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# Use of Nano-Bots to Clean Water Bodies

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**Abstract**: They say water is life, with about 70% of the earth's cover being water, it undeniably becomes one of our greatest resources. As young students, we learned about the various ways to conserve water; coming to think of it, water is used in almost every important human chore and process. It is an important element in both domestic as well as industrial purposes. However, a closer inspection of our water resources today, gives us a rude shock. Infested with waste ranging from floating plastic bags to chemical waste, our water bodies have turned into a pool of poison. In simple words, the contamination of water bodies means water pollution. Thereby the abuse of lakes, ponds, oceans, rivers, reservoirs, etc. is water pollution. Pollution of water occurs when substances that will modify the water in a negative fashion are discharged in it. This discharge of pollutants can be direct as well as indirect.

According to statistics, pollutant's prevalence and persistence have increased significantly in recent years. In order to enhance the quality of naturally accessible water to a level suitable for human consumption, a number of techniques have been employed. In this paper, we are going to show how nanotechnology can be used to remove waste materials from water and make it suitable for use. Before we get into it, we must know about Nanotechnology. It is the manipulation of matter on atomic, molecular and supramolecular level. Nanotechnology has the potential to alleviate the quality, availability, and viability of water supplies in the long run by facilitating reuse, recycling and remediation of water. The promising role of nanotechnology in wastewater remediation is highlighted in this paper, which also covers current advancements in nanotechnology-mediated remediation systems. We will know about its various properties like super para magnetism, strong sorption, high reactivity, fast dissolution as is being implemented in several Nano-based materials such as Nano-adsorbents, photo catalysts, Nano-metals and Nano membranes for water contaminant remediation.

**Keywords:** Water pollution, Nanotechnology, Waste water remediation, Nano-adsorbents, Photo catalysts, Nano-metals.

## I. INTRODUCTION

Environmental contamination is a major global challenge, and the effects of contamination are found in most habitats. In recent times, the pollution by micro plastics has come to the global attention and their removal displays an extraordinary challenge with no reasonable solutions presented so far. One of the new technologies holding many promises for environmental remediation on the microscale are self-propelled micro motors also known as 'nanobots'. They present several properties that are of academic and technical interest, such as the ability to overcome the diffusion limitation in catalytic processes, as well as their phoretic interaction with their environment. Here, we present how the nanobots work to purify waste water and their effectiveness compared to conventional methods of purification. We also discuss their various components and future prospects in the fields of nanobot based water purification.

## II. TYPES OF NANOBOTS

Nanobots, also known as Nano robots or Nano machines, are microscopic devices or robots that are designed to operate on a nanoscale, typically ranging from 1 to 100 nanometers in size. These tiny machines could potentially perform various tasks at the molecular or cellular level. There are several proposed types based on their intended functions and applications:

A. Medical Nanobots

- Medical Diagnostics: Nanobots could be designed to detect specific molecules or biomarkers in the body, enabling early disease detection.
- Drug Delivery: Nanobots could transport drugs or therapeutic agents directly to target cells, tissues, or organs, minimizing side effects and improving treatment effectiveness.
- Cell Repair: Nanobots might be used to repair damaged cells or tissues, facilitating wound healing and tissue regeneration.
- Cancer Treatment: Nanobots could be programmed to selectively target and destroy cancer cells, offering a highly targeted approach to cancer treatment.

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B. Environmental Nanobots

- Pollution Cleanup: Nanobots could be designed to remove pollutants and contaminants from water, air, and soil.
- Carbon Capture: Nanobots might capture and convert carbon dioxide into other materials, contributing to efforts to mitigate climate change.
- Water Purification: Nanobots could help purify water by removing toxins and impurities at a molecular level.

C. Manufacturing and Assembly Nanobots

- Nanoscale Fabrication Nanobots might be employed in precision manufacturing processes at the nanoscale, enabling the creation of advanced materials and devices.
- Self-Assembly: Nanobots could be used to facilitate the self-assembly of complex structures and materials, leading to new manufacturing techniques.

D. Information Processing Nanobots

- Computational Nanobots: Nanobots with computational capabilities could be used for data processing, encryption, and information storage at extremely small scales.
- Quantum Computing: Theoretically, nanobots might assist in the development and operation of quantum computing systems, which rely on manipulating particles at the quantum level.

E. Energy-related Nanobots

- Energy Conversion: Nanobots could potentially convert energy from various sources, such as light or heat, into electricity or other usable forms.
- Battery and Energy Storage: Nanobots might play a role in developing advanced battery technologies and energy storage solutions.

## III. COMPONENTS OF NANOBOTS

Nano robots are tiny machines that can perform tasks at the nanoscale, which is the size range of 1 to 100 nanometers. Nano robots have many potential applications in fields like medicine, manufacturing, energy, and environment. There are different types of Nano robots based on their design, function, and fabrication methods.

The components of Nano robots vary depending on their type and purpose, but some of the general components are:

- Power supply: This is the source of energy for the Nano robot to operate and function. It can be a battery, a fuel cell, a solar cell, or a chemical reaction.
- Payload: This is the section that carries the material or substance that the Nano robot is designed to deliver or manipulate. It can be a drug, a gene, a sensor, or a catalyst.
- Sensors: These are the devices that allow the Nano robot to detect and measure various physical or chemical properties of its environment or target. They can be optical, electrical, magnetic, thermal, or biochemical sensors.
- Motors: These are the devices that enable the Nano robot to move or rotate in its environment. They can be based on magnetic fields, light, sound, or chemical reactions.

The fabrication methods of Nano robots can be divided into two main approaches: positional assembly and self-assembly. Positional assembly involves using external tools or devices to manipulate and arrange individual atoms or molecules into desired structures or patterns. Self-assembly involves using natural forces or interactions to guide atoms or molecules to form ordered structures or patterns without external intervention.

## IV. HOW NANOBOTS WORK TO CLEAN WASTE WATER

Nano robots, also known as nanobots or nanoscale robots, are hypothetical microscopic devices that could perform tasks at the nanoscale level. The concept of Nano robots has been explored in various fields, including medicine, electronics, and environmental applications such as cleaning wastewater.

The idea of using Nano robots to clean wastewater involves creating tiny machines that can target and remove pollutants, contaminants, or particles from water at the molecular or nanoscale level. The basic principle would involve designing Nano robots with the following components and functions:

- Nanorobot Design and Fabrication: Develop efficient and scalable methods for fabricating nanorobots with the required functionalities. Design nanorobot structures that can withstand the harsh conditions of wastewater environments and avoid aggregation.

- Propulsion and Navigation: Explore propulsion mechanisms that allow nanorobots to move effectively through water and reach target areas. Investigate different navigation strategies, such as controlled movement through external fields or biomimetic approaches.

- Sensing and Detection: Develop sensitive and selective sensors that can identify a wide range of pollutants and contaminants.Design sensor systems that can function reliably in complex and changing wastewater environments.

- Contaminant Capture and Removal: Design nanorobot surfaces or coatings that can efficiently capture and bind contaminants.Investigate strategies for physically removing particles and pollutants from water using nanorobots.

- Chemical Reactions and Catalysis :Research reaction mechanisms and develop nanorobot-enabled reactions for breaking down pollutants into harmless byproducts. Explore catalytic nanomaterials that can facilitate efficient and targeted chemical transformations.

- Energy Sources and Efficiency: Investigate energy harvesting methods that can power nanorobots using available resources in the wastewater environment.Optimize energy efficiency to ensure sustained operation of nanorobots.

- Remote Control and Communication: Develop methods for remotely controlling and guiding nanorobots within water systems. Explore communication protocols that allow nanorobots to work together and share information.

- Safety and Environmental Impact: Conduct thorough assessments of the potential environmental risks associated with introducing nanorobots into water ecosystems. Design nanorobots with biodegradability and minimal impact on aquatic life.

- Integration with Existing Systems: Investigate ways to integrate nanorobots with existing water treatment infrastructure.Develop strategies for efficient deployment and retrieval of nanorobots.

- Regulatory and Ethical Considerations: Address regulatory hurdles and ensure compliance with safety and health standards.Consider ethical implications related to the use of nanorobots in water treatment and potential unintended consequences.

- Demonstration and Validation: Conduct real-world testing and validation of nanorobot prototypes in controlled environments.Collaborate with wastewater treatment facilities to assess the feasibility and effectiveness of nanorobot-based solutions.

## IV. COMPARISON BETWEEN CONVENTIONAL WATER PURIFICATION METHOD AND NANOBOT BASED WATER PURIFICATION

Conventional methods of water purification and nanobot-based methods represent two different approaches to achieving clean and safe drinking water. Here's a breakdown of the differences between these two approaches:

**Conventional Methods of Water Purification**

Conventional methods of water purification have been used for centuries to treat and make water safe for consumption. These methods typically involve physical, chemical, and biological processes that remove or neutralize contaminants from water. Some common conventional methods include:

- Filtration: Water is passed through various types of filters, such as sand, gravel, or activated carbon, to physically trap particles and impurities.

- Coagulation and Flocculation: Chemicals are added to water to cause impurities to clump together, forming larger particles that can be easily removed.

- Sedimentation: Water is allowed to stand so that heavier particles settle to the bottom, making it easier to remove them.

● Disinfection: Chemicals like chlorine or chloramine are added to kill harmful microorganisms and pathogens present in the water.

● Reverse Osmosis: This is a specialized filtration process that uses a semipermeable membrane to remove ions, molecules, and larger particles from water.

**Nanobot-Based Methods of Purification**

Nanobot-based methods involve the use of nanoscale devices, often referred to as nanobots, to perform specific tasks at the molecular or atomic level. In the context of water purification, nanobots could potentially offer highly targeted and efficient purification capabilities. However, it's important to note that as of my last knowledge update in September 2021, nanobots for water purification were more theoretical than practical. Here are some potential differences:

● Precision: Nanobots have the potential to target specific contaminants with a high degree of precision, potentially leading to more efficient and effective removal of pollutants.

● Scale: Nanobots operate at the nanoscale, which is incredibly small. This could allow them to access hard-to-reach places and treat water at a molecular level.

● Energy Efficiency: Nanobots could potentially be designed to operate with minimal energy consumption, leading to more sustainable purification processes.

● Automation: Nanobots could be designed to function autonomously, reducing the need for constant human intervention in the purification process.

## V. RECENT DEVELOPMENTS ON NANOBOTS

**Fuel-driven micro- and nanorobots**

Also known as 'chemical' or 'catalytic', exploit the reaction between a catalyst and a chemical fuel (or substrate) to move. Despite its toxicity, hydrogen peroxide ($H_2O_2$) is the most frequently used fuel and the expensive noble metal platinum (Pt) is its most efficient decomposition catalyst, resulting in micro- and nanorobotic propulsion by bubble ejection or self-phoresis. The latter is the spontaneous motion of a particle in response to the generation of a quantity gradient, such as solute concentration (self-diffusiophoresis), electric potential (self-electrophoresis) or temperature (self-thermophoresis). For example, Pt microrockets self-propel in $H_2O_2$ owing to the continuous jet stream of $O_2$ bubbles, which also produce powerful thrusts and motility in high-ionic-strength media, such as seawater. Enzymes, such as catalase, urease and glucose oxidase, are the biological counterpart of inorganic catalysts. Micro- and nanorobots with uneven distribution of catalase (an enzyme catalysing the decomposition of $H_2O_2$) undergo bubble propulsion in $H_2O_2$, whereas urease and glucose oxidase hydrolyse more biocompatible substrates, like urea and glucose, generating a product gradient for micro- and nanorobotic self-phoresis. However, their use is restricted to biomedical applications where the substrates are naturally present, for example, the bladder for urea. Disintegration of the robots is mediated by catalytic reactions that simultaneously consume the robot's engine and fuel, similar to the reaction between Mg and water. However, fuel-driven micro- and nanorobots suffer from poor control over the motion (on–off, directionality) and limited life span.

**Multifunctional micro- and nanorobots**

In addition to simple swimming, robots are also required to perform tailored tasks in specific applications. Multifunctionality is imparted to micro- and nanorobots by integrating different modules, such as organic or inorganic molecules and materials. Each micro- and nanorobot's module has a defined role: the structural material provides a robust scaffold, the engine is responsible for the motion, the imaging material enables traceability, the magnetic material introduces magnetic properties (such as collectability under magnetic fields) and the surface material interacts with the environment, including water contaminants in the robot's proximity through intrinsic properties or surface functional groups (ranging from simple molecules to supramolecular structures and polymers). For example, DNA-engineered micro- and nanorobots exploit the self-propulsion, programmability and specificity of Watson–Crick base pairing for the intracellular detection of cancer biomarkers or gene delivery. However, the choice of single-task or multi-purpose robots must be thoroughly assessed, because integrating multiple units entails several fabrication, assembly and scaling challenges.

## VI. FUTURE PROSPECTS

Micro/nanobots are being developed which show autonomous and guided motion and are capable to perform 'programmed' tasks. With this advancement in technology of micro/nanobots, lab-on-chip heterogeneous systems can be developed. Due to their small size, nanobots can be used in the field of medicine to perform surgeries, drug delivery, cancer treatment, etc. The nanobots can also be applied for the environmental remedy such pollutants sensing and water remediation.

Where the smart micro machines already presented differ from those being worked on by Martina Ussia and her colleagues is in their composition. Until now, scientists have used mostly inorganic materials such as titanium, platinum or iron to create micro robots. The disadvantage of using these materials is that, among other things, unwanted side effects occur sooner or later. Often, they are not environmentally friendly. CEITEC scientists want to avoid this. Inspired by nature, they see polymers as the future.

The term polymer comes from Greek and denotes many parts. It refers to macromolecules, i.e., chains of same molecules with different shapes and sizes. This results in numerous classes of polymers whose diverse properties Brno scientists are trying to use in the production of micro- and Nano robots. For a better idea, there are natural and synthetic polymers. All living organisms consist of natural ones, such as proteins or nucleic acids, etc.

"Polymers, such as stimulus-responsive hydrogels, soft programmable matter, rubbery elastomers, and liquid crystal polymers (LCPs), play an essential role in achieving adaptive mechanisms of smart micro machines," describes Martina Ussia. She points out that polymers are already used in the production of artificial systems, but mostly in larger robots, with very few examples on a micro- and Nano-scale.

## VII. SOME IDEAS TO LOWER THE COST

Using nanobots to clean water is a fascinating concept with potential benefits for environmental and public health. Lowering the cost of implementing such technology requires innovative approaches and considerations. Here are some ideas to help reduce the cost of using nanobots to clean water:

### A. Mass Production Techniques

Explore scalable manufacturing processes such as 3D printing, microfabrication, or even self-replicating nanobots that can be produced in large quantities at a lower cost per unit.

### B. Energy Efficiency

Design nanobots that require minimal energy to operate. Energy-efficient nanobots would reduce operational costs and potentially allow for the use of renewable energy sources.

### C. Miniaturization and Integration

Continue to push the boundaries of miniaturization, making nanobots smaller and simpler to produce. Integration of multiple functionalities into a single nanobot could reduce the number of units required for effective water cleaning.

### D. Self-Powered Nanobots

Develop nanobots that can harness energy from their environment, such as sunlight or water flow, to power their functions. This could eliminate the need for external energy sources.

### E. Autonomous Operation

Create nanobots with advanced autonomous decision-making capabilities. This could reduce the need for extensive human supervision, thereby lowering labor costs.

### F. Reusable Nanobots

Design nanobots that can be collected, cleaned, and reused multiple times. This approach could decrease the frequency of replacements and result in long-term cost savings.

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G. Distributed Networks

Instead of deploying a large number of nanobots to a single location, consider using a distributed network of nanobots that work together to clean water across a larger area. This approach could optimize resource utilization.

H. Long-Term Investment

Consider the long-term benefits of water cleaning through nanobots. Initial investment costs may be high, but the potential for sustained improvements in water quality and reduced environmental impact can make the technology cost-effective over time.
Remember that while lowering costs is crucial, safety, ethics, and environmental impacts must also be considered during the development and deployment of nanobot's technology for water cleaning.

## VIII. CONCLUSION

In brief, Micro/Nanobots have been used over the past decade to remove wide range of contaminants from water bodies. The surface chemistry, shape, size, and speed of micro/nanobots play an important role in the removal of pollutants present in water. The thrust generated by these bots helps in the movement and is sufficient enough for large scale water treatment. Apart from fuel-powered bots, some fuel-free bots have also been developed over the past few years.

Developing functional and practical nanobots for water purification is a complex challenge. Designing, fabricating, and controlling nanobots at such small scales involves intricate engineering and requires addressing issues like power sources, communication, and potential environmental impacts.

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