# Assessment of nano-particles for the removal of bacteria and viruses from aquatic systems

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## Abstract

Utilising a designed material or finished product with at least one dimension between 1 and 100 nm is the foundation of nanotechnology's enabling power. In addition to their size and optical characteristics, nanomaterials also differ from bulk materials in terms of their composition, shape, surface layer, reactivity, and toxicity, among other physical and chemical characteristics. With over 1800 nanoproducts currently available on the market, nanotechnology is expected to transform product development and manufacturing, potentially generating up to three trillion US dollars in global economic output by 2020. Direct exposure and its effects on certain aquatic creatures are the main topics of studies on the safety of nanomaterials in aquatic environments. Little is known about how nanomaterials interact with biotic and abiotic elements and how this affects creatures in the food web at the cellular and molecular level. The interaction and impacts of the most common metal nanoparticles in the aquatic environment have been examined in this paper. To harness the power of this enabling technology, nanotechnology, "safe by design" nanomaterials will be developed as a result of the current work's understanding of the eco-bio-compatibility of these novel materials.

**Keywords:** Nano-particle, Eco-bio-compatibility, Nanotechnology

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## Introduction

Over the past 20 years, the manufacturing of engineered nanomaterials (ENMs) has increased dramatically on a global scale. Personal care, health and fitness, electronics, textiles, sports, energy, automotive, medical, agriculture, and environmental remediation are just a few of the industries that have benefited from nanotechnology's enabling nature (Vinusha *et al.*, 2024). By 2020, it is anticipated that the global market for ENMs would have grown by $3 trillion (Ali and Al-Fatlawi, 2023). It is anticipated that between 270,000 and 320,000 metric tonnes of the most commonly utilised ENMs are produced annually. 21% of all ENMs are expected to be discharged into aquatic systems, 17% into soil, and 2.5% into the atmosphere. Since biotic and abiotic factors are crucial in determining the fate of ENMs, it is wise to comprehend the threat that such a high number of ENMs pose to the aquatic ecosystem (Bašić and Džananović, 2018; Singh and Kumar, 2024). Metal and metal oxide nanoparticles, such as silver (Ag), titanium dioxide ($TiO_2$), and zinc oxide (ZnO), are the most widely used and expanding nanomaterials with uses in apparel, personal care products, and health care items (Bhardwaj and Ramesh, 2024). Quantum dots (QD) are another popular nanocrystalline semiconductor nanomaterial that is utilised in LEDs, transistors, and other optoelectronic devices (Ali and Al-Fatlawi, 2023; Gyamfi *et al.*, 2022). QDs with zinc or cadmium sulphide shells and core materials like CdTe, CdSe, ZnSe, or PbSe have special qualities like narrow emission, broad excitation, and tiny size (Abu-Dief and Hamdan, 2016). The model type II-VI semiconductor ENMs are represented by the cadmium telluride quantum dot (CdTe QD) (Jamil *et al.*, 2020). The research done for this dissertation investigated how ENMs fared in the aquatic environment when model biotic and abiotic elements such fish, bacteria, protozoa, and clay minerals were present (Kedir, 2021; Chatterjee and Singh, 2023). The research done for this dissertation investigated how ENMs fared in the aquatic environment when model biotic and abiotic elements such fish, bacteria, protozoa, and clay minerals were present (Hulloli and Savanur, 2020).

## Framework of the Proposed Model

Both freshwater and marine environments are home to microscopic algae, often known as microalgae. Usually unicellular, they can exist alone, in chains, or in colonies. Diatoms, cyanobacteria, and green microalgae that have been isolated from aquatic environments in the state of Goa are referred to as "microalgae" in this section. There are numerous aquatic systems in Goa (Alfuraydi, Alminderej and Mohamed, 2022). The isolation and culture of microalgae from lakes, ponds, flooding in rice fields, estuaries, and coastal locations are described in this chapter. Molecular phylogenetic study has confirmed the broad morphological identity of these cultures. This study's goal was to separate and characterise the microalgae before using them as hosts to separate viruses from related aquatic environments (Kamani *et al.*, 2023). Samples of water were taken from a variety of freshwater, marine, and estuarine locations in Goa, India. In every instance, a sterile container was used to gather surface water samples (ranging in depth from 0 to 2 m). Since the formation of microalgal cultures was the main goal of sample collection at this point, samples were gathered throughout the year. Water samples were gathered from a number of coastal sites. First, zooplankton and other big particles were eliminated from the samples by filtering them through a 200 µm nylon mesh. After passing the filtered water through a 20 µm nylon mesh, the phytoplankton-containing retentate was moved to a Petri dish. A 100 X magnification Olympus inverted microscope was used to view phytoplankton (Ghanavat Amani and Jalilzadeh Yengejeh, 2021). Automated Sanger sequencing was used to sequence the purified fragments. After combining the forward and reverse sequences to create a contig, the resulting sequence was compared to known sequences in the NCBI-GenBank database using BLAST to determine the closest match.

The foundation of the food chain in aquatic environments is made up of cyanobacteria and microalgae. Viral top-down control over these organisms' populations is mostly responsible for their regulation. Thus, the entire food chain is affected by viruses that infect and kill cyanobacteria and microalgae. Furthermore, cyanophages constitute a statistically significant part of the viral population since cyanobacteria are the second most prevalent planktonic species after bacteria (Bhardwaj *et al.*, 2021). Cyanobacteria lysis makes a substantial contribution to the nutrient pool, which in turn affects nutrient cycling. Additionally, the diversity and community composition of microalgae and cyanobacteria are influenced by the viruses that infect them. Through horizontal gene transfer, they increase their hosts' genetic diversity and decrease their photosynthetic efficiency. Figure 1 display Microbial identification in water below.

## Proposed Methodology

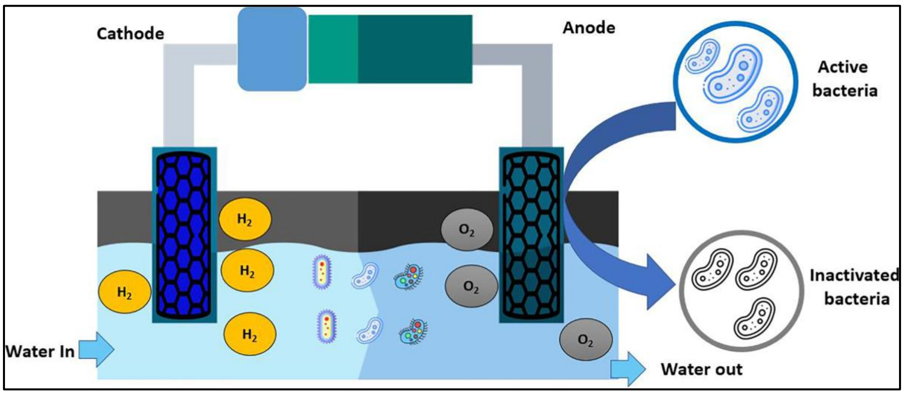


**Figure 1: Microbial identification in water.**

## Results

A cross-sectional investigation of the nanoparticle-based diagnostic community is undertaken through an exploratory study to measure the level of sensitivity and to analyse the barriers faced during the detection of virus and algae.

H: There is a strong positive correlation between surface functionalization and nanoparticle efficacy, with more efficacy resulting in better material performance and surface characteristics.

**Table 1: Nano-particle efficacy and surface functionalization.**

| Job performance | Extremely confident | Quite confident | Somewhat confident | Slightly confident | t Statistics | p Value |
|---|---|---|---|---|---|---|
| nano-particles be used in combination with other water treatment technologies | 4.3400 | 3.8136 | 4.0000 | 3.8400 | 4.160* | 0.000 |
| environmental factors affect the removal efficiency of nano-particles for bacteria and viruses | 3.6400 | 3.8475 | 3.8889 | 3.6267 | 0.082 | 0.935 |
| removal efficiencies of different types of nano-particles | 3.6177 | 3.6102 | 3.5848 | 3.7800 | 1.004 | 0.318 |
| nano-particles be designed to target specific types of bacteria and viruses, and what are the potential benefits and limitations of this approach | 3.8200 | 3.6441 | 3.2222 | 3.9200 | 0.743 | 0.459 |
| nano-particles interact with bacterial and viral membranes, and what are the implications for removal efficiency | 3.9000 | 4.2000 | 4.0000 | 4.0533 | 1.238 | 0.218 |
| primary mechanisms by which nano-particles remove bacteria and viruses from aquatic systems | 4.2000 | 3.8400 | 3.8889 | 3.8904 | 0.066 | 0.947 |
| surface properties of nano-particles (e.g., hydrophobicity and hydrophilicity) influence their interactions with bacteria and viruses in aquatic systems | 3.8400 | 3.7600 | 3.5848 | 3.7600 | 3.202* | 0.002 |
| optimal size and shape of nano-particles for maximizing the removal of bacteria and viruses from aquatic systems | 3.7600 | 3.9800 | 3.2222 | 3.5467 | 1.770 | 0.079 |
| physical and chemical properties of nano-particles | 3.9800 | 4.0200 | 4.2000 | 3.6667 | 0.592 | 0.555 |

Surface functionalisation improves along with nanoparticle efficacy. Better surface characteristics are typically found in more effective nanoparticles, which enhance material performance. Researchers can create and develop more effective nanoparticles for a variety of applications by comprehending the relationship between surface functionalisation and nanoparticle efficacy (Table 1).

## Conclusion

It is commonly known that interactions with newly released chemical entities in the environment are significantly influenced by both biotic and abiotic variables. Consequently, upon entry, these variables may interact with designed NMs and change their initial characteristics. Studies on the safety evaluation of nanoparticles in aquatic environments have detailed the toxicity of NPs at the level of individual model animals, including fish, bacteria, protozoa, and crustaceans. Without going into detail about their potential consequences at the ecosystem level, preliminary research has documented the influence of pristine NMs in a contrived laboratory-scale food chain. With an emphasis on viruses from as-yet-undiscovered freshwater and estuarine environments, the current study advances the area of aquatic virology. Research on the prevalence of viruses in different aquatic environments has shown that floodwaters from rice fields have extremely high viral populations. An ecosystem where the host organisms are important may be significantly impacted by the presence of huge numbers of lytic bacteriophages and cyanophages. The presence of novel viruses in both viromes is confirmed by a large percentage of unidentified sequences, which encourages more metagenomic research on uncharted aquatic systems.

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