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8.“Application of Nano Material for Remediation of Wastewater”

Komal Rajoriya, Ramhari Meena, Anita Kumari

Department of Chemistry,
University of Rajasthan,
JLN Marg, Jaipur, Rajasthan, India.

Abstract:

Nanotechnology is the most significant field of research today. It is a multidisciplinary subject with various branches of science and technology. However, Nanomaterials with stable physicochemical prospectus are one of the emerging methods that have been studied in recent years for wastewater treatment. In view of the importance of the water quality and emerging utilities of nanomaterials, attempts have been made to discuss various aspects of water treatment by adsorption, filtration and catalyzation. In this chapter we conclude with key insights and acquired knowledge in nanomembranes, nanocatalysts, nanoadsorbents, nanobubbles. The Membranes traditionally act as size-exclusion based filters, physically preventing harmful microbes or particles from passing through in wastewater sample. The nano-catalysts, especially those of inorganic materials such as semiconductors and metal oxides, are effective in application of wastewater treatment. Nanoadsorbents have proved to be excellent adsorbent materials due to their exotic properties that include small size, catalytic potential, high reactivity, larger surface area and a large number of active sites for interaction with various impurities. Nanobubbles offer the potential to replace or improve efficiency of current wastewater treatment processes. Here we will summarize the chapter with overcoming implementation barriers for nano materials in drinking water treatment and its future perspective.

Keywords: *Nanomaterial, Nanomembranes, Nanocatalysts, nanoadsorbents and Nanobubbles.*

8.1 Introduction:

All living organisms require clean water to survive. The demand for clean and safe water is rapidly increasing all around the world as people become more concerned about their health and the environment. Water resources have been contaminated worldwide as a result ofthe rapid rate of industrialization and the tremendous population rise [1,2]. Aside from other demands, water demand has risen dramatically in the agricultural, industrial, and home sectors, with 70, 22, and 8% of available freshwater used, respectively, resulting in the formation of significant volumes of wastewater [3–5] carrying a variety of 'pollutants.' Heavy metal ions and dyes are two of the most common types of aquatic pollutants, and once they enter the water, it is no longer safe to drink, and it can be difficult to thoroughly clean the polluted water [6,7]. Aquatic contaminants are typically extremely harmful to living organisms and have a negative impact on the ecology.

As a result, removing these contaminants from polluted water is critical to avoid harmful consequences for human health and the environment. Various wastewater treatment systems have been developed during the last few decades [8–13]. Among the most important processes are solvent extraction, micro and ultrafiltration, sedimentation and gravity separation, flotation, deposition, coagulation, oxidation, evaporation, distillation, reverse osmosis, adsorption, ion exchange, electrodialysis, and electrolysis.Because of its ease of operation, cheap cost, and wide range of adsorbents, adsorption is a crucial strategy for treating wastewater among the approaches discussed above. Adsorption may also be used to remove organic, inorganic, and biological contaminants, both soluble and insoluble. Adsorption can also be used in potable, industrial, and other water-related applications for source reduction and reclamation.Despite these facts, adsorption has several limits, such as the inability to acquire a good commercial position. It's most likely owing to a lack of appropriate high-adsorption-capacity adsorbents and the restricted application of adsorbents on commercial size columns. Furthermore, a single adsorbent cannot remove all types of contaminants. Depending on the characteristics of the contaminants, different adsorbents are utilized. A comparison of adsorption techniques with different water treatment technologies was conducted. Adsorption >evaporation > aerobic > anaerobic > ion-exchange > electrodialysis > micro-and ultra-filtration > reverse osmosis > precipitation >distillation > oxidation > solvent extraction is the order of cost-effectiveness [14].Despite several drawbacks, it was determined that adsorption will be deemed a useful water treatment method shortly. Many studies have been done on the removal of various contaminants from water using a batch mode adsorption technique [14,15]. Activated carbon was once employed to remove contaminants from water, but it has since been superseded by several more cost-effective adsorbents [16–18]. Nanotechnology has made great progress in the previous two decades, with applications in practically every field of science and industry. Nanotechnology can break down financial and technological barriers to ensure that present and future generations have access to safe drinking water. Additional water purification techniques will become accessible in the future as science and technology advance. A variety of nanomaterials have been developed and employed to remove aquatic contaminants [19]. Given the importance of the quality of water and the growing benefits of nanotechnology, numerous elements of the treatment of water by adsorption utilizing nanoparticles have been discussed. Developing nanomaterials provides the potential to establish local and practical remedies to global groundwater contamination in this regard.

Green manufacturing, which generates nanomaterials using natural resources, will tackle the environmental and budgetary challenges related to nanomaterial synthesis. It is vital to invest in nanotechnology's leapfrogging potential to protect both the amount and quality of water. Several scientists have expressed reservations about several of the uses and characteristics of nanomaterials. They have the potential to spread to humans and other aquatic creatures due to their small size. They may or may not work depending on the interaction, concentration, pH, and other variables.As a result, considerable effort will be necessary to explore all elements of this new technology to maximize benefits while limiting negative consequences.

Nanomaterials for wastewater treatment have a promising future, but they will require serious and honest efforts from scientists, businesses, and government organizations. Nanomaterials have the potential to play a key role in the development of water purification systems that are quick, cost-effective, energy-efficient, and practical.

This chapter provides a high-level review of the technical suitability of nanoscale materials for the degradation of dissolved aquatic contaminants, as well as their applicability. Though several excellent scientific papers have been published on the importance of nanomaterials in water treatment and environmental remediation, some of them are material and/or adsorbent specific (e.g., CNTs, graphene-based nanomaterials, nano metal oxides, nano zerovalent iron, cellulose nanomaterials [20–26]) or adsorbate specific (e.g., CNTs, graphene-based nanomaterials, nano metal oxides, nano zerovalent iron (e.g., metals [22,24,27], dyes [28], pharmaceuticals and personal care products [29]).

This chapter compiles the main findings of numerous types of nanomaterials used in water treatment as adsorbents, photocatalysts, and/or antibacterial agents.

8.2 Nanomembranes:

Membranes have traditionally been employed as size-exclusion filters to keep harmful germs and particles out. However, it was only recently discovered that adding reactive functional groups and, more recently, nanoparticles to the pores may improve them even further. Because the membranes have relatively wide pore sizes (50–200 nm) and open designs, incorporating NPs into porous micro-filtration membranes for remediation applications is of interest[31]. These characteristics are crucial because they allow the membrane's immobilized NPs to react quickly with aqueous pollutants. When the flow is turbulent and the contact area is large, this is especially true. Polymers such as poly (vinyl alcohol) (PVA), [32–34] poly(acrylic acid) (PAA), [32,34] polyethersulfone (PES) [35], and chitosan make up the bulk structure of the membrane[36]. Membranes can be made in a variety of techniques, including phase inversion, solution casting, and heat grafting polymerization[32,37]. Electrospinning, on the other hand, [32–34,37] uses electrostatic repulsion to generate fine fibers. The resultant fiber mat is then immersed in an aqueous solution of iron salt, where the iron ions mix with the fibers to form, for example, zero-valent INPs. Chemical reduction of the ions, commonly with sodium borohydride, produces zero-valent INPs, which is a reasonably inexpensive and quick method.

8.2.1 Macroscopic Membranes Made of one-Dimensional Nanomaterials for Water Purification-[38]:

Water pollution has become a severe concern for flora, wildlife, and humans as the world's population and civilization have grown exponentially. Growing environmental concerns need the development of innovative High-performance water treatment materials and technologies. Treatment speed, efficiency, and selectivity have all benefited from the development of nanomaterials with large specific surface areas and well-controlled structures. Membranes are popular materials for water decontamination due to their solute selectivity, handling robustness, and simplicity of operation without the requirement of additional energy. A combination of nanomaterials and membrane technology during water cleaning is required for both scientific research and real-world applications in this circumstance. Small organic chemicals such as antibiotics and dyes were removed from water utilizing one-dimensional (1D) nanomaterials-based membranes (e.g., self-assembled nanowires, nanobelts/ribbons, nanotubes, nanofibers) with interconnected open pore architectures and huge surface areas.

8.2.2 Removal of Nano/Microplastics from Via Organic Membrane Filtering Systems [39]:

Many micropollutants, including nano plastics (NPs) and microplastics, are considered to be removed in drinking water treatment plants (DWTPs) (MPs). However, little research has looked at how NPs and/or MPs are produced throughout the water treatment process. In drinking water treatment facilities, we may be able to release NPs and MPs via organic membranes. On the probability of membrane rupture during long-term usage, the impacts of physical cleaning, chemical agents, mechanical stress, aging, and wear were studied. The membrane filtering systems might leak NPs/MPs into drinking water supply networks, according to further research based on membrane aging mechanisms and material attributes. Although additional research into the toxicity of membrane materials to the human body is needed, the following steps must be done to address NP/MP leakage in DWTPs:

- A thorough examination of the processes that cause NPs/MPs to form and release.
- A rethinking of the membrane's life cycle design.
- Toxicity evaluation to determine NPs/MPs concentration limits in drinking water.
- Increasing the speed at which biomembrane and inorganic membrane materials are developed.
- Standardization of NPs/MPs sample and testing, as a result, additional study is needed to look at the release of NPs and/or MPs from DWTPs.

8.2.3 Ceramic Disc Filter Covered with Nano Zno for Eliminating Escherichia Coli from Water-[40]:

Due to rising population and demand, global water security is under jeopardy. A viable water treatment approach for tiny rural and distant settlements in low-income developing nations is urgently needed. The reduction of E. coli using ceramic water dishes covered with nano ZnO was explored to develop a low-cost solution. Several aspects in the filter manufacturing process impacted the performance of modified ceramic disc filters. According to the factorial analysis, the pore size of the disc filters was the most important element in affecting E. coli removal effectiveness, while the clay content of modified disc filters was the most important factor in determining flow rate. The change in disc filter surface and porosity was caused by the nano ZnO coating. Both filter retention and nano ZnO's photocatalytic antibacterial activity might be responsible for the E. coli decrease. The effects of initial E. coli concentration, illumination period, and lamp power on E. coli eradication efficacy were also discovered. The findings may aid in the development of a safe and cost-effective solution to drinking water problems in developing countries' tiny rural and isolated populations.

8.2.4 Functional Carbon Nanotubes for Membrane-Based Water Treatment and Desalination: Challenges and Opportunity-[41]:

CNT-based membranes are a great starting point for the creation of materials that may be employed in electrochemical filtration. However, there are a number of drawbacks to using electrochemical CNT membranes in real water treatment procedures.

Electrochemical filtration of phenolic chemicals, for example, causes passivation and clogging of anodic-CNT electrodes, limiting its practical applicability in real-world water treatment.Carbon nanotubes (CNTs) have attracted international interest for their outstanding absorption capabilities and potential physical, chemical, and mechanical features in environmental applications.

The functionalization of carbon nanotubes, which entails the chemical/physical alteration of pure CNTs with various types of functional groups, increases CNT's desalination and/or waterborne pollution removal capabilities. As a result, the goal of this chapter is to provide a thorough examination of functional Nanomaterials (f-CNT) and their current and potential applications in membrane-based water treatment and desalination processes, with a focus on critical evaluation of advances, knowledge gaps, and future research directions.

At the bench size, CNT nanocomposite membranes have been investigated for their ability to successfully remove a variety of aqueous contaminants and salts,with CNT functionalization processes being developed for future enhancement. Improved water permeability, excellent selectivity, and antifouling capabilities are all shown to be benefits of CNT-based membrane applications. Their full-scale application, however, is still constrained by their high cost. Finally, we emphasize the need of considering f-CNTmembranes with promising removal efficiencies for respective pollutants for commercialization and to achieve holistic performance in water treatment and desalination.

a. Nanomaterials for water treatment and desalination are an emerging topic aimed at meeting the world's ever-increasing need for freshwater. Carbon nanotubes, for example, have gotten a lot of interest for building membranes because of their inherent adsorption and sieving characteristics, which assist to remove pollutants and minerals from water.

b. Extensive research in the field of nanomaterials and CNTs in the development of f-CNTs and f-CNT membranes has revealed that novel techniques for achieving maximum contaminant removal efficiency are emerging through a variety of methods, including chemical and physical modifications of CNTs with other reagents such as sulfonic acids and aromatic groups.

c. Inorganic pollutants, emerging organic contaminants, and microbiological contaminants may all be removed using f-CNTs and f-CNTmembranes. Contaminants in water have been extensively researched and proven to be effective. Furthermore, f-CNT membranes have shown considerable promise in the field of desalination.

d. The toxic effects of f-CNTs and f-CNT membranes – they harm microorganisms by producing reactive oxygen species – as well as the high electrical conductivity, hydrophilicity, and negative charges on the surface of f-CNTs, which allow these membranes to repel foulants, have been attributed to these membranes having better anti-fouling properties.

e. Despite the significant work put into understanding the function, structure, characteristics, and synthesis of f-CNTs, there is still a lot of opportunity for f-CNT membrane development for water treatment and desalination.

8.3 Nano Catalysts:

Researchers are paying close attention to nano-catalysts, particularly those made of inorganic materials such as semiconductors and metal oxides, in wastewater treatment applications. Photocatalysts (Dutta et al., 2014), electrocatalysts (Dutta et al., 2014), Fenton-based catalysts (Kurian and Nair, 2015) for enhancing chemical oxidation of organic pollutants (Ma et al., 2015), and antimicrobial activities are all used in wastewater treatment (Chaturvedi et al., 2012)

8.3.1 A Potato-Like Ag_2MoO_4 Composite with Nano Agbr Attached as a Highly Visible-Light Active Photocatalyst for the Treatment of Industrial Wastewater [42]:

Because of their great visible light absorption capabilities and low bandgap energy, as photocatalysts for industrial waste-water treatment, silver (Ag)-based semiconductors have sparked a lot of attention. Nano-sized AgBr coated potato-like Ag_2MoO_4 composite photocatalysts were created to remove organic pollutants from the aquatic environment.The photocatalytic activity of these photocatalysts was validated by visible-light elucidation of the decomposition of Rhodamine B (RhB) dye.

When compared to pure AgBr and A Ag_2MoO_4, AgBr/AAg_2MoO_4 composites demonstrated dramatically improved photocatalytic performance. Surprisingly, the AgBr/ Ag_2MoO_4 combination was able to completely remove the RhB dye in just 25 minutes. In addition, the AgBr/ Ag_2MoO_4 composite shows high photostability, according to the recycling experiment.

As a result, the AgBr/ Ag_2MoO_4 composite as obtained would be an appropriate photocatalytic material for industrial waste-water treatment.

8.3.2 Application of the $Ndvo_4$ Nano Photocatalyst as Dye Removal from Contaminated Water [43]:

Nanostructures of neodymium vanadate were made using a simple sonochemical method. Decolorization of dye as organic contamination using neodymium vanadate nano-photocatalyst. The impact of dye type, irradiation source, pH, and catalyst loading on catalytic function efficiency was investigated. The $NdVO_4$ nanoparticles are created using an ultrasound-assisted technique in the presence of ethylenediamine, with various preparation parameters such as solvent, sonication power, and sonication duration being changed.

It was generally recognized that employing ethylenediamine to avoid particle agglomeration was a good idea. When methanol was utilized as a solvent, the lowest particle size was attained. Under UV and Vis light, $NdVO_4$ as a semiconductor degrades Eriochrome black T with sufficient efficiency. Furthermore, the effect of several factors on photocatalytic activity of samples was studied, including dye type, light source type, pH, and nanostructures dosage as a catalyst. Under UV and visible light, the produced catalyst has photocatalytic efficiency of 77.42 percent and 47.5 percent, respectively.

8.3.3 Micromotors Made of Carbon Nanotubes, Ferrites, and Manganese Dioxide for Enhanced Oxidation Processes in Water Treatment [44]:

Multifunctional SW-Fe_2O_3/MnO_2 tubular micromotors are used for 'on-the-fly' increased water oxidation of industrial organic contaminants. Catalytic breakdown of H_2O_2 as an oxidation agent creates oxygen bubbles and hydroxyl radicals, which are required for the complete mineralization of model contaminants into CO_2 and H2O.The rough catalytic layer created by the carbon backbone with Fe_2O_3 nanoparticles allows for greater speed (16-fold acceleration compared to smooth equivalents) and a higher rate of radical generation.

The micromotors can drive themselves in complicated wastewater samples (400 ms, 2% H_2O_2) using a biocompatible surfactant, eliminating the requirement for costly Pt catalysts.

Self-propelled micromotors operate like extremely effective dynamic oxidation platforms, allowing for substantially shorter and more efficient water treatment procedures while lowering chemical reagent consumption. The SW Fe_2O_3/MnO_2 micromotors' efficiency is demonstrated by the oxidative degradation of Remazol Brilliant blue and 4-chlorophenol at mg L-1 values. The pH, navigation time, and a number of motors were all evaluated as factors impacting the micromachine-enhanced oxidation process. Following a 60-minute treatment of spiked wastewater samples at pH 4.0–5.0, high degradation rates of up to 80% were achieved for both contaminants. The outer Fe_2O_3 layer's unique magnetic characteristics allow for reusability of the micromotors as well as easy recovery and disposal following treatment. Such appealing performance has a lot of potential for use in large-scale water treatment systems as well as a variety of environmental, industrial, and security defensive applications. The importance of the environment Anthropogenic activities is directly threatening water supplies, which are essential for life's survival. Appropriate wastewater management, whether biological, physical, or chemical, is necessary to safeguard persons and the environment.

8.3.4 Bactericidal Paper Impregnated with Silver Nanoparticles for Water Treatment [45]:

There is a significant demand for low-cost point-of-use water purification systems. Percolation through a paper sheet containing silver nanoparticles is used to destroy harmful germs. The silver nanoparticles are formed when silver nitrate is reduced in situ on the cellulose fibers of a sheet of absorbent blotting paper. Instead of removing germs from the effluent through filtering, the goal is to inactivate microorganisms during percolation through the sheet. As bacteria suspensions percolated through the paper, the silver Nanoparticle-containing (AgNP) sheets were assessed for performance in the lab in terms of bacteria inactivation and silver leaching.

TheAgNP sheets were bactericidal against E. coli and Enterococcus faecalis suspensions, with log reduction values in the effluent of over log 6 and log 3, respectively. The AgNP sheets lost very little silver, with values < 0.1 ppm (the current US EPA and WHO limit for silver in drinking water). These findings suggest that percolating bacterially polluted water through silver nanoparticle-encrusted paper might be an efficient emergency water treatment.

Despite the fact that the bactericidal action of the AgNP paper must be tested in real-world situations where disease-causing organisms exist in a medium containing a wide range of other organic, inorganic, and colloidal contaminants, the reported results show that significant biocidal action can be demonstrated as bacteria percolate through a silver nanoparticle-impregnated paper sheet. Hopefully, this will serve as the foundation for a lightweight, low-cost, and easy-to-use water filtering method.

8.4 Nano Adsorbents:

Adsorption is a surface phenomenon in which a substance's molecules (adsorbate) adsorb on a solid surface (adsorbent). Temperature, the type of the adsorbate and adsorbent, the presence of additional contaminants, particle size, contact time, and the chemical environment are all factors that influence adsorption. Nanomaterials have proven to be good adsorbent materials because of their unique qualities, which include tiny size, catalytic potential, high reactivity, increased surface area, and a large number of active sites for impurity interaction. These characteristics lead to their high adsorption capabilities.

Various businesses produce large amounts of wastewater containing harmful and dangerous dyes, polluting water in both direct and indirect ways. The bulk of the dyes is a dangerous class of water poisons that have wreaked havoc on the ecology. Among the colors that are harmful to humans include Congo red, rhodamine B, methylene blue, methyl violet, and crystal violet.

8.4.1 Dyes Removal from Water using a Nano-Engineered Adsorbent [46]:

The ever-increasing problem of dye pollution has been examined, as well as dye cleanup options. The environmentally friendly adsorption process is highlighted. The advantages of nanoparticles due to their tiny size and the methods for making them have been summarised.

Metals, metal oxides, polymer composites, and nanoparticles including activated carbon, biomass, and clay minerals, among other nanomaterials, have all been included. The chemical composition of the substance, as well as numerous physicochemical experimental variables such as solution pH, beginning dye concentration, adsorbent dose, temperature, and so on, all influence adsorptions. As a result, these parameters are frequently employed to assess dye adsorption capability on various adsorbents. Novel and Reactive Sulfide-modified Nano Iron, nano manganese oxide-based materials, Hybrid hydrogel nano-polymer composites, and so on are some examples.

8.4.2 Improved Cadmium-Contaminated Water Treatment with Sulfide-Modified Nano Iron through Nanoparticle Seeding [47]:

Because of its possible use in groundwater remediation, magnetic sulfide-modified nanoscale zerovalent iron (S-nZVI) is of significant technical and scientific interest, albeit its production remains a difficulty. It was created using a unique nanoparticle seeding process to create a novel and reactive nanohybrid with a Fe(0) core and a highly subsidized layer with a high sulfidation extent. Seeding speeds up the reduction rate from Fe2+ to Fe0 by 19%, according to Syntheses monitoring tests.

In both crystalline and amorphous iron oxide, X-ray adsorption near edge structure (XANES) spectroscopy and extended X-ray absorption fine structure investigations show that the hexahedral Fe-Fe link (2.45 and 2.83) is formed by breaking down the 1.99 Fe-O bond. The manufactured nanohybrid has a high cadmium removal capability and might be used to clean metal-contaminated water in the future. Sulfidation greatly increases nZVI's remediation potential for several contaminant classes.

8.4.3 Using New Nano Manganese Oxide-Based Materials to Remove the Dye from Contaminated Water [48]:

Using nanosized manganese oxides as a dye remover is one option (MnOs). There has been a lot of research on the use of nanosized MnOs as dyestuff sorbents so far. Because of their amorphous nature, high specific surface areas (SSA), mesoporous structure, and low to moderate point of zero charges, they are attractive sorbents for commercial usage (pHPZC). The toxicity of dye removal from wastewater utilizing nanosized MnO sorbents, as well as current improvements. Adsorption duration, pH, starting dye concentration, the quantity of sorbent, and temperature are all important experimental factors for adsorption optimization. It has been observed that a wide spectrum of MnOs can be used as possible dye sorbents. On a commercial basis, MnOs are promising substrates for dye removal. Furthermore, they may be utilized to treat a wide range of dyes in wastewater (e.g., MB, MO, RhB, and so on). When compared to the pure substrate, manganese-based coatings or composites have shown improved dye removal capability and a quicker initial kinetic rate for dye oxidation. This is due to a drop in surface charge and an increase in specific surface area (SSA). Although their value in the natural environment has long been recognized, there is relatively limited information on the reactivity of MnOs coatings or composites. In the case of cationic dye, low pH resulted in little or no adsorption, whereas higher pH resulted in much-increased adsorption, depending on the surface charge of adsorbents. Anionic dyes had the opposite behavior. Adsorption edges and isotherm models have been used extensively to clarify dye removal processes in the majority of situations. In most research, pseudo-second order (PSO) kinetic and Langmuir models match dye removal data well. The majority of earlier research suggested that dye degradation utilized a Fenton-like oxidation process involving hydroxyl radicals generated by photocatalysis or peroxide. Due to competition, dye adsorption was observed to be reduced in the presence of another dye, metal ion, and humic acid (HA).

8.4.4 Graphene Oxide, Chitosan, And PVA in a Hybrid Hydrogel Nano-Polymer Composite [49]:

The use of a graphene oxide impregnated chitosan–PVA hydrogel nano polymer to remove Congo red dye from solution was developed. A batch technique was used to perform dye adsorption on GO produced hydrogel polymer. At varied pH levels, the swelling response of a manufactured polymer composite was studied. The dye adsorption efficiency for 20 mg/L Congo red solution with 6g/L dosage at 140 rpm rotation speed was determined to be 88.17 % at pH 2, while it was 81 % at neutral pH. Congo red dye removal from a water solution using a GO/Chitosan–PVA polymer composite. The surface of the prepared hydrogel polymer was porous, and it had good heat stability; but, beyond 340°C, it started to degrade.

8.4.5 Nano Zerovalent Iron Nanoparticles and Graphene Composites for Lead-Contaminated Water Treatment [50]:

With a graphene oxide loading of 6 wt%, a Nano zero-valent iron nanoparticles graphene composite (G-nZVI) displays adsorption of maximal Pb(II) adsorption capability. Because of its stability, lowering power, high surface area, and magnetic separation, G-nZVI has a lot of promise as an effective adsorbent for lead immobilization from water. For effective Pb(II) remediation in polluted water, a graphene-based magnetic adsorbent has been created. For adsorption, variables such as contract duration, solution pH, starting Pb(II) concentration, ionic strength, and temperature were tuned. The isotherms could be represented by the Freundlich equation, and the experimental data obeyed the pseudo-second-order kinetic model. The G-nZVI composite may be utilized to recover Pb(II) from aqueous solutions by chemisorptive recovery.

8.4.6 Zero-Valent Iron on a Nanoscale for a new Water Treatment Technology [51]:

Nanoscale metallic iron (nZVI) has been studied as a novel technique for the remediation of polluted water and soil over the past 15 years. Although the technology has attained commercial status in a number of nations throughout the world, it has failed to garner widespread adoption. The nZVI includes ways to improve particle reactivity, stability and subsurface movement, as well as aqueous corrosion, production and deployment.

The reasons for the lack of widespread acceptability are also investigated. Concerns about the long-term destiny, transformation and ecotoxicity of nZVI in environmental systems, as well as a lack of comparable research for various nZVI materials and deployment methodologies, are key problems. Few studies have looked at systems that are directly similar to the chemistry, biology and architecture of the terrestrial environment yet. These recent investigations have raised additional concerns, such as the possibility of heavy metals and radionuclides being remobilized over long periods of time.

The necessity of being able to reliably forecast the long-term physical, chemical, and biological destiny of contaminated sites after nZVI treatment is stressed, and a universal empirical testing methodology for nZVI is proposed as part of this. Nanotechnology is one of the fastest-growing industries on the planet. Over a thousand nanomaterial-based products are presently available in the private and public sectors for a wide variety of uses.

An increasing amount of theoretical and empirical research has shown that nZVI is both very successful and adaptable in the remediation of polluted water and soils. Significant advancements in manufacturing processes, physicochemical functionalizations, and subsurface stability and mobility have occurred in recent years. However, the effectiveness of nZVI in comparison to other in situ therapies such as chemical oxidation is still debatable.

Universal acceptance of nZVI as a remediation technique is possible, but only once a thorough knowledge of behavior, interactions, and impact is established. Future studies should aim to build a solid foundation of knowledge from which reliable predictions of nZVI mobility, reactivity, destiny, and ecological effect may be formed.

8.5 Nano-Bubbles:

We trace the history of nanobubbles from the first investigations that suggested their existence to the present. The influence of Laplace pressure on nanobubble thermodynamic stability is discussed, as well as why this indicates that nanobubbles are never thermodynamically stable. As a result, understanding bubble stability becomes a concern of bubble disintegration rate, and the prevailing way to doing so is described. Because of their distinct histories, bulk nanobubbles (or fine bubbles) are handled independently from surface nanobubbles. We look at early evidence for nanobubbles' existence, techniques for producing and characterization nanobubbles, evidence that they are gaseous or not, and hypotheses for their stability for each kind of nanobubble. We also look at how surface and bulk nanobubbles can be used. [52]

Since the discovery of nanobubbles (NBs) in 1994, the empirical research of NB characteristics and the commercialization of NB generators has progressed fast. NBs are stable spherical packets of gas in liquid with diameters smaller than 1000 nm in one dimension, however, they are often in the region of 100 nm in the other. While theories have yet to explain empirical evidence for the creation of stable NBs in water, a variety of NB applications have developed in several industries, including water and wastewater purification, where NBs have the potential to replace or increase the effectiveness of present treatment techniques.Access to safe drinking water is a human right, according to the United Nations, and municipal and industrial wastewaters must be purified before entering aquatic bodies. These safeguards necessitate treatment technologies that remove naturally occurring (e.g., arsenic, chromium, fluoride, manganese, radionuclides, salts, selenium, natural organic matter, algal toxins) or anthropogenic (e.g., nitrate, phosphate, solvents, fuel additives, pharmaceuticals) chemicals and particles (e.g., virus, bacteria, oocysts, clays). NBs provide up possibilities for improving or enabling innovative technologies that produce less byproducts and provide cleaner water.

8.5.1 Groundwater Cleanup using Ozone Micro-Nano-Bubbles [53]:

Because of its high oxidation ability, ozone is commonly employed in water treatment. However, due to its low solubility and quick breakdown in the aqueous phase, ozone's efficacy in groundwater remediation is restricted. Methods for enhancing ozone stability in the subsurface are becoming increasingly popular. Micro-nano-bubbles (MNBs), which have dimensions ranging from tens of nanometers to tens of micrometers, have high mass transfer rates, stay in water for a long time, and transit with groundwater flow, considerably improving gas concentration and ensuring a continuous gas supply. As a result, MNBs have a lot of promise for use in groundwater remediation. The features of ozone MNBs, such as their size distribution, bubble amount, and zeta potential, were investigated in this work.The mass transfer rate of ozone MNBs was examined experimentally. The ozone MNBs were then employed to detoxify organics-contaminated water, and they performed admirably. The effectiveness of ozone MNBs for organics-contaminated groundwater cleanup was also investigated using column testing. Field monitoring was carried out on a trichloroethylene (TCE)-contaminated site based on laboratory results. The findings revealed that ozone MNBs may significantly boost remediation efficiency and are a novel method for in situ remediation of organics-contaminated groundwater. The properties of ozone MNBs that were researched are described in this chapter.

MNBs have a large unit amount and can stay stable in water for lengthy periods. Ozone MNBs remain negatively charged under a wide range of salinities, indicating that they are stable and may be used to treat groundwater with a wide range of salinities. MNBs boost the mass transfer efficiency of ozone by a factor of ten and can stay stable in water for continuous ozone delivery. The MNB system's ozone half-life is substantially longer than the millimeter-bubble systems. Ozone had a substantial effect on organic pollutants in surface water and groundwater under laboratory circumstances, and MNBs considerably improved treatment efficiency. Field testing was conducted in a TCE-contaminated site in Japan, and an in-situ cleanup facility was built. After six days of therapy, the total clearance rate was 99 percent.

Ozone MNBs had a good effect on TCE-contaminated groundwater remediation and might be an innovative method for in situ remediations of organics-contaminated groundwater. Statement of novelty the capacity of ozone to migrate limits its employment in groundwater treatment as a frequently utilized oxidant. The goal of this chapter is to give information on the feasibility and effectiveness of using ozone in the form of micro nanobubbles to remediate groundwater (MNBs). Basic properties and mass transfer behavior of ozone MNBs were investigated, as well as the remediation efficacy of organic pollutants by ozone MNBs in laboratory and field testing. Ozone MNBs is a novel technique for in-situ remediation of organics-contaminated groundwater, and this paper will undoubtedly pique the curiosity of geo-environmental engineers interested in organics-contaminated groundwater remediation methods.

8.5.2 Water Treatment Might Be Improved with Nanobubble Technologies [54]:

This account investigates the possibility of using NBs' unique properties to improve water treatment by answering key questions and proposing research opportunities about (1) observational versus theoretical NB existence, (2) the ability of NBs to improve gas transfer into water or influence gas trapped on particle surfaces, (3) ability to produce quasi-stable reactive oxygen species (ROS) on the surface of NBs to oxidise pollutants and pathogens in water, and (4) ability to preheat water. Developing ways to evaluate NB size and surface characteristics in complicated drinking and wastewater chemistries containing salts, organics, and a broad array of inorganic and chemicals colloids is one of the top priorities.

The production of ROS by NB has the greatest potential for use in water treatment because it allows for a shift away from chemical-based oxidants (chlorine, ozone) that are expensive, dangerous to handle, and produce harmful byproducts while also assisting in the achievement of important treatment goals (e.g., destruction of organic pollutants, pathogens, biofilms). NB technology might be spread throughout continuously changing and more decentralized water treatment systems in both developed and developing nations due to the minimal chemical needs for forming NBs.

8.5.3 Getting Nanotechnology into Drinking Water Treatment: Overcoming Implementation Barriers:

In many parts of the globe, nanotechnology-enabled water treatment is a potential way to improve the efficacy and efficiency of water purification.

Nanotechnology has the potential to revolutionize drinking water treatment by increasing the versatility and versatility of treatment processes while reducing dependence on stoichiometric chemical addition (thus reducing associated waste streams), shrinking large facilities with long hydraulic contact times, and reducing energy-intensive processes. The unique material features that arise at the nanoscale provide solutions to water pollution treatment that are inefficient or useless using traditional technology. [55] This viewpoint explains why this emerging technology should be translated from promising bench-scale findings to full-scale commercialization and safe drinking water production.

8.6 Conclusion:

In the current situation, modern water technologies are required to assure high water quality, eradicate chemical and biological contaminants, and accelerate industrial wastewater production processes. Nanotechnology is one of the best possibilities for enhanced wastewater treatment procedures in this regard. For wastewater treatment, a variety of nanomaterials have been effectively created and researched. Nano-adsorbents (based on oxides, Fe, MnO, ZnO, MgO, CNT), photocatalysts (ZnO, TiO_2, CdS, ZnS:Cu, CdS:Eu, CdS:Mn), electrocatalysts (Pt, Pd), and nano-membranes are only a few examples (multi-walled CNTs, electrospun PVDF, PVC, Na-TNB). Furthermore, these nanoparticles can be used with biological processes to increase water purification (algal membrane, anaerobic digestion, microbial fuel cell). Each technology has advantages and disadvantages in terms of pollution removal effectiveness. Heavy metals such as Cr, As, Hg, Zn, Cu, Ni, Pb and Vd, among others, may be effectively removed from wastewater using nano-adsorbents. Nanoparticle photocatalysts may be used to treat both hazardous contaminants and heavy metals, with the catalyst material being modified to allow for the use of visible sunlight rather than expensive artificial UV radiation. [56] The process of electrocatalytic wastewater treatment might be enhanced by utilizing nanoparticles to achieve a bigger surface area and more uniform catalyst dispersion in the reaction fluid. Nano-membranes are particularly successful in reducing foulants, heavy metals and dyes in wastewater filtration.

Furthermore, nanotechnologies have been effectively incorporated into biological treatment processes, as the use of nano-membranes in algal wastewater treatment promotes efficient harvesting of algal biomass while minimizing membrane fouling and the usage of coagulants. No question using nanomaterials in wastewater treatment is efficient; nonetheless, this technique has certain severe drawbacks that must be addressed. During the preparation and treatment operations, nanoparticles may be released into the environment, where they might aggregate for a long time and pose major dangers. Future study is needed to prepare catalysts with the least toxicity to the environment to lessen the health risk. More research is needed to re-evaluate the ecotoxicity risk of each new catalyst alteration as well as existing materials. Furthermore, life cycle analyses of the advantages and dangers of nanomaterials are critical to be addressed. [57]Nanotechnology is rarely used in large-scale procedures. Given that most nanomaterials have not been cost-competitive with traditional materials like activated carbon, future applications will rely on efficient processes that only require small amounts of nanomaterials. Furthermore, further effort is needed to create a cost-effective way of synthesizing nanomaterials and to verify their efficiency on a broad scale before they can be used in the field. We'll conclude this chapter with a few key lessons and knowledge gaps that need to be addressed in order to promote the use of nanoparticles for water filtration.

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