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Original Research Article

Advance Technology in Wastewater Treatment: A Brief Assessment

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ABSTRACT

In the context of the characterization of increasing impurities, rapid urbanization and industrialization, and decrease in the available water resources, the application of conventional water treatment and wastewater treatment procedures is becoming more difficult. Recent development processing techniques, such as disinfection and antimicrobial mechanisms, membrane filtration, sensing and monitoring, and UV radiation, are very promising and therefore revised in this paper, providing alternatives to better protect human health and the environment. Its fundamental principles, main applications, and recent innovations have been emphasized. Particularly in comparison to their existing conclusions and recommendations research needs, the benefits and drawbacks of such technologies are demonstrated. Conventional wastewater treatment technology, along with wastewater minimization and water recycling programs, provides promise for reducing and maybe preventing, the unavoidable loss of useful water. The conclusion is that the applications of these technologies will be enhanced at an unparalleled scale alongside increasing knowledge and advances in the industrial sector.

Keywords: Nanotechnology, Water Treatment, Membrane Filtration, Catalysis, Sensing and Monitoring.

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Introduction

Our environment is continuously under attack as business and urbanization grow. Water scarcity has become the top environmental problem in the globe. In the future decades, increasing population development will raise the hygienic water requirement from the residential, farming, industrial, and energy points of view [1]. By 2025, half of the world's population is predicted to reside in areas experiencing water stress (WHO, 2014). Before 2015 there was an effective treatment of only 20% of worldwide wastewater [2]. According to the UN, almost 70% of wastewater is released in under-developed countries without proper treatment (2016). Current wastewater infrastructure and readily available safe water production both in the advanced and emerging countries are struggling to maintain the increasing need for higher-purity water regulation. This means that great efficiency requires low-cost technology for water treatment.

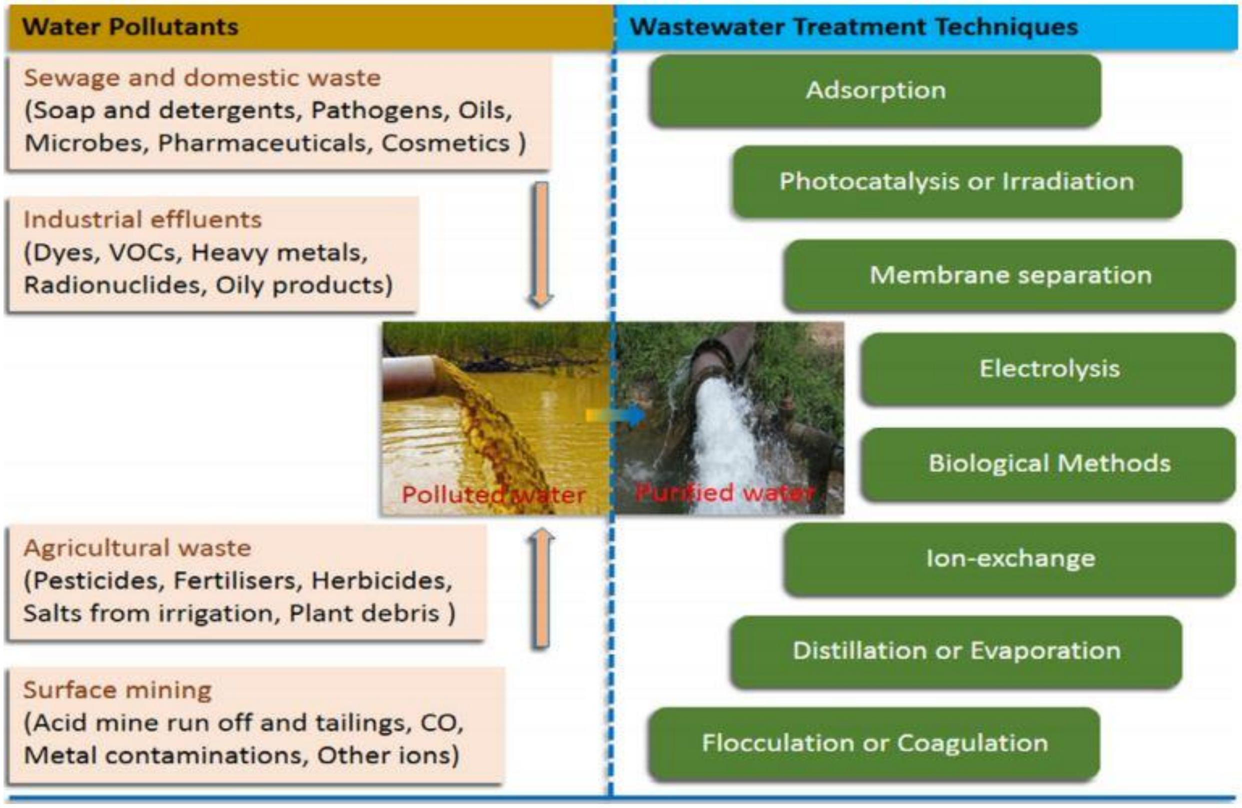

Figure1. Water contamination sources and wastewater treatment methods.

The application of nanotechnology in water and wastewater treatment is facilitated by recent discoveries in the manipulation of nanomaterials. Water nanotechnology has been the conceivable addition to regular treatment procedures in recent decades. Materials with at least one size less than 100 nanometers are nanomaterials [3]. The existing water and wastewater treatment process might be significantly increased by introducing nanoparticles into the system, taking advantage of these dimensional effects. Nanomaterials, particularly membranes [4], adsorption [5], catalytic oxidation [6], disinfection, and sensing [7] offer a wider potential and capacity for water and wastewater remediation. It is a pity the most of the nanomaterials mentioned were still in the workshop or simply evidence of the concept. Nanomaterials have enhanced their water and wastewater cleanup competitiveness by reducing their costs. However, the use of depleted nanoparticles in water and wastewater treatment methods remains inconvenient [8]. First, in a fluidized system or a stiff bed, nanoparticles tend to agglomerate leading to considerable activity loss and pressure reduction[9]. Second, it remains an arduous process to separate most of the nanoparticles exhausted from the reused treated water (except magnetic nanoparticles). From a financial perspective, it seems to be unfavorable[10]. Thirdly, the actions and implications of nanoparticles in the treatment of water and wastewater are unknown; thus it is a fundamental worry which can hinder the implementation of nanotechnology[11] that nanoparticles damage human health and the aquatic environment. To avoid or diminish the possible negative effects of using nanotechnology, it is desirable to create a device or material that may reduce the mobilization or release of nanoparticles while retaining their high reactivity. The most typical technique to create a nanocomposite is to load a range of supporting materials for depositing desired nanoparticles, such as membranes or polymers. It may be defined as a multi-phase material with a diameter of at least one phase of 100 nm [12]. The review focuses on diverse nanomaterials used for pollution separation, catalytic degradation, and water adsorption. In the water treatment process, the potential of these nanoparticles will also be briefly investigated.

Literature Review

Technology Used in Wastewater Treatment:

As the science of nanotechnology continues to grow, it will eventually be applied to water and wastewater treatment. There have been various research conducted throughout the past decades on this topic. Please see the following for a general review of nanotechnology applications in the remediation of water and wastewater, such as catalytic oxidation, adsorption and separation, sensing, and disinfection.

Filtration and Membrane

Filtration is a mechanical and physical separation method that permits liquids to flow throughout a membrane when larger solutes are retained. Due to permeate flux, high stability, process intensity, pollutant retention ability, automated process control, lower operational robustness,and chemical mass, filtration is now among the best widely utilized water purification systems for decades[13]. UF, MF, FO, RO, NF, electrodeionization (EDI), electrodialysis (ED), pervaporation, and distillation are currently utilized membrane-based filtration technologies. Microorganisms (bacteria and protozoa) and suspended particles are retained by the macroporous MF membrane (0.05–1 mm). Most viruses and colloidal contaminants are rejected by the UF membrane with mesoporous pores (0.005–0.5 mm) [14]. The nanoporous NF membrane (0.0005–0.01 mm) is used to remove inorganic and organic pollutants, as well as the ED and EDI procedures, are frequently utilized (metals and ions). Water desalination relies on RO and FO membranes with microporous pores (0.0001–0.001 mm). Desalination can be accomplished using distillation or pervaporation, though both methods are less common in practical applications. Low recrudescence, fixed solute selectivity, frequent fouling,energy-intensive processes are the drawbacks of these filtering techniques. After numerous cycles, most filtering membranes must be cleaned with chemicals and/or heated. Cleaning and replacing a membrane at the pre-treatment and desalination stages, respectively, account for 60% and 30% of the overall cost [15]. As a result, utilizing NMs is required to get the most out of conventional filtration membranes. As evidence, we examine the most commonly investigated NMs, like carbon nanotubes (CNTs), ceramic and grapheme, aquaporin, and zeolite, like a single thin-film composite (TFC)and mixed matrix (MM) membranes. Our purpose is to examine the fundamentals of every NM-based disinfection technique, including the different NMs and manufacturing techniques, recent commercialization, and separation performance initiatives [16].

Disinfection and Antimicrobial Mechanisms

The final but most important process of water treatment is disinfection to prevent the spread of waterborne disease. The perfect disinfectant should possess the following qualities: (1) no generation of harmful by-products; (2) a broad antimicrobial spectrum in a short period no generation of harmful by-products; (3) minimal toxicity to human health and the environment; (4) easy storage and must not be corrosive; (5) low energy cost and ease of operation easy storage and must not be corrosive; and (6) secure disposal [17]. Several nanomaterials, including chitosan nanoparticles, nanosilver (nAg), photocatalytic TiO_2, and carbon-based nanomaterials, have recently been shown to have excellent antimicrobial capabilities [18].

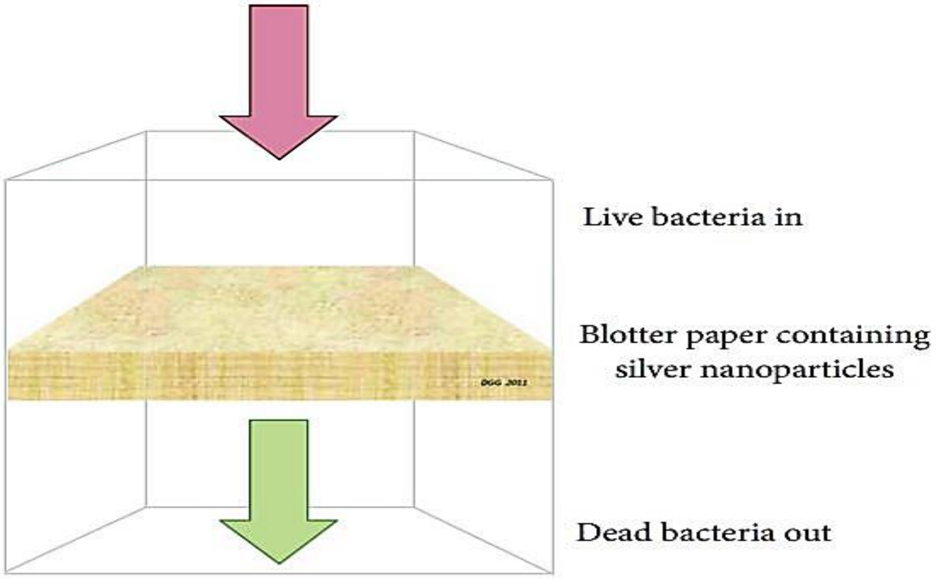

Figure 2. Schematic illustration of blotter paper disinfection with silver nanoparticles. [19] Copyright 2011 American Chemical Society.

These nanoparticles kill microbes by producing harmful metal ions (e.g., Ag+), directly disrupting cell membranes (e.g., chitosan NPs), or creating responsiveoxygen species. Unlike traditional disinfectants made of chemicals, these antimicrobial nanoparticles demobilized microbes using wider environmentally friendly methods, which is predicted to reduce the development of hazardous disinfection byproducts (DBPs) [20]. Furthermore, when combined with appropriate separation tactics, some nano-disinfectants can work continuously with great efficiency and minimal energy consumption, making them particularly appealing for decentralized water and wastewater treatment.

Sensing and Monitoring

Currently, standard monitoring and sensing methods in complex water bodies are incapable of identifying extremely low concentrations of micropollutants. In an emergency, fast and on-the-spot detection of infections and extremely harmful contaminants is critical (e.g., water-related accidents) [21]. Nanomaterials with distinctive electrochemical, optical, or magnetic properties include graphene, carbon nanotubes, noble metals (e.g., Ag or Au), and quantum dots. Such nanoparticles could be included in electrodes or sensors to particularly pre-concentrate traces of contaminants for identification. Several nanomaterials have the potential to improve spectroscopic response by several orders of magnitude (e.g., surface plasmon resonances, or Raman shift) [22]. Furthermore, the potential of next-generation nanocomposite sensors in environmental monitoring and sensing has been extensively investigated [23].

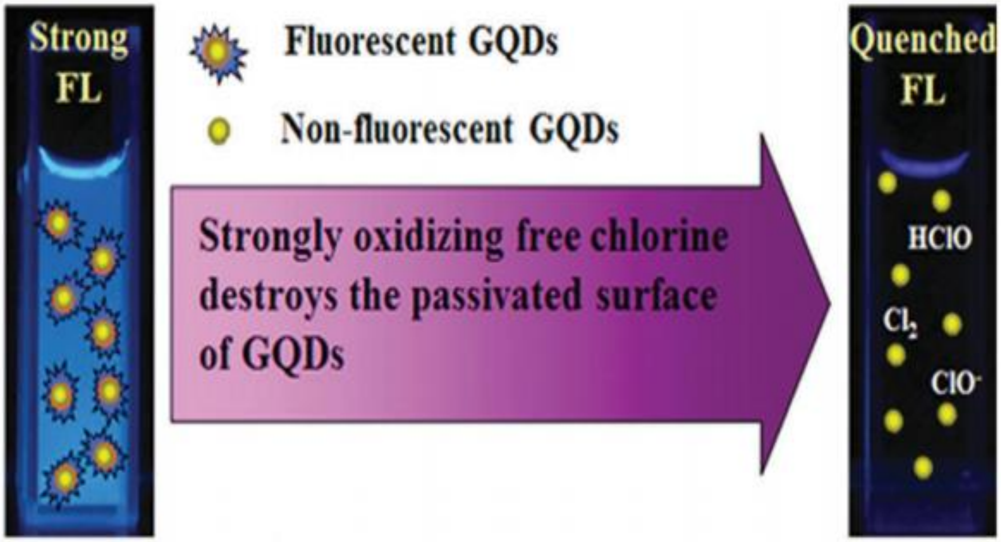

Figure3. The GQD-based nano-sensor quenches fluorescence in this illustration. [24] Copyright 2012 American Chemical Society

Adsorption & Separation

Two most commonly utilized technologies for polishing water and wastewater are adsorbents or membrane-based separation [32]. The cycle of adsorption regeneration considerably reduces the price-to-benefit ratio of conventional adsorbents. Many nanosized adsorbents, i.e., metal oxides or nanosized metal, graphene, nanocomposites, and carbon nanotubes (CNTs), are characterized by excellent selectivity and strong reactivity. They perform adsorption several magnitudes better than conventional adsorbents [25]. Membrane separation is also essential since it allows for the recycling of water from uncommon sources like wastewater. The contamination removal is mostly dependent on size exclusion. However, membrane selectivity/permeability issues still hamper the development of membrane technology, namely trade-offs in membrane selectivity and permeability [26]. Nanocomposite membranes with advanced properties were constructed by including functional nanoparticles into the membrane. This novel membrane class demonstrated better mechanical or thermal stability, porosity, and hydrophilicity features include increased permeability, anti-fouling, antibacterial, adsorptive, or photocatalysis [27]. Currently, adsorption and separation nanotechnology were near maturity.

Catalysis

To eliminate trace contaminants and microbiological pathogens from water, the advanced oxidation process of catalytic or photocatalytic oxidation is applied. It's a good approach to make both hazardous and non-biodegradable contaminants biodegradable [28]. Photocatalysis can be used to polish refractory organic molecules [29].Nanocatalysts with a high ratio of surface to the volume have significantly better catalytic performance than their bulkier equivalents. Size-dependent behavior was also seen in the bandgap and nanoscale semiconductors have a crystalline phase. Their photo-generated charge distribution and electron-hole redox potential changed with different diameters [30]. As shown in Figure 4, immobilizing nanoparticles onto diverse substances improved the nanocatalyst stability, and the resulting nanocomposites were suitable with contemporary photo-reactors [31].

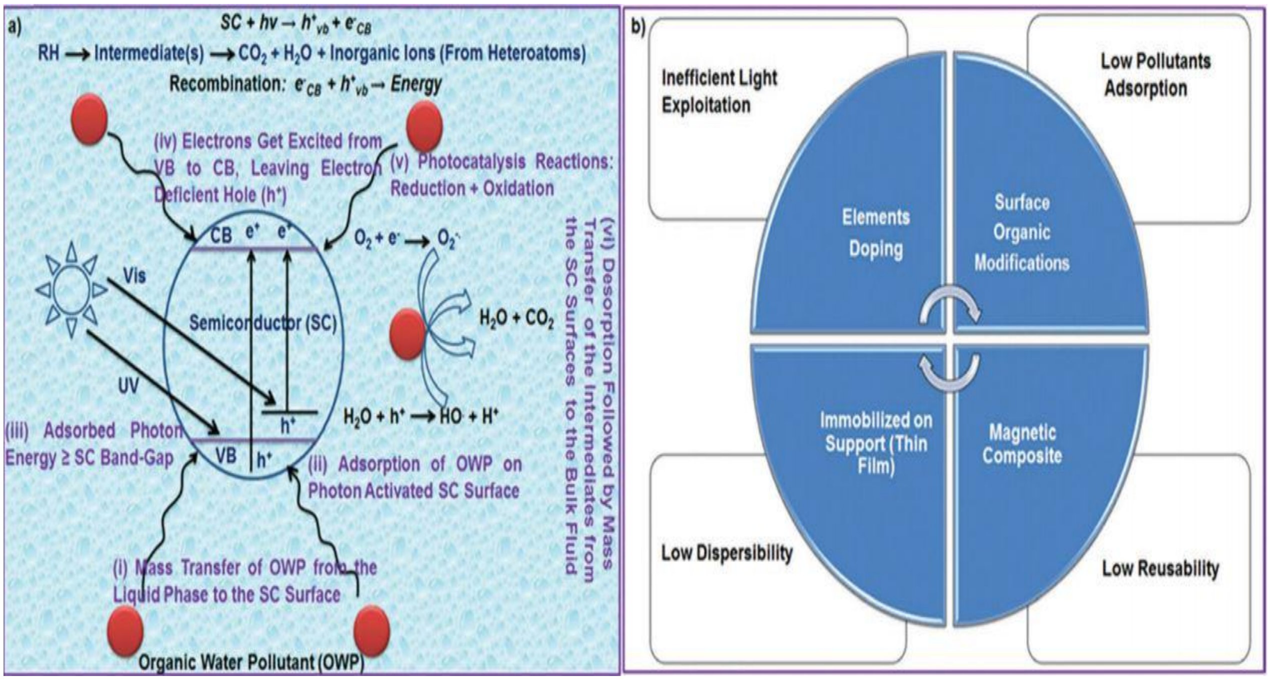

Figure 4. (a) Mechanics of semiconductors' involvement in the purification of the water; (b) countermeasures to overcome such problems (inside the circle) and depiction of photocatalyst limitations (outside the circle). [33]

Conclusions and Future Perspective

Various main water and wastewater treatment process groups have been examined. Laboratories and practical problems have shown that such methods can reduce a wide range of chemical and biology pollutants which, by the conventional treatment process, are otherwise harder to eliminate. These methods are becoming in some cases very premium, due in large part to better regulated regulatory standards and progress in the production of equipment. In solid-liquid segmentation and removal of inorganic and organic substances, the membrane filtering methods have proved highly successful. Although reverse osmosis (RO) desalination remains in the near future one of the most significant treatments of wastewater technology. As alternate disinfectant ozone has been frequently utilized to eliminate chlorinated microbiological pollutants. Ozone was also utilized to reduce color, regulate taste and odor, oxidize trace synthetic organic chemicals and destabilize particles.

A variety of hybrid methods have been proposed to continue using these advanced treatment methods by mixing enhanced treatment methods with other traditional treatment processes. These methods can be the most promising in the future as they can be the most accessible and inexpensive way of addressing the toughest environmental challenges if correctly used. Research is nonetheless needed to improve the understanding of synergistic and negative effects.

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