide with cubic lattice symmetry. The average size of nickel oxide nanoparticles is in the range of 20-40nm [1] and estimated size is 34nm [2]. The bulk properties like surface effect, size, electrical properties and unique characteristics of rapid switching time in resistance base memory, large specific capacitance and electrochemical super capacitor, gas sensors, electrode in lithium rechargeable batteries, gas sensor, fuel cell electrode, smart windows, dye sensitized photocathode, magnetic material and magnetic properties related to size and surface effect. NiO NPs are P-type semiconductor, in which NiO NPs band gaps are wide in the range of 3.6ev – 4.0ev [1]. Extensive property of NiO nanoparticles in biomedicine is due to their relevant biological and therapeutic effect that includes removal and absorbance ability of metal oxide, unique surface area and cytotoxic effects. Chemical stable nature, applications in technology, low-cost materials, optical fibers and behaving as fuel cell properties of NiO NPs giving more attention in today's world of technology. Common chemical synthesis of NiO NPs leading to utmost damages. Chemical methods synthesis, based on specific reactors and toxic chemicals. Sol gel process [3], electrospray, laser ablation, hydrothermal, thermal decomposition, co precipitation, solvothermal process, electro decomposition [4] microwave irradiation and micro emulsion techniques [5].

Green synthesis of nanoparticles by using plants is preferred where the plants can reduce the nanoparticles in the size range 1nm to 100nm. Thus, in bottom – up approach green synthesis is considered as an alternative method for the synthesis of NPs. Green synthesis method is effective due to cost effective, efficient, environmental friendly, simple and can be operated at large scale [6]. The utmost outcome of the green synthesis is to stop the production of dangerous by products. The goal of the green synthesis of NPs is to use the natural resources as ideal solvent for a system [7]. Different nanoparticles like, silver, gold, palladium, iron and nickel has been prepared by green synthesis.

Plant extracts are considered in the synthesis of metal oxide of nanoparticles due to the effective phytochemical present in various parts of the plant such as aldehyde, ketones, terpenoids, saponins, amides, phenols and carboxylic acid that are responsible for the reduction of metallic oxides. These biologically active components phenol, flavonoids, polyphonic, reductaes, alkaloids, ascorbic acid, citric acid and terpenes have the ability to reduce metal salts into metal nanoparticles [7].

Antimicrobial activity of nickel oxide nanoparticles is due to their ecofriendly and they are low-cost materials. Nickel Oxide have application in the degradation of methyl orange, methyl blue dye, in aqueous solutions by dye degradation method Removal of chromium (VI) metal from waste water by adsorption method. Plant extract of Musa paradisiaca used for the synthesis of NiO NPs is obtaining naturally. Latex of Musa paradisiaca is obtained by the cutting of the peduncle once the banana is repined. Thus, the common name of Musa paradisiaca is banana. Banana trees are present in tropical and subtropical regions as a perennial herb, which is used as folk medicine [8]. While the fruits of Musa paradisiaca show antioxidant activity, antidiabetic activity, hypoglycemic activity, allogeneic activity and antimicrobial properties. Banana is considered as interesting plant for the synthesis of nickel oxide nanoparticles because they contain a large source of starch, fats, phenolic components present. One of the most important properties of banana plant is their film forming capability, heat resistant and good O_2 barrier [9]. The aim of work is mainly an attempt to synthesize nickel oxide nanoparticles using Musa paradisiaca through green route and to determine their various biological properties antibacterial

activity and photo catalytic activity. Removal of chromium (VI) performed by nickel oxide nanoparticles and studies by UV-vis spectrophotometer. Characterization of NiO NPs using XRD, EDX and SEM analysis is studied at selected parameters.

2. Material and Methods

2.1. Chemicals and reagents

Nickel nitrate hexahydrate Ni $(NO_3)_2.6H_2O$, citric acid, ethylene glycol, distilled water, Musa paradisiaca peduncle were collected form the local markets of Lahore, Pakistan to prepare the extract for green synthesis, ethanol, Leflox (500mg), methanol, NaOH and HCl. Deionized water was used to prepare the solutions in antibacterial activity. Photo catalytic activity was reported by using methyl blue and methyl orange dye. $K_2Cr_2O_7$ used to study the adsorption studies of NiO NPs where NaOH and HCl solutions were used to maintain the pH..

2.2. Extract preparation

Banana peduncles were washed and then dried under shade followed by peeling off bark of the peduncle, cutting and grinding as shown in figure 1. 250gram of grinded peduncles were added in 1:1 of ethanol and water in 600 mL solution. Allowed it heating for 120 minutes at 65℃ with constant stirring. Then allowed it to cool down at room allowed it to cool down at room temperature for 24 hours. Now filtered the extract, the extract was collected in sterilized glass pot in order to keep it save form bactericidal and fungicidal activity and preserved in refrigerator for further use as shown in figure 2. This extract can be saved for about two months in refrigerator at 4℃ [8]

Figure 1. Banana peduncles used for extraction

2.3. Synthesis of nickel oxide nanoparticles

Prepared extract of banana peduncle in 1:1 solution of 600ml ethanol and water used to prepare Nickel Oxide nanoparticles. Solution A was formed by adding 6g of nickel nitrate hexahydrate and 1.5mL of ethylene glycol into 300mL of plant extract with constant stir at room temperature. Solution B was formed by adding 6g of citric acid in 300mL of plant extract and stir at room temperature until it gets dissolved. Solution A and solution B get mixed with constant stirring for about 2 hours and allowed it to stand on laboratory shelf for next 2 hours at room temperature and placed into oven at 80℃ overnight. Filtered solution mixture subjected to calcination. Green nickel hydroxide nanoparticles heated in oven for an hour at 80℃ for drying. Calcination of sample was performed at 400℃ for 3hour in order to obtain black nickel oxide nanoparticles as shown in figure 3 [10]..

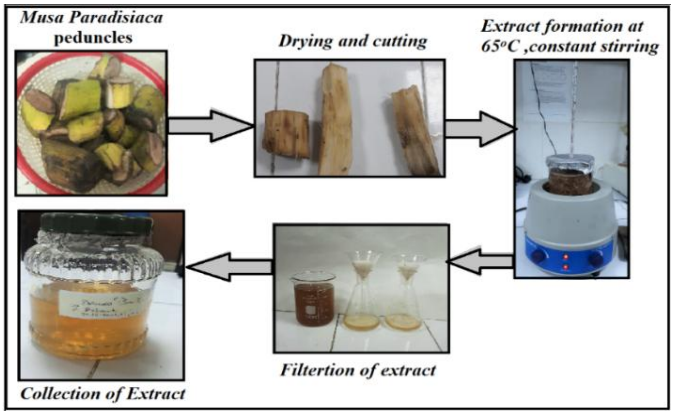


Figure 2. Preparation of *Musa paradisiaca* peduncle extract.

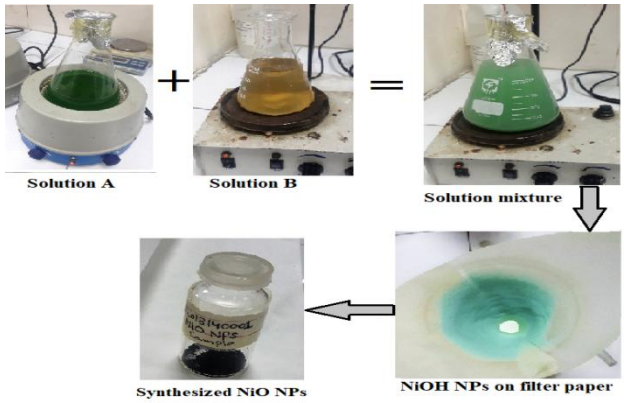


Figure 3. Schematic representation of green synthesis of nickel oxide nanoparticles.

2.4. Antibacterial activity

Leflox 500mg was used as reference standard against nickel oxide nanoparticles. While double distilled water was used as

negative control. Standard solution of Leflox (500mg) was prepared by dissolving 0.01g in 10ml of double distilled water. Different dilutions of NiO NPs were prepared in sample vials by dissolving 0.01g, 0.02g, 0.03g and 0.04g of sample into 10ml of double distilled water followed by sonication of each sample for about 30 minute before application to petri dishes. 0.8g of nutrient broth was added into 100ml of double distilled water and allowed it to pH of the nutrient broth was maintained with sterilization in autoclave at 121℃ temperatures for 15 minutes, stirred at room temperature for about 10 minutes. 7.4 Then allowed to cool down at room temperature for 30 minutes before using it for the preparation of inoculum. 7g of nutrient agar was added into 250mL of double distilled water. Heated it at 80^{o}C with continuous stirring for about 1 hour till it almost dissolved. The prepared mixture of nutrient agar was then autoclaved for 1 hour and plated into sterile petri dishes. 0.8g of nutrient broth and 1.3g of nutrient Agar was added into 250ml conical flask containing 100ml of distilled water. Heated the solution to obtain viscosity for 30 minutes at hot plate with constant stirring. Now pour the prepared solution into test tubes and capped with cotton plugged and then autoclave test tubes at 121℃ for 1hour. Then placed those test tubes at slight inclined position for overnight. After that marked the test tube with names of four different bacteria than take a loop full of bacterial culture from master slant and roll it over in prepared test tubes and paced them into incubator at 30 for 48 hours until to obtain a full growth of bacteria on slant. Prepared nutrient broth was used to make inoculum. Loop full of bacterial culture was taken from prepared slants and poured into prepared nutrient broth. Capped the nutrient broth with cotton plugged and placed it into orbital shaker for about 24 hours in order to obtain turbidity and full growth of the bacterial culture. 1.3g of Nutrient Agar and 0.8g of Nutrient broth was added in 250mL conical flask containing 100ml of double distilled water at constant stirring and heating at hot plate for 40minutes to obtain viscosity. Capped the flask tightly with cotton plugged and allow it to autoclave for about an hour. Along with nutrient agar also autoclave then properly washed and dried petri dishes. Now fill each petri dish with 30mL of nutrient agar. Then added 5mL of prepared inoculum over the nutrient broth and shake it to spread over the layer of nutrient agar. Allowed it to stand for 1 hour in order to get it solidify. Then make four bores in each petri dish marked them with positive control, negative control and sample concentrations. Then use micro syringe to add Leflox reference solution in positive control, double distilled water in negative control and different concentrations 0.01g, 0.02g, 0.03g and 0.04g of NiO NPs. Placed the petri dishes into incubator at 37℃ temperature for 24 hours. Confirmation of antibacterial activity was seen by the formation of clear zone around holes. Diameter of inhibition zones was measured by using ruler in millimeter [11]..

2.5. Photo catalytic activity of synthesized NiO NPs

Photo catalytic activity of nickel oxide nanoparticles was studied for the degradation of methyl blue and methyl orange dyes prepared in distilled aqueous solution. Dye degradation was performed under sunlight at 80,000flux and UV light for 40 minutes [12]. Dye degradation efficiency of photo catalyst was calculated by using the following equation:

Dye degradation % = $[(C_o - C_t)/ C_o] \times 100$

Where,

C_o = Concentration at equilibrium

C_t = Final concentration

2.6. Degradation of methyl blue and methyl orange dye under sunlight and UV light

A 0.01g of methylene blue was weight to make 100mL standard solution. Solution was stirred constantly for 30 minutes at room temperature to obtain homogeneity. Further, 5mL of prepared standard solution were added in 95mL of distilled water to make dilute solution. 0.05gram of nickel oxide nanoparticles was weight and added into dilute solution and stirred constantly for some time.10mL of this diluted solution as reference solution was collected into glass vial. 50mL of this diluted solution was pipetted in petri dish and allowed this petri dish to attain absorption-desorption equilibrium by retaining in dark place for about 1hour. 6mL of the solution was kept in collection vial and rest of the solution was placed under sun light for about 50 minutes. Glass vials

were used for the collection of samples for this purpose glass vials were wrapped in aluminum foil to avoid the further contact with light. 6mL of solution were pipetted from petri dish after every 10 minute and the process continued for about 50 minute to study the dye reduction under sun light. Each sample were centrifuged at 4000rmps for about 10 minute to eliminate the photo catalyst followed by filtration. Then subjected to UV spectrophotometer to check the left-over concentration of methyl blue dye. Same procedure was followed to check the degradation activity of methyl orange by nickel oxide nanoparticles under sunlight [8] [13]. Same procedure was adopted for the degradation of dyes under UV light.

2.7. Adsorption of Chromium (VI)

Standard stock solution of Cr (VI) ions (0.5g/500mL) was prepared by 1.4144g of $K_2Cr_2O_7$ in 500mL of distilled water with constant stirring for 30 minutes to obtain homogeneity of solution. Fabricated NiO NPs were used as absorbent to study the absorption of Cr (VI) ions. Absorption studies were performed in batches where specific weight of absorbent was used against standard solution of Cr (VI) ions. Different concentrations of 0.5g, 1.0g and 1.5g absorbent were used to measure absorption of chromium in 100ml standard solution of Cr (VI) ions. Effect of pH, absorbent dose and time contact were studied with 100ml standard solution of salt [14]. The experimental condition for finding the best optimum pH was set by dissolving the 1gm of absorbent for 20ml/liter salt solution *while* the pH varied between 2 to 8. Absorbent dosage varied from 0.5g to 1.5g with 20mg/liter standard solution of salt ions by keeping the contact time of 40 minute [15]. The removal efficiency and specific amount of contaminants was calculated from following formula [16].

$$\text{Removal \%} = [(C_o - C_t)/ C_o] \times 100$$

Where as,

C_o = Concentration at equilibrium.

C_t = Final concentration.

3. Results and Discussion

3.1. Characterization of Nickel Oxide Nanoparticles by Musa paradisiaca

The nickel oxide nanoparticle by paradisiaca were characterized by using XRD, SEM and EDX Analysis.

3.2. Antibacterial Activity

Antibacterial activity of nickel oxide nanoparticles was studied by using peduncle extract of *Musa paradisiaca* against gram positive and gram-negative bacteria. Results of antimicrobial activity of bacteria was shown in table 1 by using four ranges of nickel oxide nanoparticle dilutions where Leflox was used for positive control.Results of antibacterial activity confirmed the significant nature of nickel oxide nanoparticles against different strains of bacteria. However, the concentration of nanoparticles played an important role in suppressing bacterial colonies. It was observed that inhibition of bacteria was directly dependent on concentration of nickel oxide nanoparticles. The gram-negative bacteria were more resistant towards nanoparticles as compared to gram positive bacteria. So, we can say that gram positive has more resistance than gram negative [17]. Antibacterial activity order for NiO nanoparticles is as follows: E. coli < B. bronchiectasis < B. subtilis < S. aureus, as shown in table 1.

Significant zone of inhibition was observed by using nickel oxide nanoparticles that were prepared by using peduncle extract of *Musa paradisiaca*. Leflox was used as control during antibacterial activity as shown in graphical image. From above mentioned figure 4, it was interpreted that concentration of nickel oxide nanoparticles have direct effect of inhibition for bacterial activity. As the concentration increases, antibacterial activity also reached to its maximum. Concentration of NiO NPs were varied from 0.01 to 0.04g/ml. where the maximum antibacterial effect was observed at 0.04g/ml concentration of nickel oxide nanoparticles. This antibacterial effect was observed due to the reaction occurring in bacterial cell wall where the positively charged Ni^{2+} radical attached with negatively charged centered wall of bacteria due to electrostatic force of attractions and destroy the bacterial cell membrane due to strong adherence with bacterial cell wall and showed effective antibacterial activity [18].

Table 1. Minimum Zone of Inhibition of Different Bacteria's.

Samples	Bacteria	Concentration (g/ml)				
		0.01	0.02	0.03	0.04	Leflox (0.01)
NiO NPs	Minimum zone of Inhibitions (MIC) Diameter in mm					
	E. Coli	7	8	10	12	15
	B. Bronchi	13	15	16	17	19
	B. Subtilis	15	15	18	19	22
	S. Aureus	10	16	17	20	22

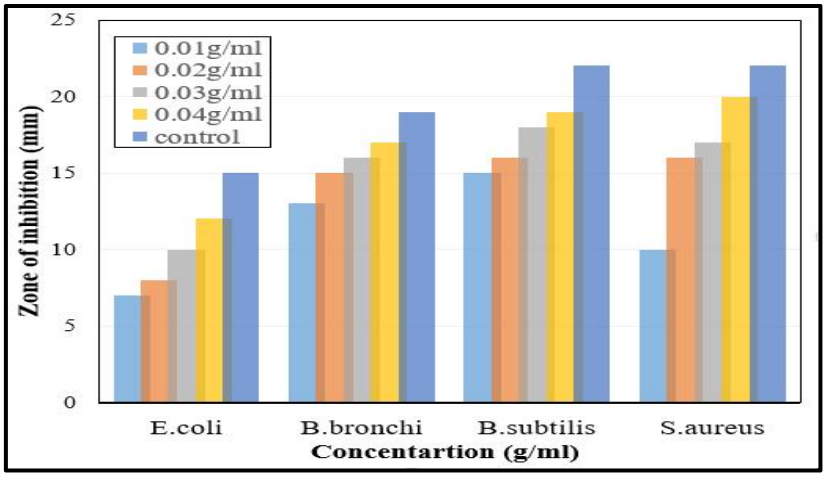


Figure 4. Graphical Representation of Antibacterial Activity.

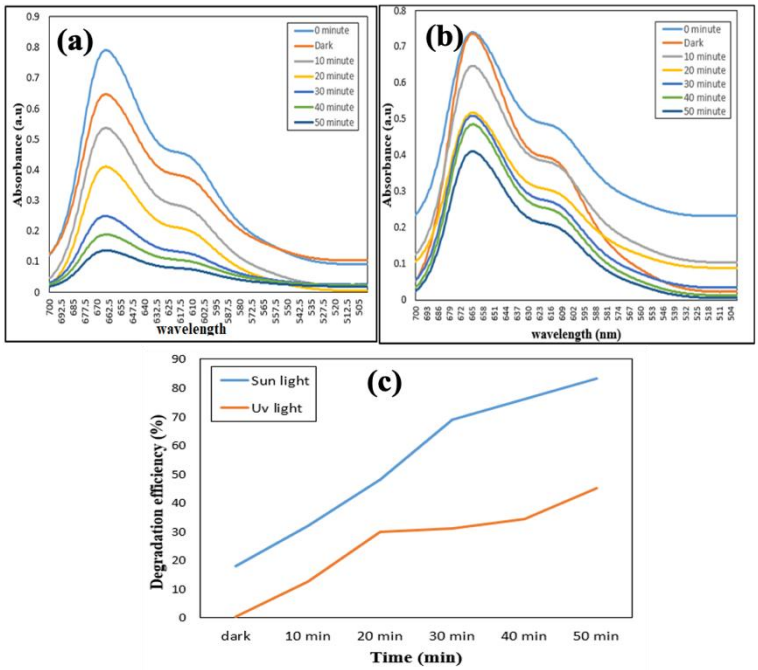


Figure 5. (a) Absorption of Methyl Blue in Sunlight, (b) Absorption of Methyl Blue in UV light, (c) Comparison of percentage degradation efficiency of Methyl Blue under sun and UV light with respect to time

The adherence of Ni^{2+} ions with cell wall reflects that not only the nanoparticle is responsible for antibacterial activity but also the sensitivity of bacterial cell also effects the antibacterial activity. On approach of the nickel oxide nanoparticles to the cell membrane certain morphological changes in the cell membrane of bacterial caused the death of the cell [19].

3.3. Analysis of dyedegradation efficiency

Photo catalytic activity of nickel oxide nanoparticles were studied by monitoring the delocalization of methyl blue aqueous particles and methyl orange aqueous particles [12]. NiO NPs dye degradation efficiency was calculated by using following formula.

Dye degradation % = $[(C_o - C_t)/ C_o] \times 100$

where,

C_o= Concentration at equilibrium

C_t = Final concentration

3.4. Degradation efficiency for methyl blue and methyl Orange

The results obtained under sunlight shows that degradation efficiency has decreased with time (reading are taken after every 10 min till 50minute) at 664nm wavelength which showed 83.5% degradation of methyl blue. This high drop rate of NiO NPs was because of their regular crystal structure, large surface area of small size particles [20].

The result obtained for degradation of methyl blue dye under UV light shows the degradation was slow process in UV light and degradation rate drops down with time (readings are taken after every 10 min for 50 minute) where 44.5% dye was degraded as shown in figure. 5 (a), (b) and (c)

3.5. Comparative analysis of methyl blue degradation under sunlight and UV lamp

Synthesized pure NiO NPs were used for photo catalytic activity of methylene blue. Nickel oxide nanoparticles of 0.05g of sample was used, dissolved in 100 ml of aqueous solution of MB. Then placed under sunlight and UV lamp. Sample was taken out after every 10 minute up to 50 minute and examined for UV analysis. Sample degradation was found to be more in sunlight then under UV light.

If we compare the graph that was shown in figure 6, It was examined that maximum dye was degraded at 30 minute and 20 minutes with 39% and 20% removal from the total degraded amount under sunlight and UV light respectively. It was also observed that in case of UV light at 30 to 40 minutes only 7% dye was absorbed by the particles while under sunlight 24% dye was removed at 40 minutes. This also show that methyl blue was more degradable under sunlight as compared to UV light.

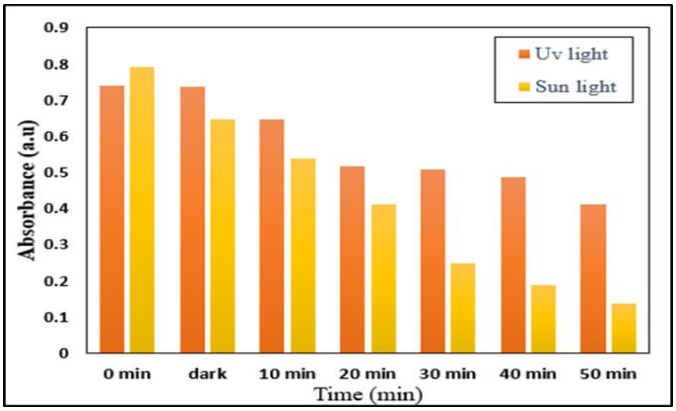


Figure 6. Comparison of percentage absorption of Methyl Blue under sun and UV light with respect to time

3.6. Degradation efficiency for methyl orange

The results obtained under sunlight suggested that the degradation efficiency has decreased with time (reading was taken after every 10 minutes till 50 minutes) at 485nm wavelength which shows 77% degradation of methyl Orange. This high drop rate of NiO NPs was because of their regular crystal structure, large surface area of small size particles.

The result obtained for degradation of methyl orange dye under UV light showed that the degradation was slow process in UV light and degradation rate drops down with time (readings are taken after every 10 min for 50 minutes) where 69% dye was degraded as shown in Figure 7 (a), (b) and (c).

3.7. Comparative analysis of methyl orange degradation under sunlight and UV lamp

Synthesized pure NiO NPs are used for photo catalytic activity of methylene orange. 0.05g nickel oxide nanoparticles of sample was used, dissolved Nickel oxide nanoparticles of

sample was used, dissolved. If we compare the graphs that shown in figure 8, was examined that maximum dye was degraded at 10 minute with 54% removal from the total degraded amount under sunlight. While in UV light removal of dye was slow process between 20-to-30-minute interval 24% dye was degraded from total degradation concentration of methyl orange at the same time 48% dye was removed under sunlight. This also show that methyl orange was more degradable under sunlight as compared to UV light. The graph as shown in figure 8, the photo catalytic activity of nickel oxide nanoparticles for methyl blue and methyl orange dyes under sun light and UV light. A comparison show that nickel oxide nanoparticles more efficiently absorbed dyes under sunlight as compared to UV light. It was examined that 83.5% methyl blue and 77% methyl orange was removed under sunlight while 69% methyl orange and 44.5% methyl blue were removed under UV light.

3.8. Analysis of adsorption of chromium (VI)

In priority list of pollutants chromium hexavalent is considered as carcinogenic metal. Which is quite harmful for plant and animal tissues. It is estimated that 0.05mg/L chromium is discharged to surface water [21]. Maximum contamination level in drinking water can be 0.1mg/L according to EPA standards. NiO NPs were selected for the removal of chromium hexavalent metal by adsorption method where the various concentrations of nickel oxide nanoparticles were used to adsorb the Cr (VI) [22]. The resultant solution was subjected to UV spectrometer for analysis. Clear peaks were obtained at 367nm. The removal efficiency of Cr (VI) was checked by using following formula:

$$\text{Removal efficiency (\%)} = \frac{(C_o - C_t)}{C_o} \times 100$$

C_o= Concentration at equilibrium

C_t = Final concentration

3.9. Adsorption of Cr (VI) using 1.5g NiO nanoparticles

It is examined that while using 1.5g/100ml NiO NPs 72.91% degradation obtained where the amount of the Cr is 0.5g/100ml. The prominent peaks have been recorded at 367nm by using the UV-Vis spectrophotometer. The graph that shown in figure 9 (a) showed the concentration of nickel oxide nanoparticles increases, removal efficiency of the chromium also increases where the concentration of Cr (VI) remains same. The reason behind more absorption is the availability of more active sites as the concentration of nanoparticles increases for the upcoming ions to get captured.

3.10. Adsorption of Cr (VI) using 1g NiO nanoparticles

It is examined that while using 1g/100mL NiO NPs 63.9% degradation obtained where the amount of the Cr is 0.5g/100mL. Prominent peaks have been recorded at 367nm by using the UV-Vis spectrophotometer. The graph that shown in figure 9 (b) showed the concentration of nickel oxide nanoparticles increases removal efficiency of the chromium also increases where the concentration of Cr (VI) remains same..

3.11. Adsorption of Cr (VI) using 0.5g NiO nanoparticles

It is examined that while using0.5g/100ml NiO NPs 58.88% degradation obtained where the amount of the Cr is 0.5g/100ml.prominent peaks has been recorded at 367nm by using the UV-Vis spectrophotometer. The graph that shown in figure 9 (c) that the concentration of nickel oxide nanoparticles decreases removal efficiency of the chromium where the concentration of Cr (VI) remains same. This is because of the less availability of active site for the upcoming ions that results in low absorption of chromium as compared to high concentration of nickel oxide nanoparticles.

3.12. Comparison of percentage adsorption of Cr (VI) at diverse concentration of NiO nanoparticles

As the below graph have shown in figure 9 (d) that the concentration of NPs increases degradation capacity of adsorbents also increases. Higher the concentration of NiO NPs higher will be the adsorbent ability because of high surface area as examined by [23] that NiO NPs having a special surface structure are potential adsorbent for wastewater treatment.

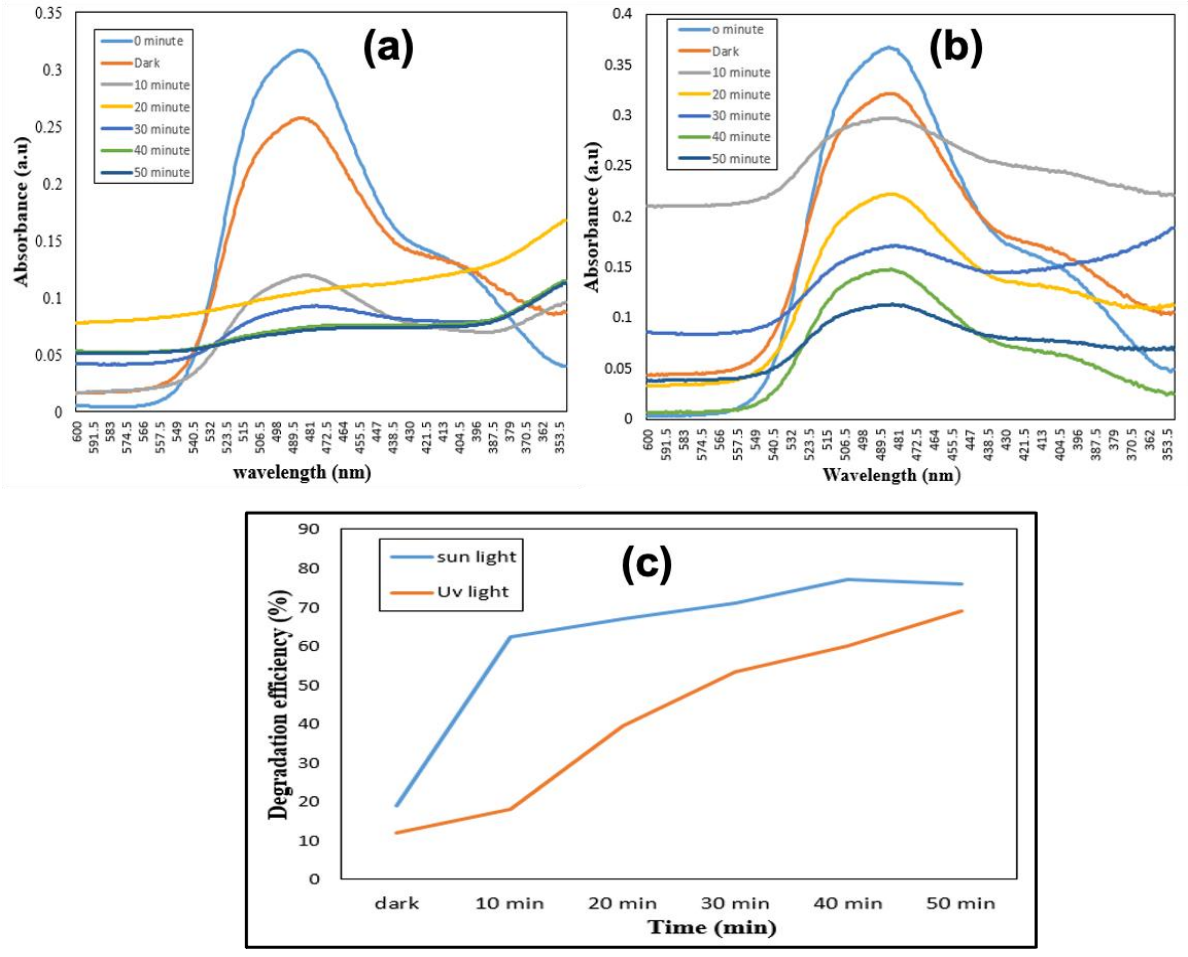


Figure 7. (a) Absorption of Methyl Orange in Sunlight, (b) Absorption of Methyl Orange in UV Light (485 nm), (c) Comparison of percentage degradation efficiency of Methyl orange under sun and UV light.

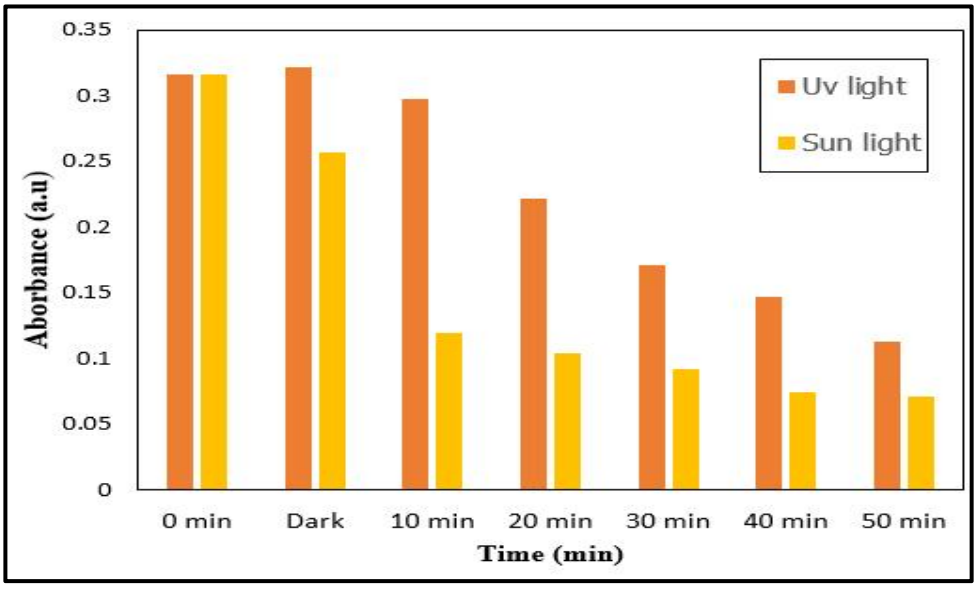


Figure 8. Comparison of percentage degradation of Methyl Blue and Methyl Orange in sunlight and UV light

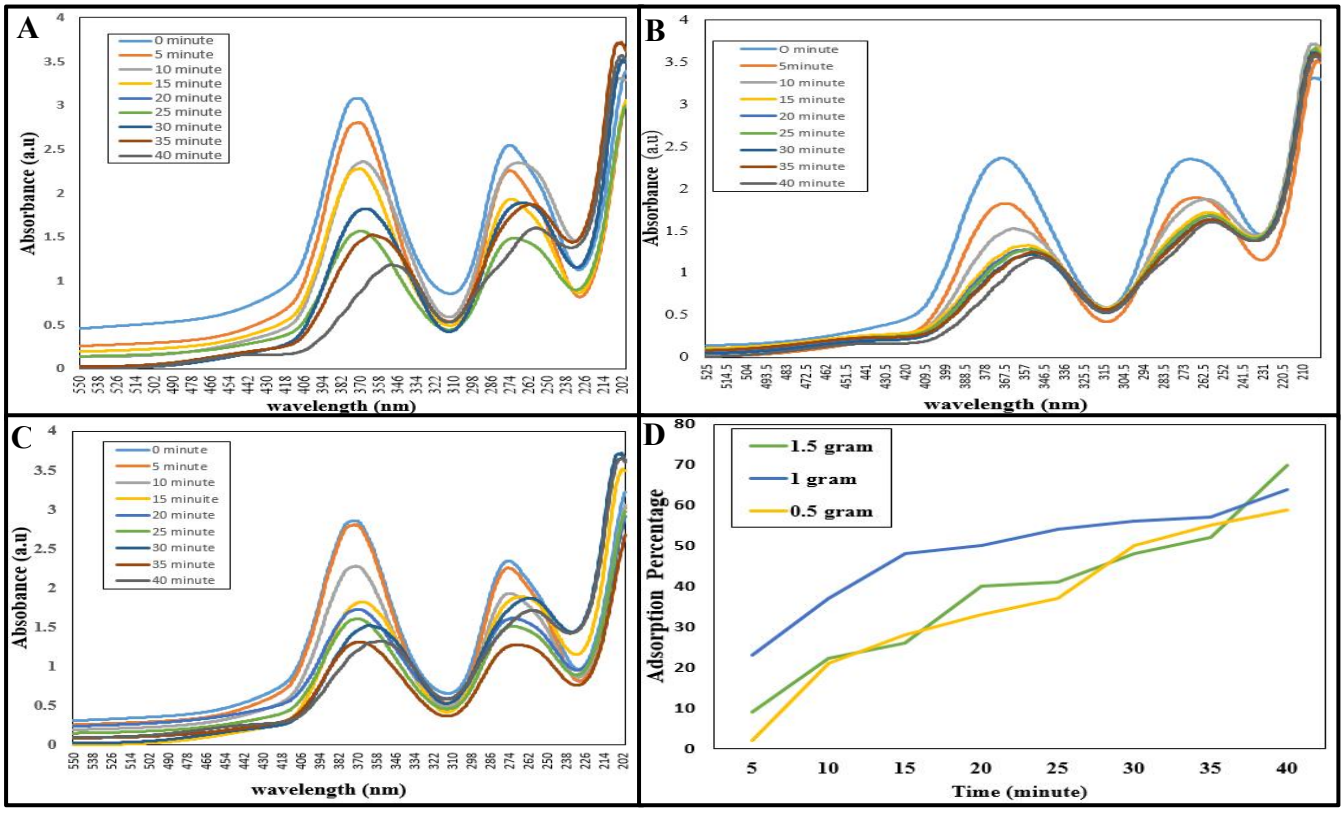


Figure 9. (A) Adsorption of chromium (VI) by 1.5-gram NiO NPs (B) adsorption of chromium (VI) by 1-gram NiO NPs (C) adsorption of chromium (VI) by 0.5-gram NiO NPs (D) Comparative znalysis of Cr (VI) adsorption

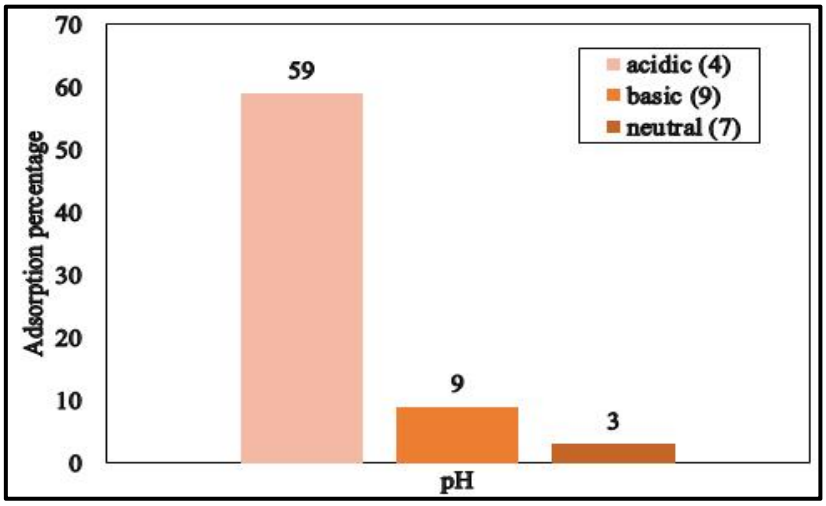


Figure 10. Comparison of Adsorbent on different pH.

3.13. Comparison of adsorbent at different pH

Metal removal efficiency of NiO NPs against Cr (VI) metal was studied at different pH under acidic, basic and neutral medium. Results showed that NiO NPs give best removal efficiency in acidic medium where the pH was 4. While in basic medium at pH 9 and in neutral pH 7 removal efficiency of chromium metal was very low as shown in figure 10. It can be concluded from above result that adsorption of chromium happened maximum when the pH was low and least when the

pH was high. This was actually because of the electrostatic forces which were stronger at low pH. At increased pH adsorbent having more negatively charged surface. [23] also reported that chromium (VI) gives good adsorption results in acidic medium as compared to high pH medium.

4. Conclusion

Simple green route has facilitated the synthesis of Nickel oxide nanoparticles by using peduncle extract of *Musa paradisiaca*. Characterization results identify the morphology and physical properties of NiO nanoparticles. Average size of 15.26nm NiO NPs was reported by XRD analysis. Round and cubic structure were seen in images obtained from SEM. Presence of Oxygen and Nickel atoms were clearly analyzed by the oxygen and nickel peaks obtained through EDX spectrum. EDX analysis provided the morphology and crystalline nature of synthesized NiO NPs. The antibacterial activity of nickel oxide nanoparticles against gram positive and gram-negative bacteria were performed by NiO NPs. better antimicrobial activity was shown by gram positive *S. aureus* with 22mm zone of inhibition with maximum concentration 0.04g/ml of NiO NPs dilutions. The lowest zone of inhibition was seen for gram negative bacteria under all dilutions i.e., 01– 0.04g/mL. The round shaped NiO NPs exhibited better photo catalytic activity under sunlight and UV irradiations for the degradation of methyl blue and methyl orange. Comparative analysis of MB and MO dyes under sunlight and Uv light showed that nickel oxide nanoparticles can adsorbed 83.5% MB and 77% MO under sunlight and 44.5% MB and 69% MO under UV light after 50 minutes by using 0.05g/mL NiO NPs. It showed that NiO NPs were more effective for the degradation of dyes under sunlight as compared to UV light. Heavy metal absorption activity was performed for the adsorption of Chromium (VI) metal by using NiO NPs concentrations ranges from 0.5g/100mL to 1.5g/100 mL and the best adsorption was recorded at pH-4 were like 58.88%, 63.90% and 72.9% respectively. Acidic medium at pH 4 was considered for better result. Where the results obtained in basic medium at pH 7-11 were not proper.

Author Contributions: Muhammad Faizan (M.F) Conceptualization and supervision, Mariyam Fatima (M.F), Faryal Shams (F.S) Methodology, Muhammad Ibrahim (M.I) and Shabab Hussain (S.H) Formal Analysis, antibacterial activity and writing original draft preparation, Ihtisham Ahmed (I.A), Kehkashan Sabir (K.S) Writing and review editing, Syed Salman (S.S), Muhammad Muzamil Arshad (M.M.A), Immad khan (I.K) and Mahboob Subhani (M.S) review, visualization and resources. All the authors have accepted responsibility for the entire content of this submitted manuscript and have approved its submission.

Acknowledgement: We would like to special thanks to Faculty of Biosciences, Comsats University Islamabad, Pakistan, Institute of Chemical Sciences University of Peshawar Pakistan, Department of Material and Chemical Engineering Chang Gung University Taoyuan Taiwan, Institute of Allied Health Sciences, Sarhad University of Science and Information Technology, Peshawar, Department of Chemistry Islamia College University Peshawar, Pakistan, and PCSIR, administrator, data collector and study participants.

Conflict of Interest: This study has no conflict of interest to be declared by any author.

Data Availability Statements: In this article, all the data that is presented can be given on demand of the corresponding author.

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

1. Mayedwa, N., et al., *Green synthesis of nickel oxide, palladium and palladium oxide synthesized via Aspalathus linearis natural extracts: physical properties & mechanism of formation.* Applied Surface Science, 2018. **446**: p. 266-272.
2. Fardood, S.T., A. Ramazani, and S. Moradi, A novel green synthesis of nickel oxide nanoparticles using Arabic gum. Chemistry Journal of Moldova, 2017(1): p. 115-118.
3. Wang, W.-N., et al., Nickel and nickel oxide nanoparticles prepared from nickel nitrate

hexahydrate by a low pressure spray pyrolysis. Materials Science and Engineering: B, 2004. 111(1): p. 69-76.

4. Fereshteh, Z., et al., Synthesis of nickel oxide nanoparticles from thermal decomposition of a new precursor. Journal of Cluster Science, 2012. 23: p. 577-583.
5. Sabouri, Z., et al., Facile green synthesis of NiO nanoparticles and investigation of dye degradation and cytotoxicity effects. Journal of Molecular Structure, 2018. 1173: p. 931-936.
6. Kuchekar, S., et al., Biosynthesis and characterization of nickel nanoparticle using Ocimum sanctum (Tulsi) leaf extract. Chem Sci Trans, 2018. 7: p. 696-702.
7. Singh, P., et al., Biological synthesis of nanoparticles from plants and microorganisms. Trends in biotechnology, 2016. 34(7): p. 588-599.
8. Venkataramana, B., et al., Phytochemical Mediated Synthesis of Silver Nanoparticles using Musa paradisiaca Peduncle Latex and Its Photocatalytic and Antimicrobial Activity. Journal of Nanoscience and Technology, 2018: p. 503-507.
9. Orsuwan, A., et al., One-step preparation of banana powder/silver nanoparticles composite films. Journal of food science and technology, 2017. 54: p. 497-506.
10. Kganyago, P., et al., Synthesis of NiO nanoparticles via a green route using Monsonia burkeana: the physical and biological properties. Journal of Photochemistry and Photobiology B: Biology, 2018. 182: p. 18-26.
11. Ezhilarasi, A.A., et al., Green synthesis of NiO nanoparticles using Aegle marmelos leaf extract for the evaluation of in-vitro cytotoxicity, antibacterial and photocatalytic properties. Journal of Photochemistry and Photobiology B: Biology, 2018. 180: p. 39-50.
12. Jeba, D.P. and T.P. Amaladhas, Green synthesis and photocatalytic activity of nickel oxide nanostructures in the degradation of organic dyes. Int. J. Res. Advent Technol, 2018. 6(11): p. 2321-9637.
13. Ganachari, S.V., et al., Synthesis and characterization of nickel oxide nanoparticles by self-propagating low temperature combustion method. Recent Research in Science and Technology, 2012. 4(4).
14. Aroosh, K., et al., Construction of Te-ZnO@ SgC 3 N 4 Heterojunction Nanocomposites for the Efficient Removal of Methylene Blue, Antifungal Activity, and Adsorption of Cr (VI) Ion. Adsorption Science & Technology, 2023. 2023.
15. Gupta, V.K., et al., Removal of hexavalent chromium ions using CuO nanoparticles for water purification applications. Journal of colloid and interface science, 2016. 478: p. 54-62.
16. Zhang, J., et al., Nickel Oxide Nanoparticles Immobilized on MWCNTs/PANI Composite Film as an Electron Transfer Facilitator for Horseradish Peroxidase: Direct Electron Transfer and H2O2 Determination. Journal of The Electrochemical Society, 2016. 164(5): p. B3001.
17. Krishnaveni, E., et al., FABRICATION OF NICKEL OXIDE NANOPARTICLES FOR ANTIBACTERIAL AND PHOTOCATALYTIC ACTIVITY. 2018.
18. Shanaj, B. and X. John, Effect of calcination time on structural, optical and antimicrobial properties of nickel oxide nanoparticles. J. Theor. Comput. Sci, 2016. 3(2): p. 149-159.
19. Khashan, K.S., et al., Synthesis, characterization and antibacterial activity of colloidal NiO nanoparticles. Pakistan journal of pharmaceutical sciences, 2016. 29(2).
20. Wan, X., et al., Effects of catalyst characters on the photocatalytic activity and process of NiO nanoparticles in the degradation of methylene blue.

Applied Surface Science, 2013. 277: p. 40-46.

21. Wei, L., et al., Selective adsorption and separation of chromium (VI) on the magnetic iron–nickel oxide from waste nickel liquid. Journal of hazardous materials, 2009. 164(2-3): p. 1159-1163.
22. Nassar, N.N. and M.M. Husein, Maximizing the Uptake of Nickel Oxide Nanoparticles by AOT (W/O) Microemulsions, in Recent Trends In Surface And Colloid Science. 2012, World Scientific. p. 257-269.
23. Zhou, Y.-G., N.V. Rees, and R.G. Compton, Electrochemistry of nickel nanoparticles is controlled by surface oxide layers. Physical Chemistry Chemical Physics, 2013. 15(3): p. 761-763.

How to cite this article:
Faizan M, Fatima M, Shams F, Ibrahim M, Hussain S, Sabir K, Salman S, Ahmed I, Arshad MM, Khan I, Subhani M. (2023). Plant Extract Mediated Biogenic Synthesis and Characterization of Nickel Oxide Nanoparticles and its Environmental and Antibacterial Applications.*Journal of Chemistry and Environment.* 2(2). p. 109-121