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Purification of Water Using Nanotechnology

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Abstract

One of the most crucial ingredients for life on earth is water. It has played a crucial role in the development of human civilizations, starting with the emergence of the first aspect of existence in seawater. The demand for clean water is universal and essential to all human species. But at the moment, pure water supplies are being poisoned. Water quality and society's level of development have recently been linked. The safety of drinking water has been put in jeopardy by several chemical and biological pollutants. Alternatives for decontaminating and reusing water are among the most desired solutions to address the issues of water shortage and the escalating disputes over this essential resource. A significant issue is the buildup of organic debris and its residues in wastewater. Significant progress has been achieved in using the chemistry of nanomaterials for purifying water as a result of the realization of the molecular nature of pollution in drinking water. Due to its capacity to produce precise, structurally controlled materials for such needs, nanotechnology offers exceptional potential in filtering applications. By extending the idea of clean, inexpensive, and sustainable water to the ecosystem as a whole, we point out that cities may live and breathe comfortably by using such technology. Sustainability in clean water may be achieved by comprehending the major environmental issues facing the world and investigating potential solutions from new nanotechnologies.

Keywords

Nanotechnology, sustainability, photocatalytic titania, reverse osmosis

1. Introduction

Water is a mythological material whose physical reality is subordinate to its symbolic meaning as the representation of life in our minds. For the world's health, ecology, and economy to thrive, sustainable supplies of fresh water are essential. Both wealthy and emerging nations share a serious concern for environmental contamination. Anthropogenic activity causes an increase in the pollutant load in the environment [1]. The capacity of human society to meet increasing demands for potable water has been severely strained by current extended droughts, population growth, decline in water quality, particularly of groundwater due to increasing groundwater and surface water pollution, unabated flooding, and increasing demands from a variety of competing users. Living creatures are endangered by pollutants, both organic and inorganic, and their prevalence and permanence have substantially increased recently. Oceans, rivers, and other inland waterways are being put under extreme strain as a result of human activity, seriously compromising their quality. Toxic substances such viruses, heavy metals, pesticides, endocrine disruptors, pharmaceutical compounds, polyaromatic hydrocarbons, organic and inorganic solvents, and other pollutants enter water bodies, dissolve in them, float in the water, or settle on the bed, and cause water pollution [2]. Therefore, in order to prevent future water stress, it is important to identify the necessity to manage current water supplies. Safe drinking water supply is a problem nowadays. The study of phenomena and the manipulation of materials at the atomic, molecular, and macromolecular scales—where characteristics differ noticeably from those at higher scales—is known as nanoscience [3]. The use of nanostructured materials as adsorbents or catalysts to remove hazardous and damaging chemicals from wastewater has received a lot of interest in recent years [4]. Since the previous decade, nanomaterials have drawn a lot of attention since they have distinct features from bulk materials. Due to their high surface-to-volume ratio, improved magnetic property, unique catalytic characteristics, etc., single and multi-metal or doped metal oxides are of equal interest to other nanomaterials [5]. As a result, diverse scientists utilized a variety of processes, including chemical precipitation, sol-gel, vapor deposition, salvo thermal, solid-state reaction, etc., for the synthesis of specific oxides [6]. Technologies for treating water that are enabled by nanotechnology are currently available. The most developed and environmentally benign technique at the moment appears to be nanofiltration, however several others are in the development and application stages. When choosing materials for water filtration, environmental destiny and toxicity of any item are crucial considerations. Even though there is considerable disagreement about whether nanotechnology is better than currently used water treatment techniques. In this paper all the facts related to purification of water by nanotechnology are discussed. Section 2 comprises about the nanotechnology and the uses of nanotechnology in water filtration is also described. The organic, inorganic and polymeric nanomaterials are discussed in the section 3, 4, 5 respectively. It is also important to know about the techniques used for water filtration which are explained in section 6. Sections 7 and 8 tell us about the various types of carbon-based nanomaterials and metal oxide-based nanomaterials.

2. Nanotechnology

The term "nanotechnology" describes the use of particles in a variety of tools, processes, and applications that range in size from a few to hundreds of nanometers. This particle size is appropriate for innovative applications since it has distinct physicochemical and surface characteristics. In fact, supporters of nanotechnology claim that this area of study might help in finding solutions to some of the most pressing issues facing humanity, such as guaranteeing a steady impart of potable water for a population that is expanding. "Nanomaterials have a substantially larger area-to-volume ratio than typical micrometer-sized adsorbents, resulting in improved photocatalytic activity, high adsorbent capacity, high removal efficiency, and quick removal dynamics" [7]. Water treatment is a major problem in underdeveloped nations because of inadequate maintenance, erratic supply, pollution, and a lack of chlorination because the chloramine or chlorine employed in the chlorine process produces carcinogenic byproducts, these chlorine-free water filtering methods built on nanotechnology have a benefit [8-12]. Since photocatalytic titania has the potential to breakdown organic pollutants and kill microorganisms when exposed to UV light [13-14] Nanomembranes covered with titania are of significant interest for water purification. These nanomembranes can also be coated with antibacterial and photocatalytic material utilizing the atomic layer deposition technique [15,16]. The creation of water filtration systems in underdeveloped nations may benefit from the usage of these nanomembranes. Toxic metal ions including Cr(VI), Cd(II), Pb(II), Hg(II), Cr(III), Co(II), Ni(II), Cu(II), As(III) ,As(V), and Ag(I), can be taken out of water utilizing nanoparticles like magnetic nanoparticles carbon nanotubes, and iron zeolite. These metal ions seriously harm people's health [17]. Zero valent ions at the nanoscale are utilized as adsorbents and also serve to catalyze photochemical oxidation, which destroys persistent contaminants [18]. Carbon nanotubes and dendrimers are commonly employed in the creation of modern water systems due to their vast adsorption properties [19,20].

Nanoparticles can reform material at a faster rate with less formation of harmful byproducts than granular forms because of their large surface reactivity and surface area. Many of the current issues with water quality may be resolved or greatly diminished with the use of Nano sorbents, carbon nanotube, pharmacologically active nanomaterials, nano-structured catalytic membranes, nanowires, magnetic nanoparticles, granules, flake, and high surface area metal particle supramolecular assemblies with characteristic length scales of 8-9 nm including clusters, two - dimensional, nanoparticles, and colloids. When compared to a microbial cell, which has a diameter of around 1.0 m, nanoparticles' extremely tiny particle sizes (1-100 nm) are what distinguish them as adaptable water remediation tools (1000 nm). Therefore, the groundwater flow can efficiently transfer nanoparticles [21]. They can also stay suspended for long enough to allow the launch of an in-situ therapy sphere. As a result, for improved water treatment, A solid matrix, like a common water treatment substance like activated carbon and/or zeolite, can be used to fix nanoparticles.

2.1. Use of Nanotechnology in Water Purification

Nowadays advancements in the study of using manganese doped ZnO nanoparticles for biologically treated sewage from the deprivation of organic colorants in the paper and tissue industries has shown promising results. Water quality, availability, and viability over the long term may be improved via nanotechnology. Water purification has necessitated the use of a variety of membrane types, including reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) [21-22]. Although RO has the capacity to produce water with the highest purity, nanofiltration membrane has emerged as a modern method for water purification. If water is allowed to pass between ultrafiltration (UF) membranes, the macro size molecules and colloids have removed them. The dimension of ultrafiltration membranes' pores ranges from 2.1 to 99.9 nm. Several years ago, the removal of living organisms or small particles microfiltration (MF) was used, which is a technique for separating particles under low pressure having sizes between 0.1 and 10 microns. Which is why MF is still frequently the most used technique in separation-based ultrapure and potable water purification While colloids, particles, lipids, and bacteria allowing molecules with low molecular weight to pass cell membrane Membranes for nanofiltration are fairly affordable in contrast to alternative forms of filtering.

Additionally, NF membranes can quickly remove TDS as well as minerals, other salts, microbes (fungus, molds, virus, and bacteria), monovalent cations, anion, and other suspended particles from surface and groundwater [23]. The NF membrane has several engineering and industrial uses, including those in oil, textiles, drinks, food, chemicals, and a wide range of other industries. It is generally known that the nanofiltration membrane's hole dimension is typically quite tiny, about 1 nm, which aids in separating bigger molecules from smaller molecules as well as aids in the removal of germs [24] explored and developed the method works on stacking two membranes with different wet abilities, with the findings demonstrating increased generation of freshwater flow and total salt rejection. The contact angle has been measured using image processing software in a tangential fashion, and some researchers have suggested that wettability measurements may also be made.

The membrane's PH wet ability via water and mineral oil as well as modified cellulose are evaluated using the contact angle. The whole membranes that are contacted by oil in air are super oleophilic in nature, with oil contact angle values that are close to zero. Due to its capacity to guide liquid flow, irregular wettability is a crucial technique for suspension separation adjusted the electrospinning fiber diameter to change the surface roughness in order to manage the wettability, and the results of the experiment reveal that the contact angles of the fibers across various diameters were raised by around 40. Surface energy and roughness are influenced by chemical composition and geometrical structure, respectively, to regulate the wettability of materials.

Regarding hydrophilic coating results, compared three membranes: a composite PVDF membrane, a superhydrophobic PVDF membrane and a hydrophobic PVDF membrane. They demonstrated that the composition of feedwater had no impact on the relationship between fouling propensity in MD treatment of real produced water and membrane surface wettability.

Protozoa (such Giardia, Cryptosporidium, and others) may be eliminated extremely well by nanofiltration. Likewise, nanofiltration can eliminate microbes effectively. Nanofiltration can also eliminate viruses for instance effectively. Nevertheless, nanofiltration has only mild efficiency in eliminating chemicals. Filtration using membrane has the potential to take the place of current filtering methods, due to the fact that traditional filtering procedures they have a certain restriction and cannot get rid of various contaminants include sedimentation, activated carbon, Coagulation and flocculation are two processes [25]. Numerous researchers have looked into the use of non-reactive membranes made of metal nanoparticles and nanostructured membranes made of nanomaterials like nanoparticles, dendrimers, and carbon nanotubes [26]. Due to its effectiveness, practicality, and relatively cheap process costs, absorption is a widely used method for water purification. Operative absorbents such activated carbon, zeolites, silica, modified clays and layered double hydroxides remove a variety of contaminants from polluted water. Nanotechnology provides a ground-breaking method for environmentally friendly water filtration, security and distribution. Filtration using membrane genuinely generates water of great grade. The improvement of polymeric and ceramic membrane is actually successful noticed, has a significant impact on how a membrane in the treatment of water. PES membrane for water treatment using NMP solvent. It is discovered that weaker fibers and minor roughness lead to significant impact on ENMs made using NMP solvents. It will have excellent rejection and flux recovery capabilities in contrast to ENMs using DMF solvents.

Additionally, it's crucial to remember that the flux performance is seen to be eight times more enhanced than commercial membranes. Only one issue exists with membrane filtration: the misconduct with the advancement of nanoscale membrane. The fouling problem can be solved at the atomic, molecular, several studies claim this [27-28]. Utilizing nanomembrane infiltration recently has been involved in a variety of technological issues, including elimination of poisons and pollutants that are organic and biological.

Additionally, certain poisons and pollutants such binding 4-nitrophenol may be dissolved in water with metal ions produced by nonreactive nanomembranes that degrade resources [29]. Silver nanoparticles should be infused into the polysulfonate ultrafiltration membrane in order to get greater operational and effective material to eradicate viruses [30].

3. Organic nanoparticles for the filtration of water

The structural flexibility and variable hybridization state of elemental carbon, organic nanomaterials exhibit distinctive chemical, electrical, and physical characteristics. The main nano-structural forms of carbon include fullerene C60, C540, graphene, carbon dots, multi-walled carbon nanotubes (MWCNTs) and single-walled carbon nanotubes (SWCNTs)[31]. Organic nanoparticles are seen schematically in Figure 2. Due to their biocompatibility, accessibility to a variety of raw materials, low toxicity, and affordability, carbon dots (CDs) are popular among nanomaterials. CDs are sub-10 nm-diameter quasi-spherical carbon nanoparticles (NPs). Due to their outstanding chemical stability, surface qualities, fluorescence and good water solubility, CDS have reached significant interest [32]. Before being employed in decontamination, carbon nanomaterials must first have their surfaces changed and activated. MWNT, SWNT, and graphene are typically used for these applications. These nanoparticles are among the finest for the adsorption of chemical contaminants in polluted water because of their remarkable adsorption properties [33]. Both physisorption and chemisorption are evident depending on the surface modification and manufacturing technique. In addition to adsorption, photocatalysis is a powerful technique for cleaning water. Titanium oxide nanoparticles conjugated with graphene have been shown to boost photocatalysis when compared to titanium oxide nanoparticles alone [34].

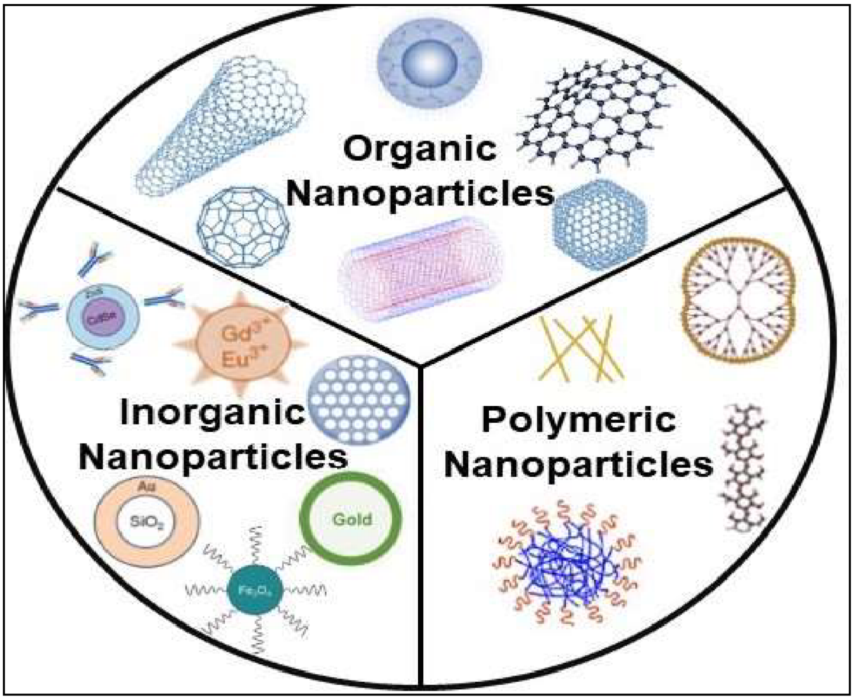

Figure 1. Classification of NPs in water purification [41]

4. Inorganic nanoparticles to purify water

Metal oxide nanoparticles (MO NPs), such as Ag NPs, TiO_2 NPs, FeO NPs, Silica NPs, and CuO nanoparticles, are the main inorganic nanoparticles utilized in water remediation [35]. MO NPs exhibits outstanding heavy metal and chlorinated organic water pollution adsorption efficiency. Due to their high adsorption capacity, quick kinetics, and flexibility to adapt in both ex-situ and in-situ applications, MO NPs cannot be avoided in remediation, especially in watery settings [36]. In the realm of decontamination, mesoporous silica nanoparticles with pore sizes ranging from 2.5 to 50.5 nm have attracted a lot of attention. SiO^2 NPs are ideal for a wide variety of applications due to the tunable pore diameter and simplicity of surface functionalization. SiO^2 NPs' [37]-OH groups support surface modification and make a range of contaminants easier to clean up [38].

5. Polymeric nanoparticles to purify water

As we have demonstrated, nanoparticles have many benefits, but one of the disadvantages is particle stability. Numerous research suggests that nanomaterials can assemble after synthesis depending on a number of factors. Aggregation of particles reduces adsorption capability. An approach is to employ polymeric NPs. Here, we use a backing material to hold the NPs in place, preventing agglutination and enhancing the stability of pure nanoparticles. The polymeric host is made up of stabilizing agents, surface-modification ligands, emulsifiers, and surfactants. The size range for polymeric NPs is between 1 and 1000 nm. Numerous contaminants, including heavy metals like iron, mercury, manganese, and arsenic, organic pollutants like medications, volatile organic compounds, pesticides, aromatic and aliphatic compounds, gases like SO2, CO2, and NO2, and microbes like bacteria, viruses, and other pathogens are all detected and removed using polymeric NPs [39-40].

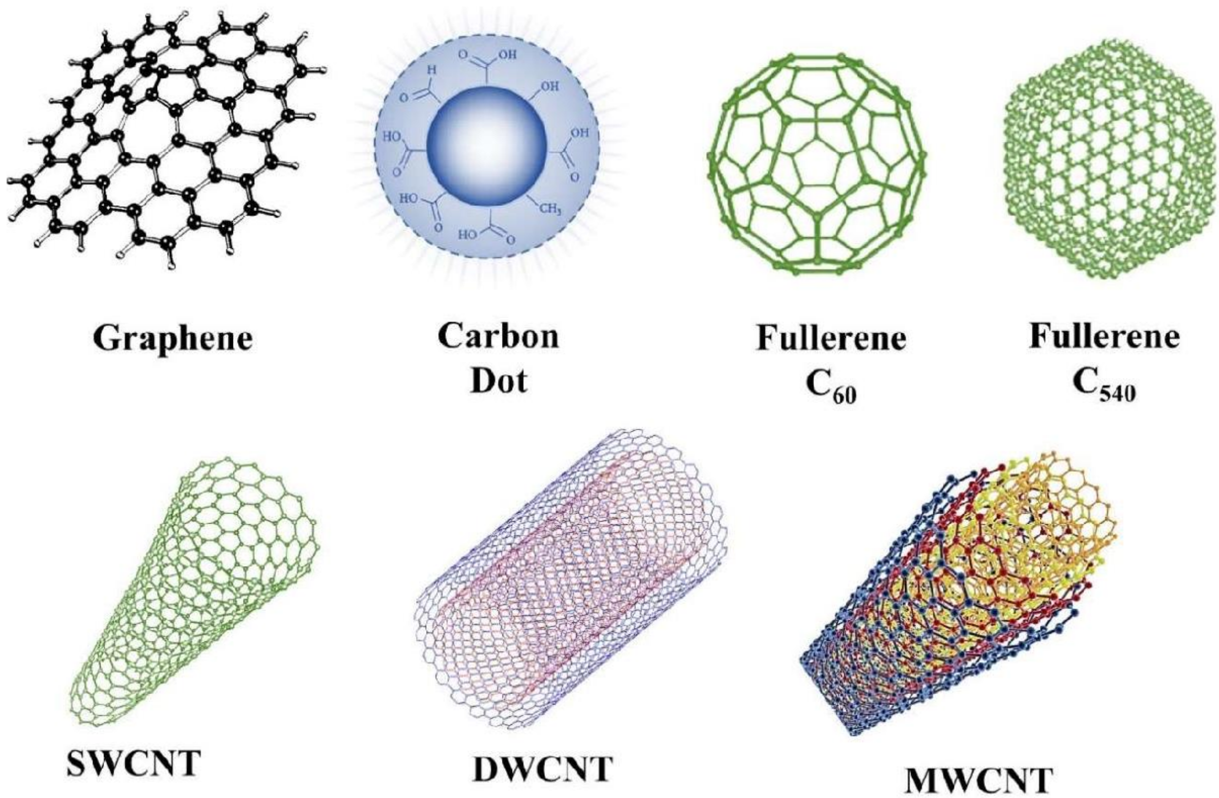

Figure 2. Types of organic nanoparticles [41]

6. Technique for Purification

6.1. Nanofiltration

The purification of water is becoming more dependent on membrane techniques like nanofiltration (NF) [42]. Membranes for nanofiltration (NF) are frequently used in water treatment to treat wastewater or drinking water. Materials of a size between 0.001 and 0.1 micrometers can be separated using a low-pressure membrane method. NF membranes, which have pores between 0.2 and 4 nm, are pressure-driven membranes having characteristics halfway between those of reverse osmosis and ultra filtration membranes. It has been demonstrated that NF membranes can filter out turbidity, bacteria, and inorganic ions like Calcium and sodium. They are used for wastewater treatment and for pretreatment in salt water. They are also used to soften groundwater, remove dissolved organic matter and trace contaminants from surface water, and remove organic and inorganic pollutants from wastewater. The removal of biological contaminants, natural organic matter, cations, organic pollutants, nitrates, and arsenic from groundwater and surface water using nanofiltration had been examined [43]. It also discovered that tiny amounts of uranium may be eliminated from the sea by nanofiltration [44]. The effectiveness of using nanofiltration to desalinate water had been studied [45]. They discovered that brackish water may be made drinkable by combining reverse osmosis with nanofiltration. An increase in water quality for a major water distribution system employing nanofiltration [46]. Additionally gaining popularity in water treatment procedures are carbon nanotube filters. Carbon nanotube filters have recently been successfully created. [47]. These new filtering membranes are made up of cylinders with walls made of carbon nanotubes oriented radially. They demonstrated that microorganisms like Escherichia coli and Staphylococcus aureus could be effectively removed from polluted water by filters.

Both ultrasonication and autoclaving are effective methods for cleaning carbon nanotube filters. Nanoaluminafibre and micro glass are combined to create nanoceramic filters, which have a strong positive charge and the ability to hold negatively charged particles. Nanoceramic filters are highly effective in eliminating germs and viruses. They can chemisorb dissolved heavy metals and have a high capacity for particles with reduced clogging [48].

6.2. Nanoscale Zerovalent Iron

The utilisation of iron nanoparticles in nanoremediation is highly beneficial. Using borohydride as the reductant, iron was produced at the nanoscale from iron (II) and iron (III). The diameter of the zero-valent iron particles at the nanoscale ranges from 9 to 101 nm. They are composed of a standard core and shell. The mixed valent oxide shell is created as a result of the oxidation of the metallic iron, whereas the core is largely composed of zero-valent or metallic iron. Because nanoscale Zerovalent Iron has a larger surface area than microscale Zerovalent Iron, it has a greater number of attacking sites than microscale Zerovalent Iron, thus it has the dual characteristics of reduction and adsorption [49].

The most extensively researched environmental nanotechnological method uses nanoscalezerovalent iron (nZVI) for groundwater cleaning. It has been demonstrated that metallic iron at the nanoscale is particularly efficient in destroying a wide range of typical pollutants, including dyes, pesticides, trihalomethanes, chlorinated methanes, chlorinated ethenes, brominated methanes, chlorinated benzenes and other polychlorinated hydrocarbons [50]. The environment's corrosion of zerovalent iron serves as the catalyst for the process.

$2Fe^{++} + 2H_2O \longrightarrow 2Fe^0 + 4H+ + O_2.$

$Fe^0 + 2H_2O \longrightarrow Fe^{2+} + H_2 + 2OH^-$

It has been discovered that nZVI may also decrease inorganic anions such as perchlorate, arsenate, arsenate, nitrate, chromate and selenate in addition to organic pollutants. In comparison to regular granular iron, nZVI exhibits many times quicker reaction rates and a substantially larger sorption capacity. Additionally, nZVI has the ability to remove dissolved metals from solutions, such as Pb and Ni. Either lower oxidation states or reduction to Zerovalent metals occur with the metals [51]. Usually, sodium borohydride may be used as the main reductant to produce nZVI. For instance, FeCl3.6H2O (0.05 M) solution is added to NaBH4 (0.2 M) (1:1 volume ratio). The following process occurs when borohydride reduces ferric iron [52]: $4Fe^0 + 3H_2BO_3- + 12H+ + 6H_2 = 4Fe^3+ + 3BH_4- + 9H_2O$ A cutting-edge groundwater remediation technique called permeable reactive barrier (PRB) technology uses reactive materials to physically, chemically, or biologically clean polluted groundwater in situ [53]. For many years, reactive barriers made of granular ZVI have been employed at several locations across the world to remove inorganic and organic pollutants from water [54]. Recently, nZVI have become more popular as desirable candidates utilizing this technology. In order to treat the pollutants without excavating water, the reactive materials are positioned in subterranean downstream of the contaminated zone and forced to flow through them. Compared to other removal techniques, this one is often less harmful to the environment.

6.3. Nanoparticle removal following water treatment

Nanoparticles will inevitably be released into the environment when they are used in environmental applications. Understanding their bioavailability, mobility, persistence, and toxicity is necessary to evaluate the possible threats they pose to the environment. The potential impact of nanoparticles in soil and water on aquatic and terrestrial life is little understood. The question of how these nanoparticles may be removed from the urban water cycle is inevitable. Sedimentation and filtration are two common traditional procedures for the removal of particle matter during wastewater treatment. Although the sedimentation velocities of nanoparticles are very modest because of their tiny sizes, substantial sedimentation won't happen as long as bigger aggregates don't form [55]. It may not be acceptable to remove nanoparticles from water using common methods like flocculation, which highlights the need for novel solutions to the issue. Pathogens have already been removed from water using membrane filtering techniques up to this point, such as reverse osmosis and nanofiltration [56]. As a result, this method may also be used to remove nanoparticles. Studies employing nanoparticles may not be applicable to determining the behavior of the particles actually in use because the majority of nanoparticles utilized in technological applications nowadays are functionalized in nature. Functionalization is frequently used to lessen agglomeration and hence enhance particle mobility. Sadly, little is now understood about how functionalization affects how nanoparticles behave in the environment.

7. Carbon-based nanomaterials

7.1. Graphene (GNMs)

Graphene is a unique nanoscale-sized sheet of graphite with significant promise for environmental protection. GNMs are being used by more and more researchers to manage the aquatic environment. A number of procedures, such as carbon nanotube conversion, chemical oxidation-reduction, and mechanical peeling are used to create graphene. In a present aquatic environment, surfactant pollution is a severe public health issue. Surfactants may easily penetrate an aquatic environment due to their surface functioning characteristics, causing eutrophication of the water. A nonionic surfactant was developed using reduced graphene oxide (rGO) and graphene oxide (GO) (TX-100) [57]. Another major worry is antibiotic water pollution. Since certain antibiotics are difficult to remove using standard wastewater treatment technology, antibiotics can have a wide range of toxicity in aquatic species. Tetracycline adsorption on GNMs may be aided by electrostatic action. Tetracycline may be effectively adsorbent using the carbon nanomaterials graphene and carbon nanotubes. They used a photocatalytic reduction technique to produce rGO, then vacuum filtering and mild UV irradiation were used to create the rGO/G-C3N4 hybrid film [58]. All of the aforementioned research suggests that GNMs might be utilized to clean up water pollution. It's important to note that when GNMs interact with their environment, their susceptibility to absorb harmful compounds might alter.

7.2. Carbon nanotubes (CNTs)

One-dimensional nanomaterial CNTs have a special combination of electrical, chemical and physical properties. It appears that CNTs have a adsorption capacity that enables them to remove certain contaminants from wastewater. Some scientists looked at the functional groups produced on the surface of CNTs using FTIR spectroscopy. It investigated how temperature affected the FTIR spectra of carbon nanotubes [59]. CNTs were made more reactive and soluble using a variety of chemical reactions, including fluorination, cycloaddition, oxidation, interaction with diazonium salt and free radical polymerization. Many experts have studied the use of carbon nanotubes in water filtration in recent years. Carbon nanotubes have also been proven in several tests that they may degrade dangerous pollutants in water. Some studies claim that although phenolic and water chemicals have poor physical adsorption to the original CNTs' outer surface, they can more successfully adsorb on functionalized CNTs [60]. In light of the concurrent presence of H-bonding and -stacking in an environment, it was shown that the attachment of phenol to CNT-OH is greater than that of hydrogen atoms. Composite materials are also accessible for the production of compounds that remove pollutants from water and carbon nanotubes.

7.3. Graphitic carbon nitride (G-C_3N_4)

The most common method of producing G-C_3N_4 is by thermopolymerase of pre-bundled C-N core or nitrogen-rich formation. Precursors including dicyandiamide, cyanamide, urea, thiourea, and melamine have all been used. Precursors typically undergo an initial transformation into melamine during the typical thermal polymerization reaction to the synthesis of G-C_3N_4, and condensation is then followed by ammonia elimination to obtain G-C_3N_4 at temperatures between 500 and 530 C. The G-C_3N_4 is extremely flammable, nevertheless, and breaks into nitrogen and cyano pieces above 700 C as well as somewhat over 600 C [61]. Surface area, photoluminescence, morphology, the C/N ratio of G-C_3N_4, and porosity are only a few examples of the features that are altered by the use of different materials and experimental needs.

7.4. Nanoporous carbon (NPCs)

Pore size may be used to distinguish between nano porous materials such as microporous (pore size 2 nm), mesoporous (2-50 nm), and microporous (pore size 50-1000 nm). NPCs are created by burning organic precursor molecules, such as wood, coal, fruit peels, polymers, and stimulating them physically, chemically. The shortcomings, poor conductivity, and graphitization at higher temperatures make these technologies less practical. Synthetic procedures can be made better by using templated or untemplated reactions, thermally unstable or thermosetting components, and catalyst-aided activation of organic precursors. Making NPCs with specific pore sizes is possible using hard and soft templates [62]. In order to create nanostructures, soft template synthesis depends on the self-assembly of organic molecules. Another widely used technique for creating mesoporous carbon compounds was established utilizing a stiff template. Create highly ordered NPCs with directed mesoporous structures using the hard template approach. The procedure involves the following steps: (a) creating a template from a solid gel with a regulated microstructure; (b) imbuing the precursor with the template; (c) crosslinking and carbonising the precursor; and (d) dissolving the template. Hard template synthesis has limited use since, when extracting from the template, it destroys the mesoporous structures of NPCs. It is feasible because there are thermodynamic constraints on how the molecules interact. Amphiphilic templates are employed in this method. High thermal stability is required, but it must also be extractable or decomposable at experimental temperatures [63].

7.5. Carbon nanofibers

(CNFs Carbon filaments with a nanoscale diameter are called carbon nanofibers. They all have fascinating applications and are distinguished by high surface-to-volume ratios, excellent mechanical stability, and high aspect ratios. Electrospinning, CVD, and templating are the three most typical synthetic approaches to carbon nanofibers. The most popular and economical method for creating premium carbon nanofibers is electrospinning. In this technique, tiny carbon filaments are produced on an electrode receiver by injecting a sol-gel into a syringe pump and stretching it under high voltage [64]. The solution is pumped at a very high voltage and steady pace using a spinneret. The solvent evaporates throughout the procedure, and the strained material hardens into nanofibers on the electrode collector with diameters of a few nanometers. Polyacrylonitrile, polyvinyl pyrrolidone, cellulose, phenolic resins, polyvinyl alcohol, polybenzimidazole, and other materials are used to make electro spun carbon nanofibers.

7.6. Fullerene

By using the laser irradiation at low pressure approach for graphite vaporization, fullerenes were the first to be added to the carbon family. The most prevalent kind of fullerene is C60, which has icosahedral enclosed cages containing 20 hexagonal and 12 pentagonal rings of sp2-hybridized carbon atoms. Graphitic carbon soot alone was the only material utilized in the original large-scale production of C60 fullerene by an arc discharge technique. Similar to how carbon nanotubes are made, fullerenes may also be made. Since 1990, arc discharge methods have been often used to produce large amounts of fullerene [65]. An electric arc is produced between graphite tubes in a neutral atmosphere in order to collect condensed soot. Diffusion flame, electron beam evaporation, laser ablation, chemical routes and ion beam sputtering, were used to synthesize fullerene. To increase the functionality of fullerene, covalent bonding is necessary. The characteristics of fullerene can be functionalized to suit certain uses. A nucleophilic method was used to add an ester group to fullerenes, and SWCNTs were used to functionalize them for sensing applications. The hydrophobic nature of fullerenes can be functionalized to make them hydrophilic or amphiphilic [66-67].

8. Metal and Oxides Based Nanomaterial

8.1. Nanosized silicon dioxide

Because of its simple production process, environmental friendliness, high SSA (50-500 nm), and inexpensive price, SiO2 has become a frequently utilized nanoparticle. In a novel experiment, the researchers coated SiO2 with cationic surfactants such cetylpyridinium chloride (CPC) of SSA m2 g 1 for improved adsorption of both polar and non-polar organic pollutants. A direct correlation between adsorption capacity and adsorbent concentrations was seen, and the CPC designs remained consistent throughout a wide range of developments. With additional nanoparticles (such Al2O3), whose adsorption of PAH-type wastewater pollutants is negligible, this kind of technique could be successful. Similar to this, dithiocarbamate-containing SiO2 nanoparticles have been employed in alternative functionalization procedures to absorb a range of inorganic metal pollutants because of their multichannel affinity [68].

8.2. Nanosized titanium dioxide

Its abbreviation is TiO2, and it is widely known for both photocatalysis and adsorption. TiO2 size, crystallinity, and SSA all have an impact on metal adsorption. TiO2 that has been reduced to nanoscales exhibits better Pb (II), Ni(II), Zn(II) Cd(II), and Cu(II), adsorption properties (329.8 nm). The number of unsaturated surface reactive atoms that are present when an NP's size is reduced increases, exposing more surface-active sites [69]. The higher porosity and crystallinity of TiO_2 NPs may also have an impact on adsorption efficiency. There are several methods for adsorbing TiO_2 NP pollutants. It might have the lowest intermolecular diffusion regulated because of the way its atomic structural organization is set up. Due to the free electron pair and overall positive charge, the Ti4+ cation may be a Lewis acid. By using oxygen anions, cationic and acidic molecules may be bonded (O2). TiO2 and impurities are affected by additional electrostatic and hydrogen bonding forces. Powdery TiO2 still presents a problem that hasn't been fully resolved. In-depth study has been done on TiO2-polymer composites for water purification. According to study, integrating TiO2 with a variety of polymers, including PAN, polystyrene, and others, improves stability and recyclability [70].

8.3. Nanoparticles of noble metal

Transitional metals such as silver (Ag), gold (Au), palladium (Pd), and platinum were considered noble metals (Pt). They frequently have high ionization energies due to their short atom sizes, which results in low oxidation potential. Additionally, their oxidation potential and ionization energies differed greatly at the nanoscale, creating multiple distinct noble metal processes. Typically, noble metal nanoparticles were created by decreasing the corresponding metal salts and regulating nanocrystal nucleation and expansion using a stabilizing agent. The stability of noble metal nanoparticles was typically enhanced by the application of surfactants and polymers [71]. Nanoparticles of Ag and Au have been utilized extensively for detecting trace quantities of organic contaminants due to their distinctive optical properties. Silver nanostructures were present, and this considerably boosted the Raman Signal. Additionally, a clear connection between pesticide content and plasmon resonance wavelength shift was found. The surface of gold nanoparticles containing indoxyl groups was transformed in the presence of pesticides, modifying the signatures of the functional groups, with the detection limit becoming close to the ppt level. Several electrodes based on Ag/Au, Au/Pt, or Ag/Pt bimetallic nanoparticles have been studied up until recently for the detection, monitoring, and photocatalysis of trace contaminants. Noble metal nanoparticles can be employed to absorb inactive microorganisms and pollutants in addition to pollution monitoring. Gold nanoparticles may effectively absorb Hg by generating $AuHg_3$, Au_3Hg, and AuHg with a capacity of 4.065 g/g Au [72]. The biocidal properties of silver nanoparticles were employed to clean water; E. coli-causing germs might become inactive when they came into contact with Ag nanoparticles. It was suggested that silver nanoparticles may directly harm cellular membranes and that the crystal structure and particle size of Ag nanoparticles affected their antibacterial activity for more potent antibacterial efficacy with higher atom density. Silver nanoparticles are now used in mouthwash, surgical masks, and textile fibers as disinfectants. Noble metal nanoparticles have also been utilized to photocatalytically destroy a variety of water contaminants, including dyes, halogenated organics, and pesticides [73].

9. Conclusion

Purification of the water supply is crucial for sustainable growth. Among other cutting-edge technologies, nanotechnology might be used to accomplish this goal to treat dangerous pollutants that were previously untreatable. Although many in the scientific world believe nanotechnology to be the next buzzword, knowledge on the topic is still widely scattered and fragmented because of the relative youth of the technology. However, the growing trends in research that have been previously described have demonstrated that nanotechnology has tremendous potential to be turned into a very effective water treatment instrument of the twenty-first century. In actuality, the nanotechnology revolution is being driven by nanomaterials and all their diverse manifestations. Solutions based on nanotechnology have enormous Possibility of enhancing competency and cost-effectiveness a larger scale of water purification Research is required. Low manufacturing costs are essential for the widespread use of nanoparticles in water purification. Reducing toxicity and improving stability are further important factors. For the usefulness of nanoparticles. Thus, in the future Studies should strengthen their financial viability and stability, lessen toxicity, and evaluate the relevant water interaction mechanisms during therapy. Another significant problem is the integration of nanomaterials into current water purification systems. Because they are adaptable, scalable, modular, and generally simple to use and maintain, membrane technologies like RO and NF are quickly becoming the industry standard for public utilities and industry.

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