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Green synthesis of Nickel Oxide Nanoparticle for the Adsorption of Water Pollutants

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Abstract

Green mediated solution combustion method for the development of nanoparticles attained considerable attraction owing to its non-toxic and eco-friendly nature. In this work nickel oxide nanoparticles have been synthesized via green supported method, in which Annona Muricata leaves extract, Simarouba glauca leaves extract, Chromolaena odorata leaves extract and Rutacea leaves extract were serve as the medium. The main attraction of this work is that, the synthesized nanoparticle is free from external capping agents and it reduces the use of toxic reducing agents. Various characterization techniques such as XRD, SEM and EDAX were used to study the morphology and structure of synthesized nanomaterial. XRD pattern confirms the formation of nickel oxide nanoparticles and predicted the face centred cubic structure of the material. Adsorption studies suggested that, nickel oxide nanoparticle is a suitable catalyst for the removal of methylene blue from water.

Keywords: adsorption, nickel oxide nano particles, methylene blue, green synthesis

1. Introduction

Dye pollution is a big concern since dyeing firms discharge a large volume of very harmful chemicals into the environment. These toxic substances have the potential to make major environmental and health consequences, such as ground water poisoning, soil degradation, and air pollution. Toxic chemicals used in the dyeing industry, including as formaldehyde, heavy metals, and benzene, are detrimental to both humans and wildlife. These compounds cause several problems to respiratory, neurological, and reproductive system as well as the possibility of cancer. Furthermore, the dyeing and finishing processes necessitate a huge amount of water, which, if dumped untreated, might contaminate nearby water bodies and create environmental damage.

Adsorption is the process by which molecules or particles are drawn to and adhere to the surface of a solid substrate. This method is widely utilised in a variety of applications, including wastewater treatment, gas purification, and the pharmaceutical industry, and it is critical for the removal of contaminants from water and air. Adsorption can be used in water treatment to remove organic and inorganic contaminants such as pesticides, heavy metals, and volatile organic compounds. Adsorption can be used to treat water contaminated with numerous pollutants and can be successful for the removal of pollutants present in low quantities. Adsorption is frequently employed as a pre-treatment phase in the water treatment process before additional treatment such as filtration or disinfection. In-terms of environmental pollution, adsorption can be used to mitigate the effects of pollution by removing pollutants from soil and water. Additionally, adsorption can be used to trap pollutants in the air, reducing the amounts of pollutants that are released in to the atmosphere.

Nickel oxide is commonly used as a catalyst and adsorbent material in various chemical and environmental processes. In recent years, it has gained attention for its potential use in the treatment of polluted water sources. [1-3] Water pollution is a major concern worldwide, with conventional treatment methods often proving to be ineffective or costly. Nickel oxide has been found to be effective in adsorbing various water pollutants, such as heavy metals, dyes and organic compounds. This is because nickel oxide has a high surface area and a strong affinity for these pollutants.[4] The adsorption process involves the transfer of pollutants from

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the liquid phase to the surface of the nickel oxide particles, where they are bound by chemical or physical forces. The scientific role of nickel oxide in the adsorption of water pollutants lies in its unique physicochemical properties. Its high surface area provides a large number of active sites for the adsorption of pollutants, while its porous structure allows for easy diffusion of molecules into its interior. Nickel oxide also possesses a high affinity for polar molecules, making it effective in adsorbing various pollutants such as heavy metals, organic compounds, and pesticides. [5-6] Research studies have shown that nickel oxide adsorbents have high removal efficiency for water pollutants, making it a promising material for the development of cost-effective and sustainable water treatment technologies.[7] Additionally, the use of nickel oxide as an adsorbent material may reduce the need for harsh chemicals and energy-intensive treatment methods, thereby reducing the environmental impact of water treatment processes.

Green chemistry, on the other hand, emphasizes the use of environmentally friendly and sustainable processes to minimize harm to the environment. Therefore, the synthesis of materials and substances used in adsorption studies has shifted towards green mediated synthesis. This approach incorporates environmentally friendly and renewable materials that are used to produce functional materials for adsorption studies. The use of green mediated synthesis in adsorption studies not only reduces the use of hazardous chemicals but also helps in the sustainable production of functional materials for a wide range of applications. [8-10]. The mechanism of adsorption of methylene blue using green-synthesized nickel oxide is due to the availability of numerous active sites on the surface of nickel oxide nanoparticles.[11] These active sites provide a high surface area for the adsorption of methylene blue molecules through the formation of van der Waals interactions and electrostatic forces.[12] The synthesis of green-synthesized nickel oxide can be achieved using a simple method, such as using plant extracts as a reducing and stabilizing agent. The obtained nickel oxide nanoparticles can then be used for the adsorption of methylene blue. The adsorption of methylene blue by green-synthesized nickel oxide nanoparticles is influenced by various factors such as contact time, initial concentration of methylene blue, and the amount of nickel oxide nanoparticles used for adsorption. The green-synthesized nickel oxide nanoparticles have shown excellent adsorption capability for methylene blue, with high adsorption efficiency and capacity compared to other materials. This makes them a suitable choice for the removal of methylene blue from wastewater.

In our current study, we are using Green-synthesized nickel oxide nanoparticles for the adsorption of pollutant methylene blue, a dangerous organic dye. This research has been able to produce ab effective adsorbent through innovative synthesis method.

2. Methodology

2. 1 Synthesis of Nickel Oxide

The methodology of the work comprises of green mediated synthesis of nickel oxide nanoparticles by a solution combustion method. The green mediums that are taken for the synthesis be Annona Muricata leaves extract, Simarouba glauca leaves extract , Chromolaena odorata leaves extract and Rutacea leaves extract.

2.1.1 Preparation of the plant extract: About 5 g of the plant part is boiled with distilled water for about 15 minutes. The obtained extract is filtered using a Whatman No1 filter paper and used as the solvent for green mediated synthesis.

2.1.2 Solution Combustion method of synthesis of NiO nanoparticles : About 5g of nickel nitrate is dissolved in extracted green medium with constant stirring at 60^{o} C.The obtained solution is concentrated until a gel is formed. The gel is placed on a heater at 100°C where it decomposed spontaneously by self-ignition, leaving behind nickel oxide nanoparticles. The obtained nanoparticles are annealed at 300°C/1 h to improve the degree of crystallization of nickel oxide nanoparticles. Sample ID of NiO samples synthesised in different green mediums are given in table 1.

Table 1 :Sample ID

Name of the green medium	**Sample ID**
Annona Muricata leaves extract	NO AM
Simarouba glauca leaves extract	NO SG
Chromolaena odorata leaves extract	NO C
Rutaceae leaves extract	NO R

2.2 Chracterisation techniques

Crystalline nature of the synthesized nickel oxide nanoparticles were analysed using Bruker D8 Advance X ray powder diffractometer with Cu Kαradiation (1.5406 Å). The surface morphology and elemental composition was evaluated using scanning electron microscope (SEM- EDAX: Jeol 6390LA/ OXFORD XMX N) with an accelerating voltage of 0.5 to 30 kV.

2.3 Adsorption studies

The adsorption experiments were performed with the stock solutions of Potassium dichromate (10 ppm), and methylene blue (5 ppm) in deionized water. All adsorption experiments were carried out by placing 0.02 g of adsorbent (NO AM, NO SG, NO R and NO C) in 50 mL of the test solution contained in different volumetric flasks, shaken well for different time intervals (15, 30, 45 and 60 min) and centrifuged. The centrifugate was separated and UV-Visible spectra were recorded.

3. Results and Discussions

3.1 Structure & Morphology

The crystalline nature of the samples is studied by XRD analysis. Figure 1 shows the XRD pattern of NiO samples. The XRD spectrum confirmed the successful formation of NiO nanoparticles. XRD spectrum further revealed the pure crystalline nature of all NiO nanoparticles along with 2 theta values of 27.33, 37.14, 43.22, 62.81, 76.95 and 79.27 which are indexed to (110), (111), (200), (220), (311) and (222) planes. All the diffraction peaks can be assigned to face-centered cubic phase of NiO (JCPDS No. 04-0835). The average crystalline sizes of all NiO samples are calculated using Debye Scherrer equation and are tabulated in table1 [13].

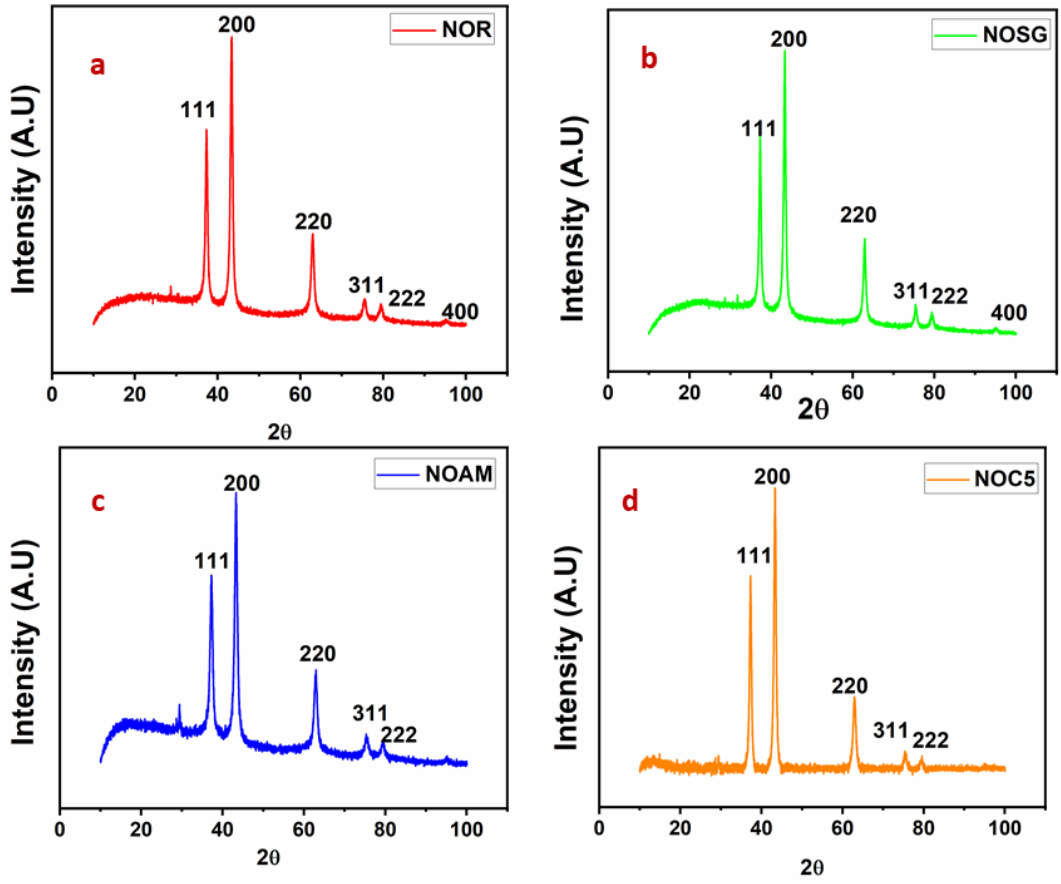

Figure 1 : XRD of NiO samples

XRD pattern shows the successful formation of NiO nanoparticles in all the green mediums. More over in the XRD pattern of NO AM and NO C 5 samples there is a tendency of formation of peak at 27.33 (110),which indicates that Annona Muricata leaves extract and Chromolaena odorata leaves extract are better green medium than Simarouba glauca leaves extract and Rutaceae leaves extract for the solution combustion synthesis of NiO nanoparticles.

Table 1: particle size of NiO

Sample ID	**Particle size (nm)**
NO AM	16.4
NO SG	16.5
NO C	21.9
NO R	14.2

In order to explore the morphology of the NO sample synthesized by solgel autocombustion technique, SEM analysis of NOR was taken as it has high adsorption property towards MB.
Irregular structure was observed in the SEM image of NO sample in which agglomeration was seen in some extend.

The purity of NO was evident in the EXAD spectrum in which the material is 100 % pure, traces of other metal or non-metal impurities were not observed in the EDAX analysis.

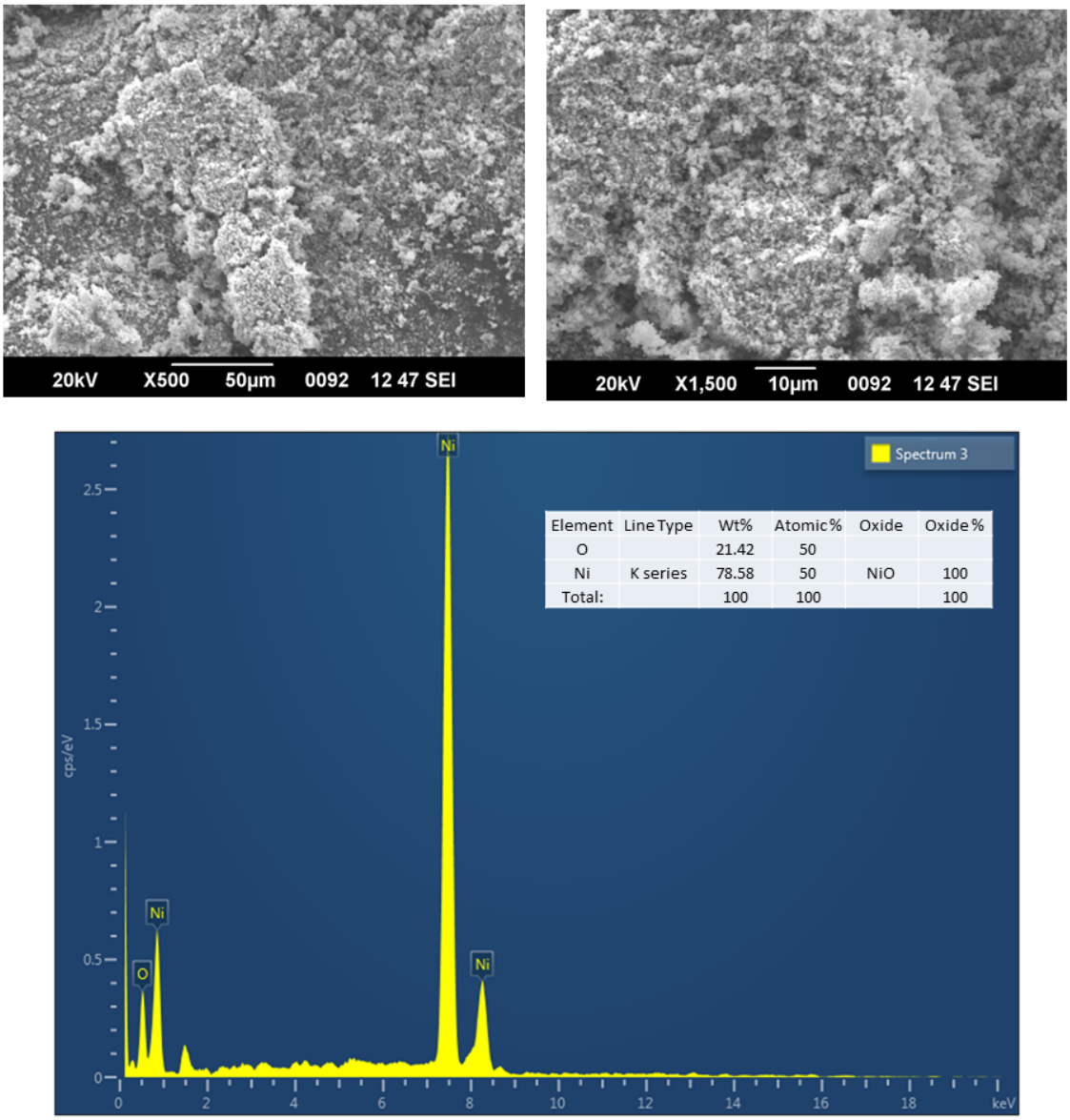

Figure 2 : SEM of NiO samples

3.2 Adsorption Studies

3.2.1 Adsorption of methylene blue

Adsorption of methylene blue by the samples was carried out as explained in the methodology section. UV spectrum recorded in the range of 400-800 nm is shown in Figure 3 – Figure 7

Adsorption time is the most critical parameter in dye removal process which depends on variables such as initial dye concentration, amount of adsorbent and the rate and type of mixing mechanism. The amount of methylene blue adsorbed against the adsorption agitation time for different NiO samples are demonstrated in figure. 4.1-4.4 It can be observed from this figure that the adsorption uptake of methylene blue on these adsorbents increased with increasing contact time for all the samples. A comparative study on adsorption capacity of a definite amount of different NiO samples towards methylene blue is also conducted and is depicted in figure 8

It is clear from the spectrum that NOR sample is found to be most efficient for the removal of Methylene blue, which can be correlated with the particle size. As the particle size decreases the surface area increases and adsorption capacity also increases [14]. The particle size of NOR is lower than that of the other NiO samples.

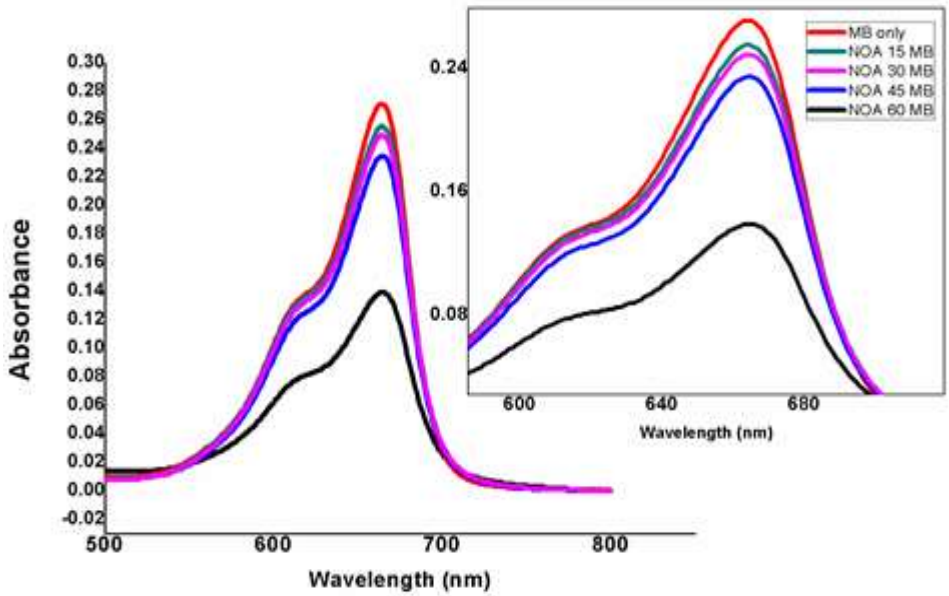

Figure 3: Methylene blue adsorption spectra of NOA at different time intervals

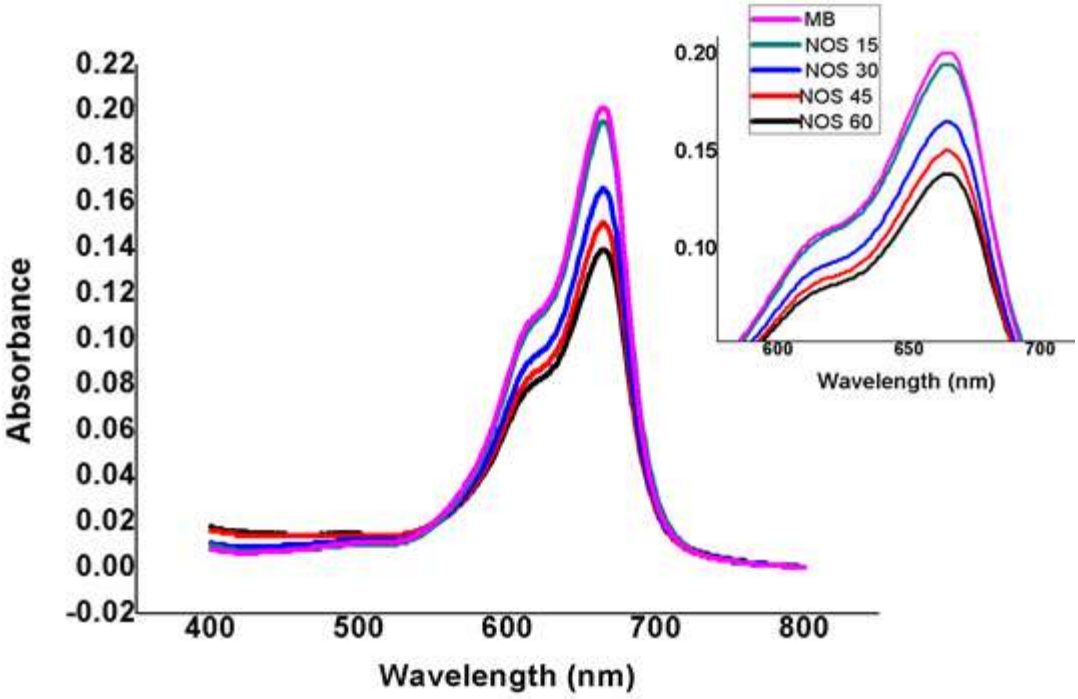

Figure 4: Methylene blue adsorption spectra of NOS at different time intervals

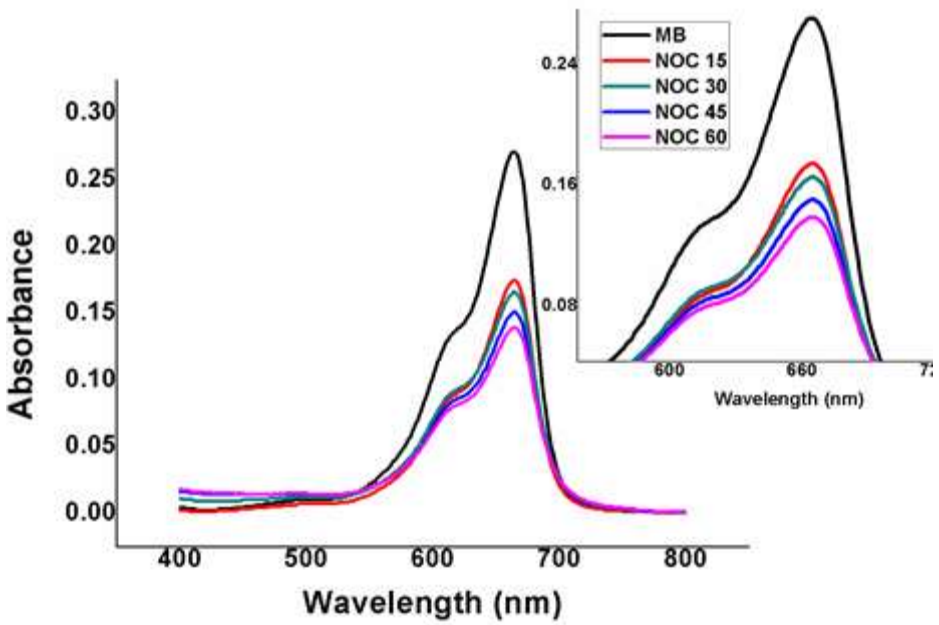

Figure 5: Methylene blue adsorption spectra of NOC at different time intervals

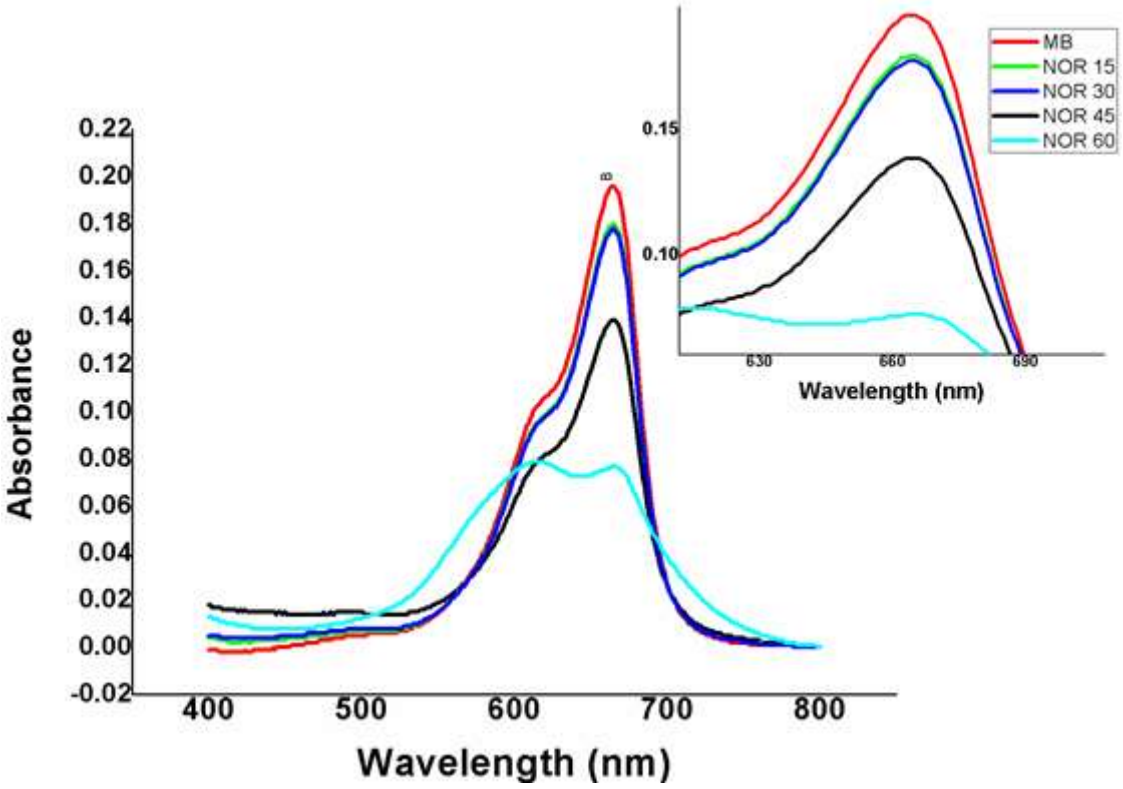

Figure 6: Methylene blue adsorption spectra of NOR at different time interval

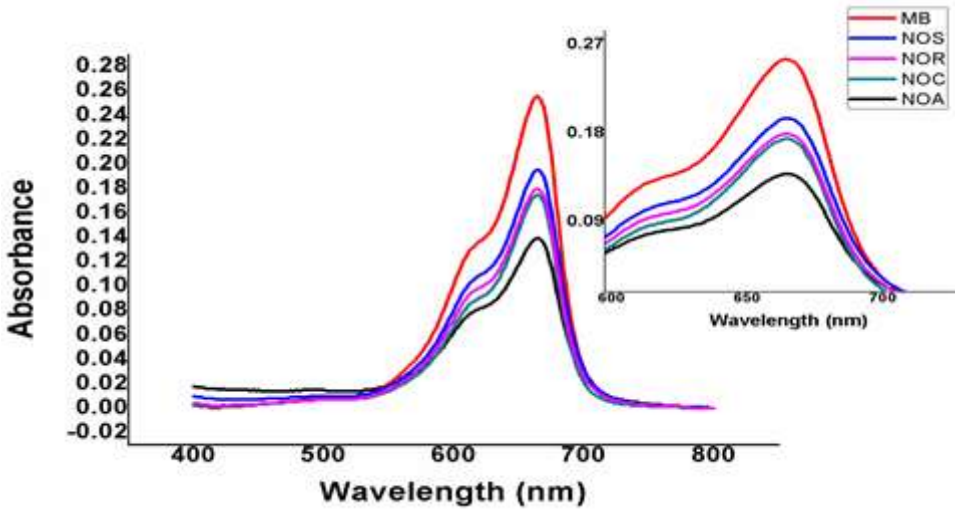

Figure 7:Methylene blue adsorption spectra of different NiO samples at intervals of 15 minutes

4. Conclusions

Methylene blue adsorption by green synthesised nickel oxide nano particles was shown to be an effective and sustainable technology for eradicating dyes from waste water. The utilisation of plant extract as a reducing agent in the extraction and production of nickel oxide nano particles is an alternative to traditional chemical synthesis processes, which are often expensive and ecologically unfriendly. The results indicate that contact time, dye concentration, and adsorbent dose all have an effect on adsorption efficiency. These findings have implications for the design of wastewater treatment systems that integrate low-cost green nano materials for efficient pollutant removal. More research is needed to refine the adsorption method and evaluate the economic viability of green synthesised nickel oxide nano material for water treatment applications.

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