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# Design and Analysis of Rural Water Purification Using Nanotechnology

Siddharth Reddy [a], Ayesha Khan [b]

[a] *Department of Nanotechnology, FutureGen Engineering College, Vijayawada, India.*
[b] *Department of Nanotechnology, FutureGen Engineering College, Vijayawada, India.*

## Abstract

Different types of nanostructures have been successfully created for decontamination and remediation processes, aimed at removing biological and chemical contaminants from water to safe levels. These nanostructures, featuring various shapes and sizes, were synthesized using a hydrothermal method. The effectiveness of a photocatalytic system that utilizes wide bandgap semiconductors hinges on the generation of electron-hole pairs, which in turn produce active radicals. The bandgap of the semiconductor photocatalyst is crucial for transferring energy from photons to electrons, allowing them to jump to the conduction band, where they can interact with free oxygen to form superoxide radicals. Interestingly, the bandgap of nanostructured semiconducting metal oxides can be adjusted to enable absorption of visible light. The challenges of providing clean water affordably are escalating so rapidly that just making small improvements to our current purification methods might leave many parts of the world struggling with insufficient supplies of clean water in just a few decades. Tackling these issues in science, technology, and society calls for a long-term vision to identify what needs to be addressed. Here are the critical challenges we'll need to confront over the next 20 years regarding clean water.

**Keywords:** Water, Absorption, Purification, Nanotechnology.



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## Introduction

Recently, oxide-based nanomaterials like Fe3O4, ZnO, and TiO2, as well as their binary and ternary nanocomposites, have been used to remove a variety of dangerous metal ions and organic dyes (Hu & Apblett, 2014). The ways we can use adsorption and modify surfaces of adsorbents to remove heavy metal ions and dyes are incredibly effective for purifying water. Across the globe, people are facing serious threats to their access to safe and clean water, which directly impacts their health and economic stability (Chaturvedi & Dave, 2019).

A strong risk management plan is necessary to reduce and eradicate the negative effects of the presence of both chemical and microbiological contaminants, which are not only extremely poisonous but also tenacious and difficult to control. We require procedures that can convert dangerous materials into safe, innocuous forms while also being economical (Ahmed, et al., 2014). Improved water treatment methods are being made possible by the use of nanotechnology.

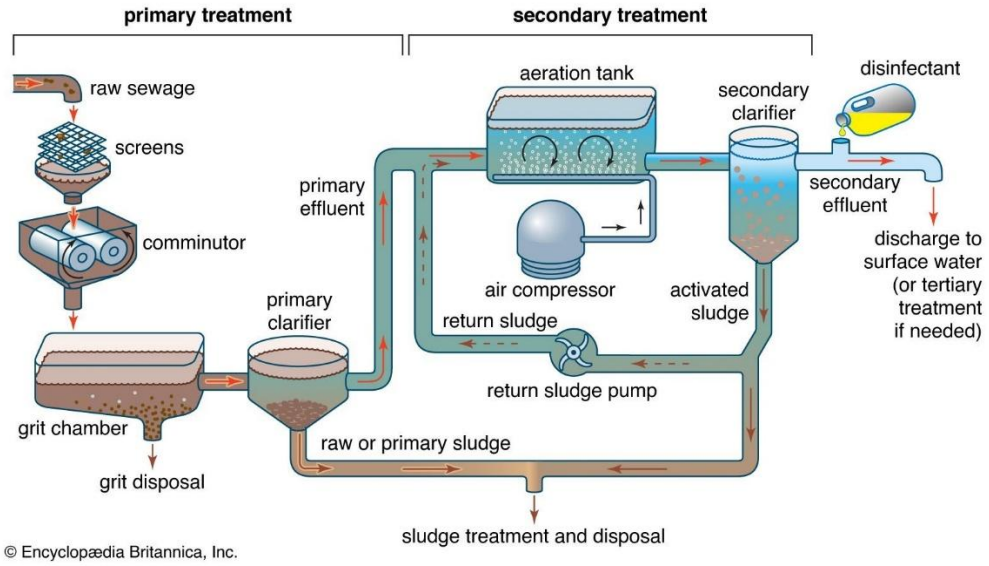


**Fig. 1: Water Purification System**

This involves using "smart materials" or "reactive surface coatings," which are specially designed to target certain pollutants and efficiently destroy, convert, or immobilize harmful substances, as well as filtering out even the smallest contaminants from water (less than 300 nm). Because nanoparticles' reduced size increases their surface area and modifies their physical, chemical, and biological properties, there has been an increase in interest in employing them to clean up the environment (Bhati & Rai, 2017). In addition to various nanotechnology techniques that can aid in water purification, heterogeneous photocatalytic systems that employ metal oxide semiconductors such as TiO2, ZnO, and ZnS are demonstrating efficacy and efficiency for water treatment (Mondal, 2020). Since they are easily extracted from the treated water, multifunctional photocatalytic membranes utilizing nanostructures are especially beneficial when compared to freely dispersed nanoparticles (Kumar et al., 2014).

### Nanostructures for Metallic Adsorption

Adsorption is a method that many researchers are exploring, utilizing various adsorbents. Scientists are particularly interested in nanomaterials as adsorbents due to their impressive physical properties, including a large surface area relative to their volume, which makes them excellent candidates for this purpose. Among these, ZnO nanoparticles stand out as one of the most talked-about types of nanomaterials, boasting a wide range of applications, including water remediation (Momba, et al., 2017).

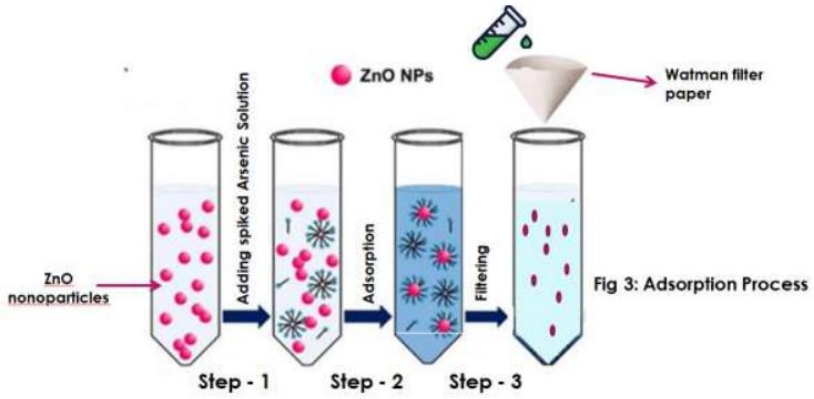


**Fig. 2: Schematic Diagram of as Removal Process Using Adsorption**

**Arsenic Adsorption Setup**

The Arsenic used in this study came from sodium meta-arsenite, which is a chemical form of Arsenic (As). We prepared a 4mM solution of ZnO nanoparticles and mixed it with 300 ppb of spiked Arsenic. Several samples of this mixture were created and stored for varying lengths of time—15 minutes, 30 minutes, 90 minutes, 300 minutes, and 600 minutes—before being filtered through a Whatman filter paper with a pore size of 100µm. Both the filtered and unfiltered samples were then analyzed using an Atomic Absorption Spectrophotometer (AAS) to measure the concentration of Arsenic. We repeated the same procedure with ZnO nanorods for comparison (Sayan, et al., 2013).

## Result and Discussion

Figure 3(a) shows the optical absorption spectra for the ZnO nanoparticles in ethanol. It shows that the nanoparticles have a notable shoulder in the wavelength range of 250-280 nm and a very strong absorption in the UV area of the electromagnetic spectrum. Figure 3(b) shows the ZnO nanoparticles' Tauc's Plot, which enables us to estimate the optical band gap at 5.54 eV and indicates the presence of extremely tiny nanoparticles. A blue shift and an increase in the band gap energy are indicated by the absorption edge at 300 nm, which is most likely the result of the quantum confinement phenomenon common in the nano regime. Finally, the individual nanoparticles are clearly visible in the HRTEM image in figure 3(c), and the inset offers a view of the particle size distribution, showing that the majority of the particles are about 4 nm in size.

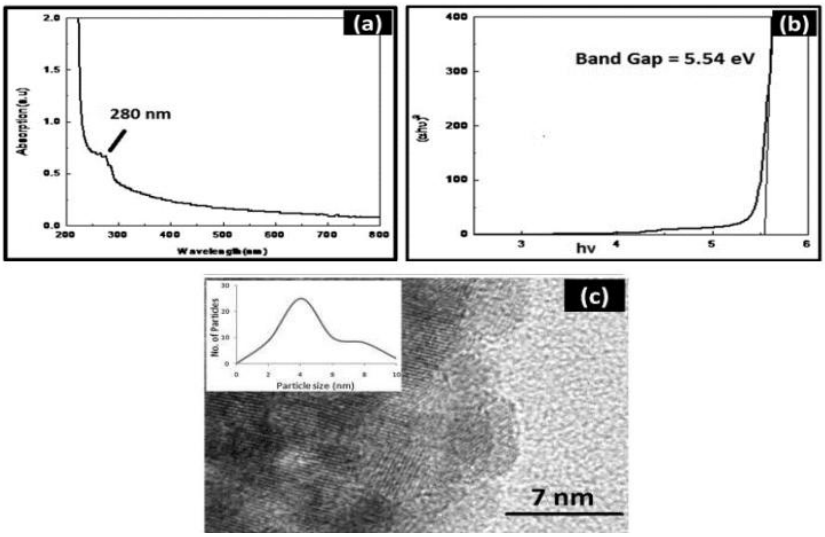


**Fig. 3: Absorption Spectrum**

We looked into how pH affects the removal of arsenic ions across various levels (from 1 to 7) at room temperature over a period of 60 minutes. We used HNO3 to adjust the pH. In this experiment, it is crucial that the sample solution

be neutral, with a pH of 7 being the desired value. The greatest amount of arsenic ion elimination took place at pH 5, as seen in Figure 4. Arsenic oxide creates oxy anions in water at higher pH values. Additionally, since there are plenty of hydroxyl ions on the surface of the nanoparticles we produced, arsenic removal tends to be more effective in acidic conditions compared to basic ones.

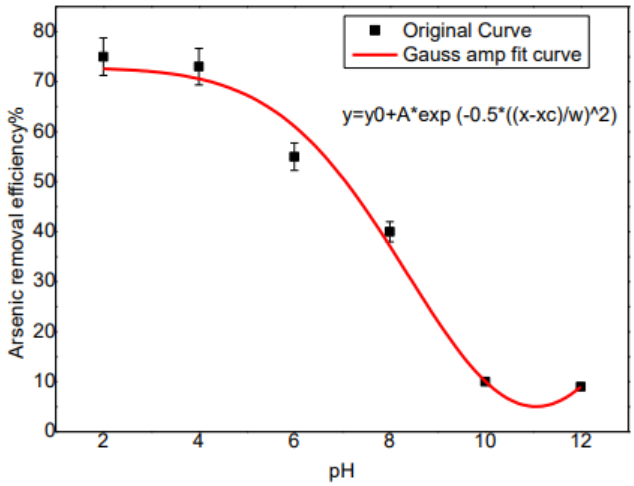


**Fig. 4: pH Values vs Arsenic Removal Efficiency**

We looked into how temperature impacts arsenic removal, testing a range from 20°C to 90°C while keeping the adsorbent content steady in acidic conditions. As illustrated in Figure 5, the percentage of arsenic uptake by the adsorbent rises as the temperature climbs from 20°C to 50°C, but then it starts to drop, as shown in Figure 4. The desorption of arsenic from the adsorbing substance may be the cause of this reduction in efficacy at higher temperatures.

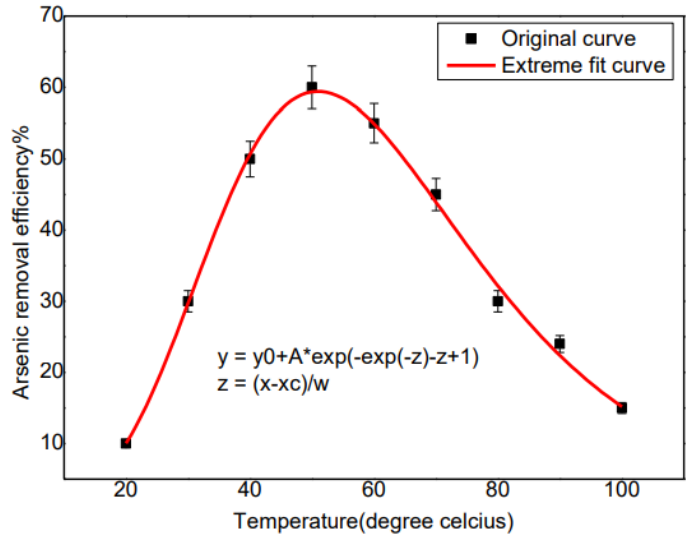


**Fig. 5: Contact Time vs Arsenic Removal Efficiency**

When ZnO nanoparticles are used to remove arsenic from water, the adsorption process is accelerated. We were able to determine the optimal conditions for maximal adsorption by carefully regulating important parameters such as pH, temperature, and contact time. The results of this investigation demonstrate the encouraging potential of ZnO nanoparticles in developing a simple, one-step solution for practical uses. This approach could eliminate the need for costly methods to remove Arsenic from water, making it safe for drinking by keeping contaminants within acceptable limits.

## Conclusion

The photocatalytic efficiency of two different kinds of nanostructured photocatalysts—ZnO nanostructures and ZnO/ZnS core/shell nanostructures—is compared in this study. The adsorption process is enhanced by employing ZnO nanoparticles to effectively remove arsenic from water. We measured the optimal values for parameters such as pH, temperature, and contact time, and by maintaining these parameters at their ideal levels, we observed maximum adsorption. The arsenic adsorption capabilities of ZnO nanoparticles highlighted in this study suggest a promising avenue for developing a practical one-step process for field applications. This could potentially eliminate the need for costly methods to remove arsenic from water, making it safe for drinking within acceptable contaminant limits.

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