# RECENT TRENDS OF NANOMATERIALS IN ENVIRONMENTAL IMPROVEMENT

**Abstract**

Researchers have recently improved contemporary technology in the area of lowering the phenomena of pollution arising from them using numerous scientific investigations. The key characteristics, such as mechanical, electrical, and optical properties and their relationships, are determined in this chapter along with the preparation techniques for nanomaterials. High-tech methods, such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffractions (XRD), were required for the study of nanomaterials, which can range in size from 1 to 100 nm. The employment of diverse types of devices, such as solar cells for creating clean energy, nanotechnologies in coatings for building exterior surfaces, and sonochemical dye decolorization by the process, results in different applications of nanomaterials in environmental improvement.

**Keywords:** Nanomaterials, Synthesis, Water Purification.

**Authors**

**Trupti B. Shinde**
K. K. Wagh Art's Commerce Science and Computer Science College, Nashik
Affiliated to Savitribai Phule Pune University

**Kailas H. Kapadnis**
Research Centre in Chemistry
MGV’s Loknete Vyankatrao Hire Arts Science & Commerce College, Nashik
Affiliated to Savitribai Phule Pune University

Copyright © 2024 Authors

## I. INTRODUCTION

By manipulating matter between 1 and 100 nm in size and having the capacity to work at the molecular level, atom by atom, to develop huge structures with fundamentally novel molecular organization, nanotechnology refers to the process of creating functioning material devices and systems. Nanotechnology is the creation, processing, and use of nanostructures or nanomaterials as well as a fundamental understanding of the links between physical characteristics or phenomena and the size of materials. It is a brand-new discipline or area of science. A nanometer ($10^{-9}$ m) is one billionth of a meter. These materials have at least one dimension in the nanometer range and contain at least 10 hydrogen or five silicon atoms organised in a straight line, roughly equivalent to 1 nm in length.

The unique optical, magnetic, electrical, and other properties that appear at this size in nanomaterials make them interesting. There is a lot of potential for these emergent qualities to be used in electronics, medicine, and other industries. Nanostructured and nanophase/nanoparticle materials are the two categories of nanomaterials. In contrast to the latter, which are often dispersive nanoparticles, the former relates to condensed bulk materials that are composed of grains with grain sizes in the nanometer size range. A nanoparticle is said to have zero dimensions by this definition if its dimensions are less than 100 nm in length. For instance, although thin films, plates, multilayers, and network nanostructures express two dimensions, wires, rods, and nanofibers have just one dimension. Furthermore, as shown in Figure 1 [2], a sphere or cluster of nanophase materials with zero dimensions is depicted as a point-like particle that is governed by the three dimensions of nanomaterials. Aeronautics, building and construction, chemical industry, optics, solar hydrogen, fuel cells, batteries, sensors, power generation, automotive engineering, consumer electronics, thermoelectric devices, pharmaceuticals, and the cosmetics industry are just a few of the significant applications of nanomaterials [3]. Finding alternative energy sources that are ecologically benign is one of the most urgent concerns of our day. This depends on the usage of nanomaterials in various applications, such as solar cells [4], paints [5], and other uses in the field of green chemistry [6].

## II. PREPARED NANOPARTICLE

The "top-down" and "bottom-up" procedures, as depicted in Figure 1, are the two fundamental methods for producing nanomaterials in a controlled and repeatable manner, either by breaking or dissociating bulk substances into small particles or by assembling or disassembling a few atoms from them. It is crucial to apply this in a variety of application domains, such as engineering, chemistry, physics, and even medical. The use of earlier methods is crucial in contemporary industry and maybe also in nanotechnology. Generally speaking, there are numerous ways to create nanomaterials, including mechanical, chemical, hydrothermal, sol-gel, chemical deposition in vacuum, pyrolysis, combustion, chemical co-precipitation, etc.

These techniques allow for the retrieval of particles with a specific dimensional shape and distribution.

1. **Top-Down:** Mechanical techniques provide the most affordable means to generate nanomaterials in bulk (split the particles into nanostructures) among the physical techniques.

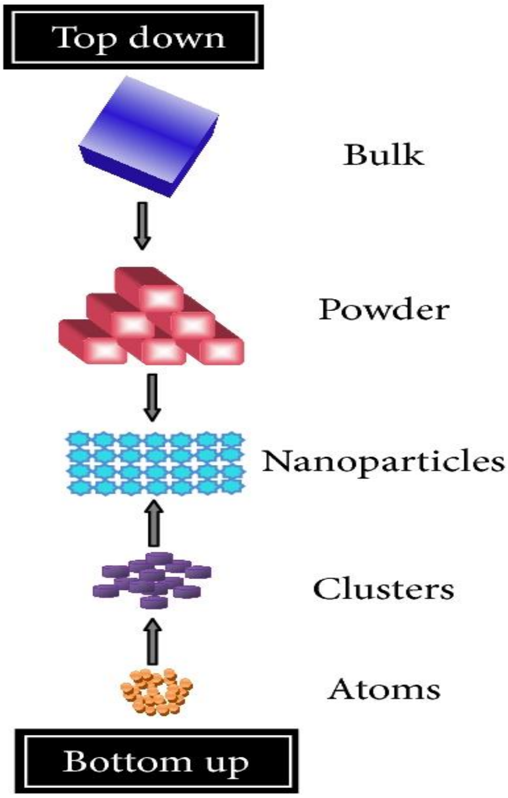


**Figure 1:** The Scheme to Prepare Nanomaterial

However, many chemical production techniques, like anodizing, are common industrial processes and are always simple to scale up [7]. Making nanostructures using a top-down technique involves starting with larger structures and breaking them down to nanoscale to create nanomaterials. This method involves fabricating a huge object that is (2–3) orders larger in one or both dimensions than the required nanoscale, and then using nanopatterning techniques to create tiny features. The microelectronics sector actually invented top-down approaches first and has been using them extensively ever since. Thin film deposition and nanopatterning techniques have progressed, pushing this method deeper into the realm of nanofabrication [8].

2. **Bottom-Up:** The term "bottom-up approach" refers to the process of creating nanostructures from small building blocks like atoms or molecules. The ordering of supramolecular or solid-state designs from the atomic to the mesoscopic scale is accomplished via bottom-up strategies, which employ self-processes. Gas-phase methods and liquid-phase methods are examples of bottom-up techniques. When beginning with a single atom or molecule, two techniques controlled the manufacturing of nanomaterials. Gas-phase techniques include chemical vapour deposition (CVD) and plasma arcing, whereas liquid-phase techniques include sol-gel synthesis, the most widely used technique. In addition, a fresh technique called molecular self-assembly appeared. Nanotechnology is used in a variety of sectors, including photonics, electronics, chemical and biological sensors, energy storage, and catalysis. Functional materials must be created from nanomaterials through manipulation.

## III. NANOTECHNOLOGY APPLICATIONS IN THE ENVIRONMENT

1. **Environmental Nanosensors:** When pollution detection technology is more widely accessible and less expensive, process control, ecosystem monitoring, and environmental decision-making are all increased [9]. The ability of humans to support sustainable human health and the environment is improved by quick and precise sensors that can identify contaminants at the molecular level [10]. A sensor is essentially a type of energy converter that can identify specific physical, chemical, mechanical, or other qualities or events in its environment and output the information as a signal, typically an electrical or optical signal. As a result, numerous sensors have been created in numerous disciplines and found numerous applications. Nanosensors are currently one of the most widely used sensors. Nanosensors are essentially nanoscale chemical, physical, or biological sensors that have extremely high sensitivity and precision for measuring changes at the nanoscale, either qualitatively or quantitatively. The most significant qualities that have contributed to a very high level of confidence in the data collected from sensors and nanosensors are high sensitivity, high detection power, and the capacity to monitor multiple species at once.

2. **Air Pollution:** Air pollution is defined as the introduction of any particle, biological molecule, or hazardous solid, liquid, or gas into the atmosphere that endangers the environment, causes sickness in living things, or has an adverse effect on the ecology of a place. There are two primary and secondary categories for this kind of pollution, which can result from either human activity or the use of natural resources. Primary pollutants include things like carbon monoxide, sulphur and nitrogen oxides, volatile organic compounds, and so on. They are typically produced by a normal activity, like the combustion of fossil fuels, or a natural process, like a volcanic eruption. Contrarily, secondary pollutants are created when main pollutants combine with one another, such as peroxyacetyl nitrate, which is created when nitrogen oxides and volatile organic molecules react [11]. These reactions prevent secondary pollutants from entering the atmosphere directly. Continuous monitoring of air pollution is one of the most crucial and fundamental requirements in connection to environmental pollution control [12]. The development of such sensors drew nearer to the point of scientific use with the creation of the first samples of smart dust [13]. The primary goal of creating smart dust is to create a collection of sophisticated sensors in the form of tiny nanocomputers [14]. These nanosensors can effortlessly float in the air for several hours [15]. These small silicon particles have their own wireless capability and can transmit the data gathered to a central base. The prototypes have a data transfer rate of around one kilobyte per second [16].

3. **Adsoption of Toxic Gases:** Nanotechnology allows for the elimination of environmentally harmful gases. Using CNTs that have been treated with gold or platinum nanoparticles as an example [16]. Carbon atoms are arranged hexagonally in CNTs' surrounding graphene layer, which surrounds the tube axis. CNTs are special molecules having one-dimensional structure, thermal stability, and extraordinary chemical properties that can be either single-walled or multi-walled nanotubes [17]. It has been demonstrated that CNTs have excellent potential as superior adsorbents for the removal of different types of organic and inorganic pollutants from the air and aquatic environments. The porous structure of CNTs and the existence of a variety of functional groups on their

Copyright © 2024 Authors

surfaces, both of which may be altered chemically or thermally to give them the necessary performance, account for the majority of their adsorption capacity.

Different harmful pollutants that are present in the air in industrial locations include benzoene dioxin, benzene, toluene, ethyl benzoene, and xylene [18]. The two benzene dioxin rings and the nanotube's surface are intimately connected. The overlap between the dioxin molecule and the entire surface of the nanotube is also connected by a porous wall with a diameter of 2.9 nm, which raises the pore's potential for adsorption. Additionally, CNTs' excellent resistance to oxidation makes them useful for regenerating adsorbent at high temperatures [19].

4. **Water and Wastewater Treatment:** Ceramic and polymer membranes are currently produced using nanotechnology for water purification [20]. These nanoscale membranes include bio-inspired membranes, organic-inorganic hybrid nanocomposite membranes, and ceramic membranes covered with catalytic and zeolite nanoparticles. Membranes made from biopolymers that incorporate protein molecules, carbon nanotube membranes, and block copolymer membranes with a comparable porosity are all examples of bio-mimic membranes. Based on water permeability, selectivity of contaminating molecules, and mechanical strength, these membranes function better. Despite outstanding performance, biomimetic membranes generally have very little marketing potential. While nanocomposite membranes are now mass-produced and have a high level of water treatment efficiency. There is very limited application for zeolite and catalytic membranes in water treatment, save from slight to moderate enhancements in the functionality of conventional membranes.

5. **Nano Biomaterials:** One of the main drivers for the creation of novel environmental systems with alluring applications has always been the development of new materials [21]. These materials have the ability to remove obstacles from earlier processes, leading to the creation of applications with potential worldwide advantages [22]. Less than 6-10 or 9-10 nanoscale materials (those whose properties may be regulated at a level less than micro) are known as nanoscale materials [23]. Because the characteristics of materials with these dimensions and sizes are radically different from those of traditional materials, research into nanomaterials is gaining momentum every day [24]. Nanoparticles are colloidal, solid particles with complex surface chemistry that range in size from 10,000 to 100 nm and contain macromolecular components. Nanoparticles can be in the shape of nanospheres or nanocapsules, depending on the manufacturing process. Nanospheres and nanocapsules are vesicular and matrix structures, respectively [25]. Nanoparticles called nanocapsules have an outer shell and an empty interior that can store and transport the needed components. In an aqueous medium, phospholipids with hydrophilic and hydrophobic heads combine to create capsules with the hydrophilic head on the exterior and the hydrophobic head on the interior. Nanocapsules can also be created using polymers like lipids and proteins [26].

6. **Porous Nanopolymers:** Water-insoluble solid particles readily take up hydrophobic organic contaminants that are introduced to the soil by water, separating them from the water [27]. The phenomenon of such pollutants' adsorption and disposal from water to soil and from soil to air is extremely complicated and is influenced by a number of variables, including their solubility in water, the presence of water in the soil network,

Copyright © 2024 Authors

and the rivalry between various soil components to absorb these particles [28]. The pollutant molecules bind to the body that has the highest chemical similarity to them when there are multiple hydrophobic molecules present in the environment. Because of this, porous nanopolymers—which resemble pollutant molecules—are the best method for removing this class of organic pollutants from soil and water. The separation of organic contaminants from drinking water and the treatment of industrial unit effluents, such as nuclear power plants, for reuse of treated effluents are the main environmental uses of these nanostructures [29]. water sources that have been cleaned of petroleum contamination. removing organic contaminants from groundwater resources [30]. The expenses of treatment are significantly lower since porous nanopolymers are frequently used [31].

7. **Environmental Catalysts:** One of the most significant water contaminants is halogenated organic compounds (HOCs). Pharmaceuticals is one of the sectors where these chemical compounds are useful as additives and solvents. These substances are toxic and hazardous, and they have been linked to diseases including cancer. Therefore, it is crucial that these chemicals are completely decomposed from water and wastewater [32].Additionally, nanocatalysts made of palladium and magnetite have been created to efficiently remove halogenated organic contaminants from effluents. Palladium/magnetite nanocatalysts function dependably under a range of water conditions, as demonstrated by numerous investigations. Additionally, they benefit from the ability to be recovered using magnetic separation technology from the needed water or effluent [33].

   Major air contaminants include carbon monoxide, hydrocarbons, and nitrogen monoxide. Catalytic converters can lower these pollutants' emissions. The air-to-fuel ratio in modern catalytic converters must match a specific stoichiometry, and these converters require pricey metal catalysts. There is a tremendous need to create low-cost, high-efficiency catalysts because of this [34].

8. **Nano-Coatings:** Modern nanostructured coatings are effective at adhering to many different surfaces, including metals, glass, ceramics, and plastics. The thickness of these coatings is merely a few microns. The enhanced anti-corrosion property of these nano-coatings is their defining characteristic [35]. Therefore, one of the uses for these coatings is to make light metals like aluminium and magnesium more corrosion-resistant [36]. These coatings can endure temperatures of up to 700 degrees Fahrenheit and are extremely heat resistant [37]. By lowering the use of raw resources, this sort of coating will preserve the environment by preventing metal corrosion [38].As a result, the liquid only leaves behind droplets on the covered surface before being quickly removed. The drying process is accelerated by this. It is clear that environmental pollution is avoided and detergent use is significantly decreased [39].

9. **Role of Nanomaterial in the Environment:** Two major environmental applications of nanotechnology can be identified:

   **Nanotechnology-based Environmental Pollution Monitoring:** Continuous monitoring of environmental pollution is one of the most crucial and fundamental requirements in regard to environmental pollution control. Data about the amount of pollution in each place, its type, and how widely it has spread will be gathered, and from there, the best course of action will be decided. In order to control pollution, environmental organisations nowadays have developed environmental rules and standards for businesses and food. It takes a lot of work, effort, and time to continuously regulate pollution-causing sources. These days, nano-sensors enable large-scale, low-cost point-by-point monitoring of the pollution status of the target areas. Nanosensors use less energy, can run for extended periods of time at low voltage without a direct power source, and can wirelessly communicate data [40].

Nanotechnology is being used to reduce environmental pollution, which is the major environmental concern. These pollutants, which have detrimental short- and long-term consequences on the ecosystem and public health, include air, soil, and water contamination. Due to their diversity, it is particularly difficult to remove contaminants from the environment. On the other hand, it's crucial to get rid of pollution where it comes from and the sources of contamination. Numerous techniques have been employed in several nations to lessen environmental contamination of the air, water, and land. By using nanotechnology, it is feasible to minimise soil pollutants, treat industrial and urban effluents as effectively as possible to prevent water pollution, and reduce various air pollutants in cities and industry to a manageable level [41].

## IV. CONCLUSION

The study of how to arrange atoms to generate novel molecular structures and new materials is known as nanotechnology. The classification of nanotechnology into many divisions and disciplines has more to do with how its products are used in each field. The chemical and energy industries can benefit greatly from the application of nanotechnology in these fields. Carbon nanotubes have the ability to selectively absorb gas from a stream of different gases. Nanotubes have the capacity to be employed for a variety of industrial applications, including the removal of environmentally harmful contaminants and toxic gases.Molecular gas sensors can be created and have their performance enhanced using carbon nanotubes. It has already been demonstrated that nanotube sensors could be used to detect several gases, including etc. It is possible to use carbon nanotubes to store hydrogen effectively. These are essentially tiny, low-diameter carbon tubes that are used to store hydrogen in the tiny crevices on the tubes and within the tube structure. The building's performance efficiency can be improved by using fuel cells inside the structure in addition to nanotubes' capacity to store hydrogen.Due to its capacity to function at low pressures, nanofiltration is a membrane technology that is more cost-effective than the RO process. Nanotechnology can be applied to the creation and utilisation of NF and RO membranes. The separation mechanism is the same in both procedures, and the effective dimensions, which are the size of the cavities, are nanoscale in both methods.

## REFERENCES

[1] Zhang ZY, Lagally MG. Atomic processes in the early stages of thin-film growth. Science. 1997;276:377-38
[2] Ngo C, Van de Voorde M. Nanotechnology in a Nutshell. 2014. DOI: 10.2991/978-94-6239-012-6
[3] Srinivasan S, Kannan AM, Kothurkar N, Khalil Y, Kuravi S. Nanomaterials for energy and environmental application. Journal of Nanomaterials. 2016;2015:2. Article ID: 979026
[4] Tala-IghilR. Handbook of Nanoelectrochemistry. 2015.
[5] Claire A, Grégory B, Garidel-Thoron CDE. Painting the future: AMIPAINTnanomaterials and the safer-by-design approach for new markets. SSRN Electronic Journal. 2017. DOI: 10.2139/ ssrn.3033840

[6] Hitesh S. Material today. Science Direct. 2018;5, 1(2):6227-6233for assembling nanocomponents
[7] AroleVM, Munde SV. Fabrication of nanomaterials by top-down and bottom-up
[8] approaches: An overview. JAAST: Material Science. 2014;1(2): 89-93
[9] Guo Z, Tan L. Fundamentals and Applications of Nanomaterials. ARTECH HOUSE 685 Canton Street, Norwood, MA 02062 P.95; 2009
[10] V. Brahmkhatri, P. Pandit, P. Rananaware, A. D'Souza, M.D. Kurkuri
[11] Recent progress in detection of chemical and biological toxins in Water using plasmonic nanosensors.
[12] Trends Environ. Anal.Chem., 30 (2021), 10.1016/j.teac.2021.e00117 T. Rasheed, A.A. Hassan, F. Kausar, F. Sher, M. Bilal, H.M.N. IqbalCarbon nanotubes assisted analytical detection – sensing/delivery cues for environmental and biomedical monitoring.
[13] TrAC Trends Anal. Chem. (Reference Ed.), 132 (2020), 10.1016/j.trac.2020.116066
[14] H. Saleem, S.J. Zaidi, A.F. Ismail, P.S. GohAdvances of nanomaterials for air pollution remediation and their impacts on the environmentChemosphere, 287 (2021), p. 132083, 10.1016/j.chemosphere.2021.132083
[15] R. Sha, T.K. BhattacharyyaMoS2-based nanosensors in biomedical and environmental monitoring applicationsElectrochim. Acta, 349 (2020), p. 136370, 10.1016/j.electacta.2020.136370
[16] G. Mengali, A.A. QuartaHeliocentric trajectory analysis of Sun-pointing smart dust with electrochromic controlAdv. Space Res., 57 (2016), pp. 991-1001, 10.1016/j.asr.2015.12.017
[17] L. Niccolai, M. Bassetto, A.A. Quarta, G. MengaliA review of Smart Dust architecture, dynamics, and mission applicationsProg. Aero. Sci., 106 (2019), pp. 1-14, 10.1016/j.paerosci.2019.01.003
[18] Bałaga, M. Siegmund, M. Kalita, B.J. Williamson, A. Walentek, M. MałachowskiSelection of operational parameters for a smart spraying system to control airborne PM10 and PM2.5 dusts in underground coal minesProcess Saf. Environ. Protect., 148 (2021), pp. 482-494, 10.1016/j.psep.2020.10.001
[19] H. Cui, X. Zhang, D. Chen, J. TangGeometric structure and SOF 2 adsorption behavior of Pt n (n = 1-4) clustered (8 , 0) single-walled CNT using density functional theoryJ. Fluor. Chem., 211 (2018), pp. 148-153, 10.1016/j.jfluchem.2018.04.012
[20] V. Adavan, B. Fugetsu, I. Sakata, Z. Wang, M. EndoJournal of Colloid and Interface Science Aerogels from copper (II) -cellulose nanofibers and carbon nanotubes as absorbents for the elimination of toxic gases from airJ. Colloid Interface Sci., 582 (2021), pp. 950-960, 10.1016/j.jcis.2020.08.100
[21] F. Su, C. Lu, S. HuColloids and surfaces A: physicochemical and engineering aspects adsorption of benzene, toluene , ethylbenzene and p -xylene by NaOCl-oxidized carbon nanotubes, 353 (2010), pp. 83-91, 10.1016/j.colsurfa.2009.10.025
[22] I. Mubeen, S. Tulaphol, L. Shengyong, D. Pan, P. Zhang, M. Sajid, M. Yan,W.R. StevensOnline measurement of 1 , 2 , 4-trichlorobenzene as dioxin indicator on multi-walled carbon nanotubesEnviron. Pollut., 268 (2021), p. 115329, 10.1016/j.envpol.2020.115329
[23] A. Esmaeili, A.A. BeniA novel fixed-bed reactor design incorporating an electrospun
[24] PVA/chitosan nanofiber membraneJ. Hazard Mater., 280 (2014), pp. 788-796, 10.1016/j.jhazmat.2014.08.048
[25] P. Prediger, M. Gurgel, A. Vieira, N. RuthAdsorption of Polycyclic Aromatic Hydrocarbons from Wastewater Using Graphene-Based Nanomaterials Synthesized by Conventional Chemistry and Green Synthesis : A Critical Review 422(2022), 10.1016/j.jhazmat.2021.126904
[26] A. Dey, G. Pandey, D. RawtaniFunctionalized nanomaterials driven antimicrobial food packaging: a technological advancement in food scienceFood Control, 131 (2022), p. 108469, 10.1016/j.foodcont.2021.108469
[27] D. Liu, W. Gu, L. Zhou, L. Wang, J. Zhang, Y. LiuRecent advances in MOF-derived carbon-based nanomaterials for environmental applications in adsorption and catalytic degradationChem. Eng. J., 427 (2022), p. 131503, 10.1016/j.cej.2021.131503
[28] S. Forruque, M. Mofijur, N. Rafa, A. Tasnim, S. Chowdhury, M. Nahrin, A.B.M.S. IslamH. ChyuanGreen approaches in synthesising nanomaterials for environmental nanobioremediation : technological advancements , applications , benefits and challengesEnviron. Res., 204 (2022), p. 111967, 10.1016/j.envres.2021.111967
[29] N. Zhang, J. Li, B. Liu, D. Zhang, C. Zhang, Y. Guo, X. Chu, W. Wang, H. Wang, X. Yan, Z. LiTalanta Signal enhancing strategies in aptasensors for the detection of small molecular contaminants by nanomaterials and nucleic acid amplificationTalanta, 236 (2022), p. 122866, 10.1016/j.talanta.2021.122866
[30] M. Samadzadeh, S.H. Boura, M. Peikari, S.M. Kasiriha, A. AshrafiProgress in Organic Coatings A review on self-healing coatings based on micro/nanocapsules
[31] Prog. Org. Coating, 68 (2010), pp. 159-164, 10.1016/j.porgcoat.2010.01.006

Copyright © 2024 Authors 

[32] K. Karakosta, A.C. Mitropoulos, G.Z. KyzasA review in nanopolymers for drilling fluids applicationsJ. Mol. Struct., 1227 (2021), p. 129702, 10.1016/j.molstruc.2020.129702
[33] S. Ali, R. Al-tohamy,Koutra Moawad, M. Kornaros, A.M. Mustafa, Y.A. Mahmoud, A. Badr, M. E.H. Osman, T. Elsamahy, H. Jiao, J. SunScience of the Total Environment Nanobiotechnological advancements in agriculture and food industry : applications , nanotoxicity , and future perspectivesSci. Total Environ., 792 (2021), p. 148359, 10.1016/j.scitotenv.2021.148359
[34] E.I. El-aswar, H. Ramadan, H. Elkik, A.G. TahaA comprehensive review on preparation , functionalization and recent applications of nanofiber membranes in waste water treatmentJ. Environ. Manag., 301 (2022), p. 113908, 10.1016/j.jenvman.2021.113908
[35] S.A. Younis, H. Ali, J. Lee, K. KimNanotechnology-based sorption and membrane technologies for the treatment of petroleum-based pollutants in natural ecosystems and wastewater streamsAdv. Colloid Interface Sci., 275 (2020), p. 102071, 10.1016/j.cis.2019.102071
[36] S. Aliannejadi, A. Hessam, H. AhmadFabrication and characterization of high-branched recyclable PAMAM dendrimer polymers on the modified magnetic nanoparticles for removing naphthalene from aqueous solutionsMicrochem. J., 145 (2019), pp. 767-777, 10.1016/j.microc.2018.11.043
[37] B. Gao, L. Liu, J. Liu, F. YangA photo-catalysis and rotating nano-CaCO3 dynamic membrane system with Fe-ZnIn2S4 efficiently removes halogenated compounds in waterAppl. Catal. B Environ., 138–139 (2013), pp. 62-69, 10.1016/j.apcatb.2013.02.023
[38] M. Kempasiddaiah, V. Kandathil, R.B. Dateer, M. Baidya, Shivaputra A. Patil, Siddappa PatilEfficient and recyclable palladium enriched magnetic nanocatalyst for reduction of toxic environmental pollutantsJ. Environ. Sci. (China), 101 (2021), pp. 189-204, 10.1016/j.jes.2020.08.015
[39] M. Qu, Z. Cheng, Z. Sun, D. Chen, J. Yu, J. ChenNon-thermal plasma coupled with catalysis for VOCs abatement : a reviewProcess Saf. Environ. Protect., 153 (2021), pp. 139-158, 10.1016/j.psep.2021.06.028
[40] S. Liu, K. Li, Q. Shen, D. Shao, S. Huang, Y. XieApplied Surface Science nanocoatings enhance osteoblastic electrical stimulationAppl. Surf. Sci., 545 (2021), p. 148827, 10.1016/j.apsusc.2020.148827
[41] R. Malhotra, Y. Han, C.A. Nijhuis, N. Silikas, A.H.C. Neto, V. RosaGraphene nanocoating provides superb long-lasting corrosion protection to titanium alloyDent. Mater., 37 (2021), pp. 1553-1560, 10.1016/j.dental.2021.08.004
[42] D. Wang, Y. Li, Y. Wen, X. Li, X. DuColloids and Surfaces A : physicochemical and Engineering Aspects Simple and low cost fabrication of large area nanocoatings with mechanical robustness , enhanced broadband transmittance and antifoggingColloids Surfaces A Physicochem. Eng. Asp., 629 (2021), p. 127522, 10.1016/j.colsurfa.2021.127522
[43] L. Grineviciute, H. Badorreck, L. Jensen, D. Ristau, M. Jup, A. Selskis, T. TolenisApplied Surface Science Impact of Deposition Conditions on Nanostructured Anisotropic Silica Thin Films in Multilayer Interference Coatings 562(2021), 10.1016/j.apsusc.2021.150167

Copyright © 2024 Authors 