

Nanotechnology Based Water Purification Systems for Rural Communities

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One of the essentials for life, water is also a crucial resource for all living things and is required for industrial and agricultural processes. Water is a translucent, odorless, inorganic material that makes up approximately 333 million cubic miles, or nearly 71%, of the earth's surface. Just 2.5% of the water in this is freshwater, with the remaining 97.5% being saltwater. Water seems colorless in little or minimum amounts, but it actually has an inherent blue tint due to the absorption of red-wavelength light. Issues with water quality and purification might be overcome with "nanotechnology." Zero-valent iron nanoparticles are widely used in environmental remediation because of their quick response time, efficiency in eliminating pollutants, and ability to address groundwater problems through the use of a permeable reactive barrier that incorporates zero-valent iron. These nanoparticles were created by combining an extract with a metal salt solution to create nanoparticles that contained zero-valent iron. As far as we are aware, this research is the first to investigate whether zero-valent iron nanoparticles can effectively treat municipal wastewater. In particular, the effect they have on BOD and COD metrics is being evaluated.

Keywords: CPD and BOD reduction, Zero valent iron nanoparticles, UV visible spectra, Phase contrast microscope.

1. Introduction

These days, a wide range of industries, including agriculture, electronics, medical, environmental monitoring and cleanup, food processing and packaging, energy production, and agribusiness, use nanomaterials' unique physical features. These nanomaterials can be made in essentially two ways: "top down" and "bottom up." The top-down category includes things like milling and solid state routes, while the bottom-up category includes things like vapour phase and wet chemical routes [1]. Characterization techniques, such as AAS, XRD, SEM, TEM, EDX, AFM, STM, UV-Visible spectroscopy, Raman spectroscopy, FTIR spectroscopy, etc., are used to analyze various properties, such as physical, chemical, optical, electrical, thermal, mechanical, etc., of the nanomaterials or structures synthesized by both techniques. This chapter explains the many approaches taken, the materials utilized to synthesize nanomaterials, as well as the methods used to characterize them.

The air, water, and soil have all been severely contaminated due to the industrial sector's explosive growth. Efforts to address pollution-related concerns have negatively impacted our ecosystem, which has resulted in health consequences [5]. As a result of the world's increasing industrialization, organic pollutants have emerged as a significant pollutant that contributes to environmental deterioration [13]. As a result, a significant amount of research is focused on finding effective ways to remove or degrade these toxins. Worldwide, water pollution is a serious environmental problem, particularly when it comes to drinking water, which is mostly derived from surface and ground water. In addition to other nanotechnology-based approaches that may be helpful for treating water, heterogeneous photocatalytic systems powered by metal oxide semiconductors such as TiO_2 , ZnO , ZnS , and many more can function successfully and efficiently for water treatment [2].

These days, the supply of safe and clean drinking water is a big concern on a global scale [3]. Every drop of water contains massive unseen microorganisms that swim and eventually multiply into billions [11]. Water for drinking must be pathogen-free in order to prevent and control diseases that are spread by water [8]. The most frequent bacterial illnesses spread by water include cholera, typhoid fever, severe diarrhea, gastroenteritis, pneumonia, and bacillary dysentery, among others.

➤ Role of Nanoparticles in water purification

Because of their small size, which ranges from 1 to 100 nm, nanoparticles frequently have unique chemical and physical features, such as increased surface area, more reactivity, better mechanical capabilities, and optical properties. They can be applied in a variety of sectors, including electronics, biological and pharmaceutical sciences, energy technologies, catalysis, and water purification applications, due to their special qualities [L. Qiu, 2020:1-81]. Numerous nanomaterials, whether single or composite, have been extensively employed to remove a wide range of contaminants from wastewater. The two materials in most demand are metal oxide nanoparticles and AC due to their special qualities that aid in the removal of contaminants from wastewater. [10] Because of their small size, which ranges from 1 to 100 nm, nanoparticles frequently have unique chemical and physical features, such as increased surface area, more reactivity, better mechanical capabilities, and optical properties. They can be applied in a variety of sectors, including electronics, biological and pharmaceutical sciences, energy technologies, catalysis, and water purification applications, due to their special qualities [L. Qiu, 2020:1-81]. Numerous nanomaterials, whether single or composite, have been extensively employed to remove a wide range of contaminants from wastewater. The two materials in most demand are metal oxide nanoparticles and AC due to their special qualities that aid in the removal of contaminants from wastewater. Adsorbates such as metal oxides, clay, zeolites, graphene oxide, and carbonaceous materials are utilized in the purification of water. Because of their huge surface area, which facilitates the deposition of more contaminants, carbonaceous materials—in particular, AC—have drawn increased attention among these adsorbate materials. Additionally, using AC produced from biomass or biowaste can help reduce environmental pollution.

➤ Synthesis of nanoparticles

There are two primary methodologies used in the manufacturing of nanoparticles: top-down and bottom-up. The method of creating nanoparticles is explained by the top-down approach,

which divides bulk materials into tiny parts. The top-down approach primarily falls under the physical technique of NP synthesis since it uses a huge tube furnace to break up bulk material into tiny pieces (Chen et al., 2016).[4] On the other hand, the bottom-up strategy suggests using smaller molecules to produce the required quantity of NPs. In order to stabilize the generated NPs, chemical reduction is primarily employed in this procedure, occasionally in conjunction with the capping agent. The bottom-up approach also takes into account the biological process of NP synthesis, which produces nanoscale materials by combining proteins with metallic compounds. the notion of bottom-up and top-down tactics. The techniques can be divided into three groups: physical, biological, and chemical techniques. [14].

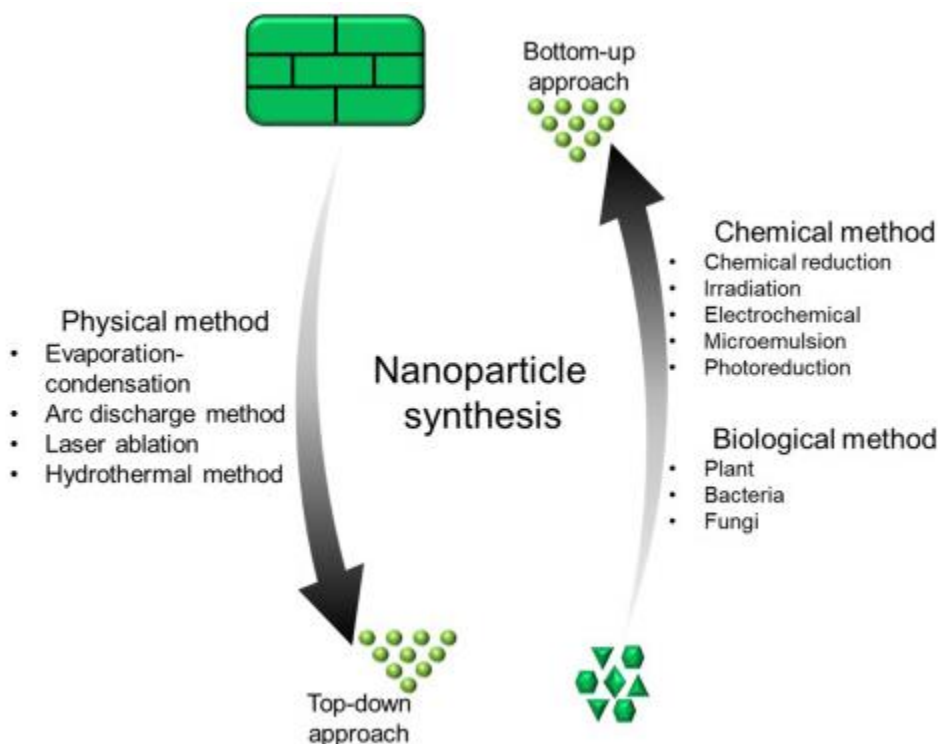


Figure 1: Top-down and bottom-up approach in nanoparticle synthesis.

➤ Methods for synthesis of nanomaterials

For many nanotechnology applications, precise control over the size, shape, and crystalline structure during the nanomaterials' synthesis has become crucial. Using the top-down method, a huge material is divided into increasingly smaller pieces until it reaches nanoscale size. The ultimate structure of the bottom-up approach, on the other hand, is formed by physical or chemical deposition of precursors in the liquid, solid, or gas phase. Bottom up technique is more preferred because it is less expensive and is suitable for large scale production, compared to top down technique. Nanomaterials may be produced using a variety of bottom-up techniques, including hydrothermal, combustion, gas phase [6], sol-gel processing etc. Hydrothermal synthesis process employing both convection and microwave heating was the methodology adopted for synthesis of the nanostructured sensing materials used to design the

sensors for different applications

2. Literature Review

After the discovery of carbon nanoparticles in 1991, single-wall carbon nanotubes with a diameter of one nanometer were synthesized and reported by Iijima and Ichihashi in 1993 (Chen et al., 2021). Carbon nanotubes, also known as Bucky tubes, are a class of nanomaterials that are distinguished by a two-dimensional, hexagon-shaped lattice of carbon atoms. The carbon atoms are bent and joined in a single direction to produce a hollow, cylindrical structure known as a nanotube. Carbon nanotubes are the carbon allotropes that lie between two-dimensional graphene and zero-dimensional fullerene. [7].

Lea reported the synthesis of citrate-stabilized silver colloid almost 120 years earlier (Nowack et al., 2011). Particles with an average size ranging from 7 to 9 nm are produced using this method. This technique achieves nanoscale dimensions and citrate stability, which is similar to previous discoveries on nanosilver production combining silver nitrate and citrate. Studies conducted as early as 1902 indicate that proteins were also used to stabilize nanosilver. Since 1897, the commercially produced nanosilver known as "Collargol"—whose particles have an approximate size of 10 nanometers (nm)—has been used in medicine. The fact that this size characterization dates back to 1907 validates Collargol's positioning in the nanoscale range. Gelatin-stabilized silver nanoparticles, a unique variety of silver nanoparticles with sizes ranging from 2 to 20 nm, were first shown by Moudry in 1953. In addition to Collargol, there is another way to make these nanoparticles. A patent statement highlights the vision of those who developed nanosilver formulation decades ago, stressing that optimal efficiency depends on dispersing silver as colloidal particles with a crystallite size of less than 25 nm. [12].

Gold nanoparticles, also known as AuNPs, have a long history in the field of chemistry dating back to the Roman Empire, when they were first applied to glassware to decorate and stain it. With the groundbreaking work of Michael Faraday, who may have been the first to notice the unique characteristics displayed by colloidal gold solutions as compared to bulk gold, the modern era of AuNP synthesis began more than 170 years ago. Faraday began studying the constituents and synthesis of colloidal suspensions of "Ruby" gold in 1857. These nanoparticles confirm their position as magnetic nanoparticles with their distinct optical and electrical properties. Faraday provided an example of how different lighting conditions may produce different colored solutions using gold nanoparticles. [9].

3. Methodology

3.1 Characterization of Iron Oxide Nanoparticles

We used X-ray diffraction analysis (XRD) according to the protocol developed by Boukhoubza et al. to ascertain the size and make-up of the iron oxide nanoparticles that were produced. The pellets were re-dispersed in sterile double-distilled water and centrifuged at 10,000 rpm for ten minutes. The resultant iron oxide nanoparticles then went through a fifteen-minute centrifugation step at 10,000 rpm. After baking in an oven set to 50°C, the purified pellets were examined using an XRD (Pan Analytical, X-pert pro, Netherlands). Utilizing an

X-ray dispersive reflectance (XRD) system operating at 45 kV and 40 mA, the iron oxide nanoparticles extracted from *Spinacia oleracea* leaves were evaluated within the 20–80 scattering range using a Cu-K α radiation source. The produced iron oxide nanoparticles' grain size and structure were determined using X-ray diffraction spectroscopy.

4. Result and Discussion

A reduction in BOD from 56 mg/L to 22 mg/L and in COD from 405 mg/L to 85 mg/L is seen when zero-valent iron nanoparticles are added to sewage treatment, underscoring the importance of treating municipal wastewater before releasing it into natural water sources. As a result, after 15 days, the estimated removal efficiency for BOD is 60.31% and for COD is 73.82%, both of which are consistent with previously noted removal rates. According to a study by Suhendrayatna et al. (2012), removal efficiency for BOD and COD are 50.15% and 56.72%, respectively, in the photo-reduction method employing spontaneous saccharin for municipal wastewater treatment.

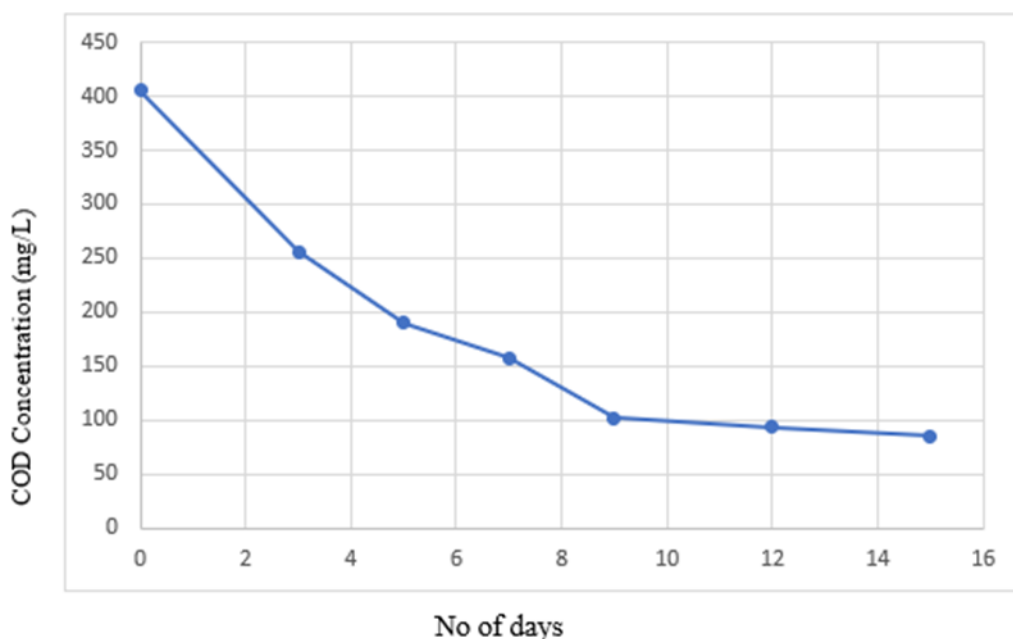


Figure 2: COD reduction from Municipal Waste Water by FeNP from *Spinaciaoleracea* leaves extract.

5. Conclusion

Within predetermined bounds, the most recent study demonstrates the effective removal of BOD and COD from municipal wastewater. In order to maintain the sustainability of nanobiotechnology, a synthetic approach that is beneficial to the environment should be used to create nanoparticles. *Spinacia oleracea* can be used to produce zero-valent iron

nanoparticles, which have been shown to reduce BOD by 60.314% and COD by 73.82%. With its many appealing qualities, this creative green chemistry offers an economical and successful way to protect the environment through bioremediation.

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