Nanotechnology for Water Purification

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Abstract: ***Sufficient and feasible supplies of clean water are essential to the world's wellbeing, condition and economy. As of now impressive difficulties are confronted in taking care of rising requests of consumable water as the accessible supplies of freshwater are diminishing because of developed dry seasons, Decrease in water quality because of expanding groundwater and surface water contamination and expanding requests from users. The problem of access to safe water is inevitable and requires tremendous research to devise new, cheaper technologies for purification of water. Advances in Nano scale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly ameliorated. The capacity to see Nano-surveyed materials has opened a universe of potential outcomes in an assortment of businesses and logical attempts. Since nanotechnology is basically an arrangement of strategies that permit control of properties at a little scale. This paper gives a review of the utilization of nanomaterial in water filtration. We highlight late advances on the improvement of Nano scale materials and procedures for treatment of surface water, groundwater and modern wastewater contaminated by harmful metal particles, radio nuclides, natural and inorganic solutes, microorganisms and infections.***

Keywords: Nano-scale, Nano-surveyed materials, Nanotechnology, water filtration, radio nuclides, inorganic solutes

1. Introduction

Water covers 33% of the world's surface; a large portion of it is saline and unusable for human utilization, only 2.5 percent of the world's aggregate water is fresh. Sadly, notwithstanding being rare, fresh water is likewise exceptionally unevenly circulated, and the greater part of the wetlands has vanished from earth. All through the world, the most concerning issue individual's face is insufficiency in access to perfect and safe water [1].The protection of water treatment systems against potential chemical and biological terrorist acts is also becoming a critical issue in water resources planning[2].Supra molecular assemblies with characteristic length scales of 10^{-9}–10^{-7} m including clusters, macromolecules, nanoparticle sand colloids have a significant impact on water quality in natural environmental systems[3].Nanotechnology can enable a distributed water reuse and treatment paradigm and offer leapfrogging opportunities to obviate concerns of water quality degradation within distribution networks, alleviate dependence on major system infrastructure, exploit alternative water sources[4].Nanotechnology-enabled water and wastewater treatment promises to not only overcome major challenges faced by existing treatment technologies, but also to provide new treatment capabilities that could allow economic utilization of unconventional water sources to expand the water supply. Nanomaterial have numerous properties, for example, solid adsorption, improved redox, and photo catalytic properties giving extraordinary chances to treat contaminants in water [5]. It is stressed that amid the treatment of water against contaminants utilizing nano material, the accompanying four point of reference conditions ought to be met: (1) condition security, (2) reuse of treatment operators, (3) ease, and (4) high treatment proficiency. The primary highlights for the review and improvement of water medications are plan, blend, and utilization of Nano sorbents, Nano catalysts, redox dynamic nanoparticles, and nanostructures [11].The application of specific nanoparticles either embedded in membranes or on other structural media that can effectively, inexpensively, and rapidly render unusable potable water is being explored at a variety of institutions. Innovative use of Nano particles for treatment of industrial wastewater is another potentially useful application. Many factories generate large amounts of wastewater. Removal of contaminants and reusing of the purified water would provide significant reductions in cost, time, and labor to industry, resulting in an improved environmental stewardship. Groundwater remediation is also a critical issue, becoming more important as water supplies steadily decrease and demand continues to increase. Most of the remediation technologies available today, very often are costly and time-consuming, particularly pump-and-treat methods. The ability to remove toxic compounds from subsurface and other environments that are very difficult to access in situ, and doing so rapidly, efficiently and within reasonable costs is the ultimate goal [11].

2. General Practice

Water refinement is the procedure in which contaminated, recovered, suspicious or potentially messy water experiences different procedures with a specific end goal to make it appropriate for reuse, drinking and for irrigation. Expanding water contamination and abuse, alongside the progressing worldwide water crisis and atmosphere changes, have made water reusing an undeniably famous zone of research and work in the previous decade. The term Water Purification comprises of an extensive variety of treatment and refinement strategies going from basic water boiling, through natural water purification utilizing living beings, for example, fish, plants and microbes, to chemicals, for example, chlorine and iodine. To accommodate this requirement for clean water for modern, farming and residential uses, numerous techniques were created so as to recover, treat and decontaminate water and its sources. The advancements and arrangements vary between the source of contamination and the water source itself [6].

2.1 Desalination

Desalination is a process that removes minerals from saline water. More generally, desalination refers to the removal of salts and minerals from a target substance. Challenges with desalination are its high cost,energy requirement, waste disposal and membrane fouling. Progresses in nanotechnology are giving extraordinary chances to make more cost effective also, earth amicable water decontamination forms. Conventional water treatment techniques are being complimented by new rising advancements. Nanotechnology based new strategies for water desalination are prominent, for example, Nano filtration, sunlight based desalination and layer building [1].

The cost of desalination per produced water volume is somewhat inversely proportional to the production capacity of the plant. Disadvantages of desalination includes:-

1) The procedure of desalination requires pretreatment and cleaning chemicals, which are added to water before desalination to make the treatment more productive and fruitful. These chemicals incorporate chlorine, hydrochloric corrosive and hydrogen peroxide, and they can be utilized for just a restricted measure of time. Once they've lost their capacity to clean the water, these chemicals are dumped, which turns into a noteworthy ecological concern. These chemicals frequently discover their way once again into the sea, where they harm plant and creature life.
2) Brackish water (brine) is the side result of desalination. While the filtered water goes ahead to be handled and put into human utilize, the water that is left over, which has a super saturation of salt, must be discarded. Most desalination plants pump this salt water again into the sea, which introduces another natural downside. Sea species are not prepared to adjust to the quick change in saltiness brought on by the arrival of saline solution into the region. The super-soaked salt water additionally diminishes oxygen levels in the water, bringing on creatures and plants to choke [1].
3) Desalination is not an idealized innovation, and desalinated water can be destructive to human wellbeing also. By-results of the chemicals utilized as a part of desalination can get into the "unadulterated" water and imperil the general population who drink it. Desalinated water can likewise be acidic to both funnels and stomach related frameworks.

2.2 Decontamination

Decontamination is the way toward purifying a substance to expel contaminants, for example, small scale living beings or dangerous materials, including chemicals, radioactive substances, and irresistible diseases. Three basic methods of decontamination are physical removal, chemical deactivation, and biological deactivation of the agent. Biological deactivation has not been developed to the point of being practical. Decontamination of casualties is an enormous task. The process requires dedication of both large numbers of personnel and large amounts of time [1].Even with appropriate planning and training the requirement demands a significant contribution of resources.

Disadvantages of decontamination includes: Chemically inert materials, e.g., coke deposits cannot be removed. Severely fouled or fully plugged equipment will require mechanical cleaning since the circulation of chemical cleaning liquids would be impossible or so limited as to render the chemical cleaning less effective. Corrosion or equipment damage during chemical cleaning is generally low, but severe damage can occur if improper procedures are applied or unskilled personnel are employed in the application process. A variety of chemical and non-chemical decontamination technologies are available Selection of the best one suited for a specific application requires a site-specific and project- specific cost benefit analysis Even in some cases decontamination may only be of marginal benefit and must be carefully considered.

2.3 Disinfection

Disinfection is a process in which most or about all microorganisms on clothing, hard surfaces, or potentially wounds are killed using chemicals, warmth, or ultraviolet rays. Disinfection gives a beam of hope for battling against the water-borne irresistible operators in drinking water. Normally utilized disinfectants for treating drinking water are chlorine, ozone, Chloro-amine and chlorine dioxide. A few waterborne pathogens have been decimated and evacuated by disinfectants but yet at the same time the utilization of disinfectants is not working as new pathogens grab hold in water, and disinfection byproducts (DBPs) formed are harmful [1]. Disinfection byproducts produced by disinfectants: Chlorine reacts with organic contaminants and humic acid, forming a chlorinated product. This product, with other halogens, produces halogenated DBPs such as halo acetonitriles and iodo acetic acid, which are toxic and carcinogenic [1, 14, 15, 16].Ozone and chlorine dioxide produces the oxygenated species of DBPs [1,14], Chloro amine introduces nitrogen species such as cyanogens chloride as by-products[1,14].Disinfectants are dangerous waste. They contain halogenated mixes. Most disinfectants contain an abundance of natural safety level of 0.01 percent of the halogenated mixes. This makes it hard for disinfectants to be arranged as common waste. Actually, a few disinfectants are considered as risky, as well as harmful. Amyl phenol is a case of a dangerous and unsafe disinfectant

3. Applications of Nanotechnology

Nanotechnology provides filters and membranes that are made from different nanomaterials such as CNTs, dendrimers, nanoporous ceramics, nanofibers, zeolites and nano-sponges. These nanomaterials offer high porosity, active sites for metal binding, and a small size, regeneration after exhausting and faster removal of contaminants [1, 17, 18]. Nanotechnology based applications may enable us to boost drinking water by refined filtration mechanisms (carbon nanotube (CNT)membranes)[1,20,23] advanced detoxification of menacing pollutants(zero-valent iron NPs); detection of impurities and pathogens by nano-sensors, catalytic degradation of water pollutants by titanium dioxide NPs, nano-porous polymers, nano-porous zeolites for water treatment; and magnetic NPs for water purification and remediation[19].

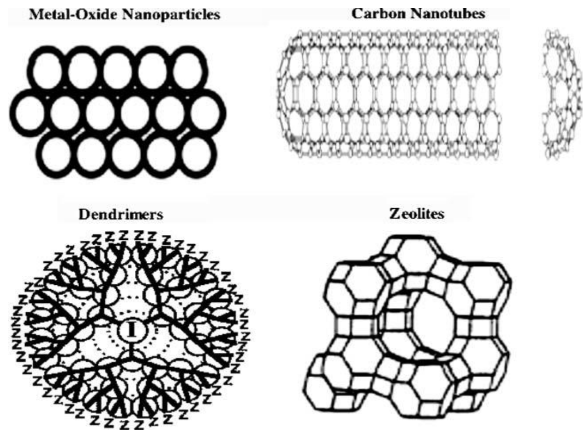

Figure1: Different nanomaterials used for water purification [2]

Figure above highlights four classes of nanoscale materials that are being assessed as practical materials for water decontamination: (1) metal-containing nanoparticles, (2) carbonaceous nanomaterials, (3) zeolites and (4) dendrimers. These have a wide scope of physicochemical properties that make them specific appealing as partition and receptive media for water purification.

3.1 Nano-adsorbents

Nano-adsorbents are nano materials for the removal of metallic pollutants from water and waste-water. Nano-adsorbents have two principle properties: natural surface and outside functionalization. Their physical, compound, material properties are additionally identified with their outward surface structure, evident size and inherent organization. Nano-adsorbents are broadly classified into various groups based on their role in adsorption process. It includes metallic nano-particles, nanostructured mixed oxides, magnetic NPs and metallic oxide NPs. nano-adsorbents shows high affinity for the removal of different pollutants such as Cr^{3+} Co^{2+},Ni^{2+},Cu^{2+},Cd^{2+},Pb^{2+} and As^{3+} simultaneously from wastewater[12].

3.2 Nano-catalysts

Nano-catalysts are heterogeneous catalysts broken up into metal nanoparticles in order to speed up the *catalytic* process. There are various kinds of nano-catalysts are employed for wastewater treatment such as photo catalysts , electro catalysts, and Fenton based catalysts for improving chemical oxidation of organic pollutants and antimicrobial actions. During the last decade, titanium dioxide (TiO_2) nano particles have emerged as promising photo-catalysts for water purification.TiO2 nano-particles are very versatile; they can serve both as oxidative and reductive catalysts for organic and inorganic pollutants [2].Photo-catalysts are comprised of semiconductor metals that can degrade variety of persistent organic pollutants in wastewater. Semiconductor nano-catalysts are also highly effective for degradation of halogenated and non-halogenated organic compounds. The mechanism of the working of photo-catalysis is based on the photo-excitation of electron in the catalyst. Results have shown that the use of visible light sensitive N-doped TiO_2 and ZrO_2nanoparticles helped to achieve significant improvements in bio-film and *Escherichia coli* bacteria photo-degradation efficiency [12].

3.3 Carbon Nanotubes

A carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. There are many different types of carbon nano-tubes, but they are normally categorized as either single-walled (SWNT) or multi-walled nano-tubes (MWNT).CNTs have High Electrical Conductivity and very High tensile strength. CNTs are highly flexible. It can be bent considerably without damage. CNTs have High thermal conductivity. CNTs have a low thermal expansion coefficient. CNTs are fascinating in advanced membrane technologies for water desalination since they provide low energy solution for water treatment. CNT membranes provide near frictionless water flow through them with the retention of a broad spectrum of water pollutants. The inner hollow cavity of CNTs provides a great possibility for desalinating water [11].

3.4 Zeolites

Zeolites are microporous, alumino silicate minerals commonly used as commercial adsorbents and catalysts. Zeolites have a porous structure that can accommodate a wide variety of cations, such as Na^+, K^+, Ca^{2+}, Mg^{2+} and others. These positive ions are rather loosely held and can readily be exchanged for others in a contact solution. Some of the common mineral zeolites are analcime, chabazite, heulandite, natrolite, phillipsite and stilbite. Zeolites are widely used as ion-exchange beds in domestic and commercial water purification, softening, and other applications. In chemistry, zeolites are used to separate molecules (only molecules of certain sizes and shapes can pass through), and as traps for molecules so they can be analyzed. Hardness in water is due to the presence of carbonates and bio-carbonates of Calcium or Magnesium (when it is temporary hardness) or sulphates and chlorides of Calcium and Magnesium (when it is permanent hardness).Temporary hardness of water can be removed easily by boiling water or by adding washing soda. Permanent hardness cannot be removed by merely boiling or adding washing soda. A complex salt called sodium aluminium silicate (zeolite) is used to remove permanent hardness in water.

3.5 Dendrimers

Dendrimers are a new class of polymeric materials. They are highly branched, mono- disperse macromolecules. The structure of these materials has a great impact on their physical and chemical properties. The structure of dendrimers molecule begins with a central atom or group of atoms labeled as the core. From this central structure, the branches of other atoms called ‘dendrons’ grow through a chemical reactions. Dendrimers has properties such as poly-valency, self-assembling, electrostatic interactions, chemical stability, low cytotoxicity, and solubility. Dendrimers show some potential to selectively attract contaminants and retain them in their branched structures and due to their large size, to prevent them passing through membranes. Dendrimers could be used to enhance water filtration techniques. Examples of dendrimers that may be used in this type of process include cation-binding dendrimers, anion-binding dendrimers, organic compound-binding dendrimers, biological compound-binding dendrimers, viral-binding dendrimers and combinations of these. An ultrafiltration membrane requires less energy than nano-filtration or reverse osmosis [12].

4. Conclusion

With the overall increase in the demand and need for safe drinking water, it has become a mandatory issue to address the quality of water. Water purification techniques are currently under research to develop cutting edge technologies for better efficiency and efficacy of such systems. Some of the conventional techniques discussed in this paper are desalination, decontamination and disinfection. The challenges faced in the current methods involves high cost and high energy requirements. In recent times, there has been a shift towards design of low-cost systems.

Nanotechnology serves as a valuable tool in building up effective water filtration systems. Nano-based systems offer advantages in terms of porosity, size and cost. Some of the widely used nano-materials presented in this review are carbon-nanotubes, dendrimers, nano-catalysts, nano-adsorbents and zeolites. The major function of these nano-materials is retention of water pollutants. Nano-adsorbents play a vital role in removing metal impurities. Hence, nanotechnology can give a significant contribution towards building more robust water filtration systems.

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