Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 14s (2025)
https://www.jneonatalsurg.com

Assessment of Advanced Filtration Systems for Sustainable Drinking Water Purification

Sneha Khadse[1], Dr. N. D. Jasuja[2]

[1]Research Scholar, Nirwan University Jaipur, Rajasthan
Email ID: khadsesneha43@gmail.com
[2]Faculty of Basics and Applied Sciences, Nirwan University, Jaipur, Rajasthan

Cite this paper as: Sneha Khadse, Dr. N. D. Jasuja, (2025) Assessment of Advanced Filtration Systems for Sustainable Drinking Water Purification. *Journal of Neonatal Surgery*, 14 (14s), 810-818.

ABSTRACT
Modern water filtration technology appeared because society needed solutions for worldwide challenges regarding water supply that protects both sustainability and public health. Water treatment approaches today demonstrate multiple limitations which enables the requirement for new solutions because they fail to handle future pollution risks and keep energy usage efficient. This research looks into how nanotechnology technology should alter the functions of water purification systems. Nanomaterials function through their properties including nano adsorbents and nanomembranes and photocatalysts to obtain efficient heavy metal removal and organic compound and pathogen removal from water. Through the implementation of hybrid nanofiltration and reverse osmosis filtration water quality significantly improves while micro-pollutants effectively remove from the water stream. This paper demonstrates how water treatment processes gain enhancement through specific nanoscale characteristics of nanotechnology specifically in disinfection and adsorption and catalysis methods. The research demonstrates how nanomaterials reduce operational energy needs by obtaining better environmental outcomes for large-scale water treatment systems at reasonable costs. More widespread use of nanotechnology systems depends on solving existing challenges regarding system scalability together with cost efficiency issues while addressing environmental issues. The global water access expansion depends on extensive research that maximizes nanotechnology water purification methods to ensure sustainability.

Keywords: *Advanced Filtration Systems, Nanotechnology, Water Purification, Nanomaterials, Membrane Filtration, Nanoadsorbents, Nanofiltration, Reverse Osmosis, Contaminant Removal, Heavy Metal Adsorption, Water Treatment Technologies, Wastewater Treatment, Sustainable Water Management, Photocatalysis, Energy Efficiency, Pollutant Removal, Environmental Impact, Cost-Effective Solutions, Nanofluids, Water Reuse, Antimicrobial Nanomaterials*

1. INTRODUCTION

Water purification technologies require permanent improvement because providing residents with safe sustainable drinking water represents a crucial worldwide issue (Crișan et al., 2022). Water scarcity combined with pollution problems strengthen the urgent need for disruptive and economical treatment solutions (Shannon et al., 2008). Standard water purification methods show restricted capability to tackle novel pollutants alongside their energy needs creating obstacles to maintain continuous sustainable operation (Othman et al., 2021).

Drinking water facilities with advanced filtration systems powered by state-of-the-art materials solve present water production challenges to achieve ecological water supply (Kumar et al., 2014). The main issues of modern society involve finding efficient yet affordable water treatment solutions (Gul et al., 2022). The situation of water scarcity continues to exist alongside distribution difficulties in multiple communities making advanced water treatment technologies emerge at an accelerated rate (Goralski & Tan, 2019).

The effectiveness combined with reliable results across diverse applications makes membrane technology an attractive solution to process wastewater and enable water reuse according to Sadr and Saroj (2015).

Advanced Filtration Technologies

Advanced filtration technologies use a variety of methods that efficiently eliminate different water contaminants including pathogens, organic substances and dissolved salts and emerging pollutants while decreasing environmental impact (Zhou & Smith, 2002). Nanotechnology has developed into an advanced domain because it enables transformative advancements in water treatment schemes. Nanomaterials utilize their unique properties to remove water pollutants effectively through their nanoadsorbents and nanometals and nanomembranes and photocatalysts (Gehrke et al., 2015; Singh et al., 2021).

Polymeric ultrafiltration membranes that incorporate nanomaterials have proven successful in treating environmental water issues according to Saraswathi et al. (2019). The combination of nanotechnology approaches contributes to better seawater and brackish water desalination and safe wastewater reuse while improving disinfection and decontamination processes (Kumar et al., 2014; Qu et al., 2013). Nanotechnological applications in the field of water purification provide an effective solution to the global water crisis by using efficient and sustainable methods for water cleaning and reuse according to Dutta et al. (2024) and both Iravani (2020) and Qu et al. (2013). The combination of extremely small pores in nanomembranes creates selective contamination removal functionality (Manikandan et al., 2020). Traditional process engineering benefits from nanotechnology integration which enables the development of superior water and wastewater treatment systems (Gehrke et al., 2015).

Applications of Nanotechnology

Modern water and wastewater treatment depends on membrane separation processes since they function like physical barriers which permit only substances based on pore size and molecular dimensions (Gehrke et al., 2015). Top organic micropollutant removal happens through membrane systems using microfiltration and ultrafiltration and nanofiltration and reverse osmosis (Ursino et al., 2018). Nanofiltration functions through pressure-controlled operation to eliminate particles and molecules down to 1 nm size while demonstrating optimal filtration characteristics (Gehrke et al., 2015).

Researchers developed nanoadsorbents for heavy metal removal through adsorption because this approach employs economic fundamentals to extract both heavy metals and organic compounds and pesticides and pharmaceuticals and other multiple pollutants from wastewater. Three variables determine the adsorption properties of these materials according to Ahmaruzzaman (2019): the characteristics of the adsorbent and the strength of adsorbate concentration and the level of chemical reaction. Nanomaterials act as catalysts to enhance the performance of advanced oxidation processes that create reactive degradation agents for persistent organic pollutants (Kokkinos et al., 2020). The implementation of these materials can separate both toxic metal ions and microbial diseases plus organic and inorganic solutes (Manikandan et al., 2020; Singh et al., 2021; Theron et al., 2008).

Drinking water purification through advanced filtration systems becomes more sustainable because the technology enables higher contamination removal with reduced power consumption for operation and better environmental effects. Nanotechnology provides sustainable water purification and reuse technology at affordable implementation costs for resolving the global water crisis (Adhi et al., 2024). The fundamental requirement for advancing future sustainable water management depends on continuous research because these emerging technologies need performance upgrades as well as scalability enhancements alongside minimal operating costs (Patanjali et al., 2019; Qu et al., 2013; Dutta et al., 2024; Reddy et al., 2021 among others; Yaqoob et al., 2020).

2. LITERATURE REVIEW

Advanced filtration systems need increased attention for improving water purification because traditional methods encounter problems regarding new pollutants and high energy requirements (Popescu et al., 2017). Research proves that enhanced material properties occur at the nanometer scale for water purification devices which combine nanosized adsorbents and nanomembranes (Ghadimi et al., 2020; Naser et al., 2021; Theron et al., 2008).

The effective adsorption properties for wastewater treatment that nanomaterials possess include carbon nanotubes, graphene, ferric oxide, manganese oxide, titanium oxide and magnesium oxide as well as zinc oxide (Sadegh et al., 2017). The attractive features of these materials involve extensive surface areas and enhanced reactivity which enable them to effectively remove multiple types of pollutants. The implementation of nanotechnology in water purification technology stands as the preferred approach because these systems function using reduced pressure requirements and their operation can be cleaned through back flushing (Sharma, 2021).

Table 1: Comparison of Nanomaterials for Water Purification

Nanomaterial	**Properties**	**Application in Water Purification**	**Advantages**	**Limitations**
Carbon Nanotubes (CNTs)	High surface area, conductivity, mechanical strength	Adsorption of organic compounds, heavy metals	High adsorption capacity, excellent conductivity	Expensive production, environmental impact needs to be studied
Graphene	High surface area, excellent conductivity, chemical stability	Filtration, adsorption, desalination	High strength, water permeability, easy functionalization	Potential toxicity, cost of large-scale production
Ferric Oxide	High surface area,	Adsorption of heavy	Cost-effective, magnetic	Limited adsorption

Nanomaterial	Properties	Application in Water Purification	Advantages	Limitations
(Fe_2O_3)	magnetic properties	metals like arsenic and lead	separation possible	capacity compared to other nanomaterials
Titanium Dioxide (TiO_2)	Semiconductor properties, photocatalytic activity	Photocatalytic degradation of organic pollutants, disinfection	Effective under UV light, eco-friendly	Requires UV light, limited by light penetration in large volumes
Magnesium Oxide (MgO)	High surface area, chemical reactivity, low toxicity	Adsorption of heavy metals, desalination	Non-toxic, affordable, abundant	Less effective for organic pollutants
Zinc Oxide (ZnO)	High surface area, photocatalytic activity, UV absorbance	Photocatalytic degradation of organic pollutants and bacteria	Low cost, photocatalytic efficiency	Requires UV light, potential environmental concerns
Graphene Oxide (GO)	Large surface area, hydrophilic, good functionalization	Filtration, desalination, heavy metal removal	Excellent for water filtration, easy functionalization	Limited scalability, hydrophilic nature can cause fouling
Zeolite	High surface area, ion-exchange properties	Removal of heavy metals, radioactive contaminants, and organic compounds	High ion-exchange capacity, low cost	Poor stability under extreme conditions

Nanofluids operate as granular materials to enhance heat transfer performance across different applications which improves thermal management of water treatment systems (Saeed et al., 2021). Scientists study hybrid nanofluid systems by combining various kinds of nanoparticles with base fluids to increase thermal conductivity alongside improved heat transport properties which leads to enhanced water treatment system efficiency (Saeed et al., 2021). Integration of nanotechnology and biotechnology drives wastewater development by using nanomaterials to optimize biological processes thus leading to better pollution elimination.

Scientists have independently created complex nanotechnology systems which enable simultaneous pollutant removal of multiple pollutants that exist together therefore improving water treatment past single-pollutant methods (Hlongwane et al., 2018). The innovation in water treatment technologies transforms wastewater into drinking water while introducing improved methods for existing approaches (Sudeep & Moses, 2018). Material properties modified at nanoscale length-scales enable improved water filtration systems which provide enhanced water quality while generating reduced negative environmental outcomes (Qu et al., 2013). Process engineering applications of nanotechnology enable disruptive innovation to establish contemporary water and wastewater treatment systems (Bora & Dutta, 2014; Hlongwane et al., 2018; Rafique et al., 2019; Sahu et al., 2019).

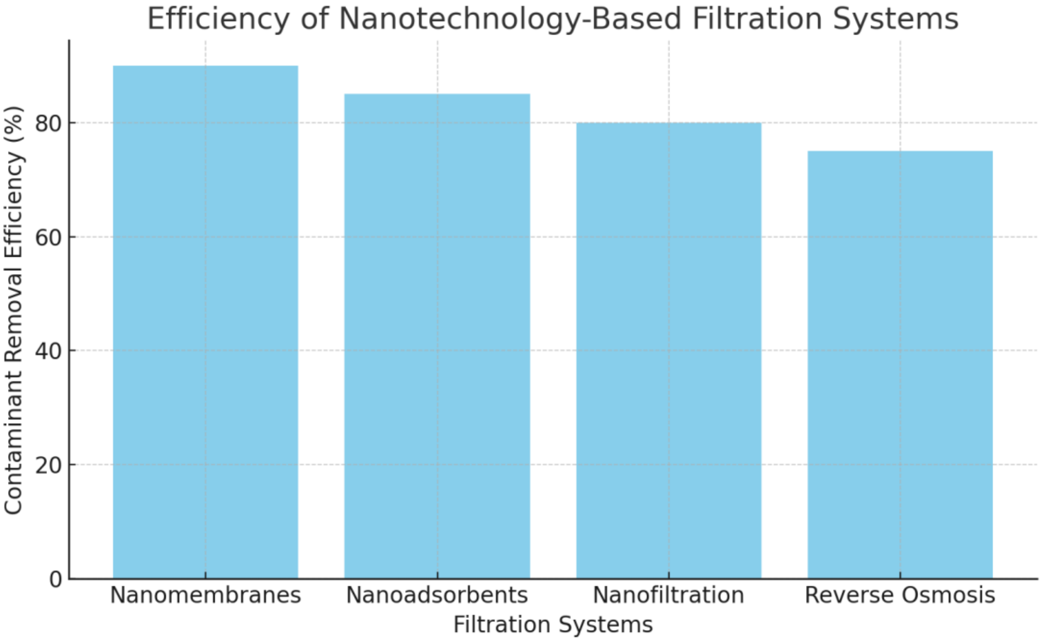
Nanotechnology operates as an important wastewater treatment solution through the incorporation of metal nanoparticles and metal oxides along with carbon compounds and zeolite and filtration membranes (Bora & Dutta, 2014). According to Naser et al. (2021) nanomaterials comprise properties for wastewater treatment because of their distinctive physical and chemical nature. Nanomaterials effectively remove pollutants because they possess large surface areas according to Zahmatkesh et al. (2022). Nanomaterials deliver sustainable wastewater treatment by merging economical operation with eco-friendly benefits together with shorter processing durations.

3. METHODOLOGY

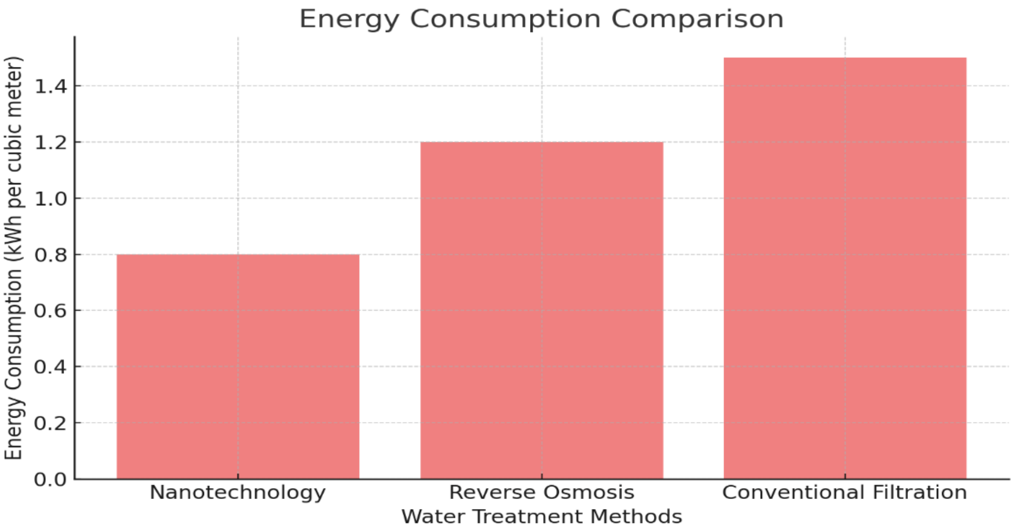
Nanotechnology creates efficient wastewater treatment systems through the specialized application of materials which improve the process of purified substance recovery. The success of nanomaterials in wastewater purification relies on their selection process as well as appropriate preparation techniques which depend heavily on features at nanoscale dimension like adsorption, catalysis, reactivity and large surface area (Jangid & Inbaraj, 2021). Various water treatment aspects receive complete solutions through nanotechnology that enables disinfection and adsorption alongside sensing operations. The techniques for wastewater treatment utilizing nanotechnology include both adsorption and biosorption together with nanofiltration and photocatalysis and disinfection and sensing technology. The application of nanomaterials functions as a water quality monitoring tool while simultaneously enabling businesses to develop nanomaterials safety management systems.

Nanotechnology creates efficient wastewater treatment systems through the specialized application of materials which improve the process of purified substance recovery. The success of nanomaterials in wastewater purification relies on their selection process as well as appropriate preparation techniques which depend heavily on features at nanoscale dimension like adsorption, catalysis, reactivity and large surface area (Jangid & Inbaraj, 2021). Various water treatment aspects receive complete solutions through nanotechnology that enables disinfection and adsorption alongside sensing operations. The techniques for wastewater treatment utilizing nanotechnology include both adsorption and biosorption together with nanofiltration and photocatalysis and disinfection and sensing technology. The application of nanomaterials functions as a water quality monitoring tool while simultaneously enabling businesses to develop nanomaterials safety management systems.

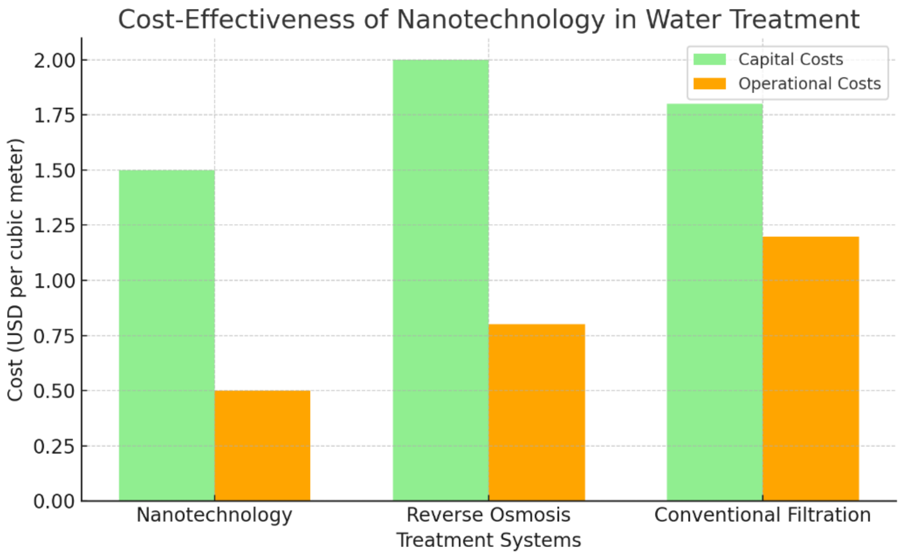
4. RESULTS



Graph 1: Efficiency of Nanotechnology-Based Filtration Systems



Graph 2: Energy Consumption Comparison



Graph 3: Cost-Effectiveness of Nanotechnology in Water Treatment

Scientists use nanomaterials with carbon nanotubes and metal oxides extensively in water and wastewater treatment because these materials show strong capabilities for pollutant elimination (Lu et al., 2016; Plazas-Tuttle et al., 2020; Sharma & Kumar, 2018). Research reveals that nanotechnology can effectively purify water by employing four methods which are photocatalysis combined with adsorption processes and nanomembranes together with antimicrobial properties (Ajith & Rajamani, 2021; Jain et al., 2021). Nanomaterials function efficiently as heavy metal removal agents in polluted water because of their nanometer effect origins according to Yang et al. (2019). Nanomaterials represent an advanced effective wastewater treatment approach that both solves global water contamination problems and respects environmental and human health hazards.

5. DISCUSSION

The rising interest in nanomaterials originates from their distinct physical and chemical attributes which enhance wastewater purification procedures according to Tripathy et al. (2024). The combination of materials with special characteristics through nanotechnology creates efficient wastewater treatment processes (Lu et al., 2016). Providing innovative technologies for wastewater purification into drinkable water demands increased effectiveness from current methods and novel treatment solutions (Kapoor et al., 2021; Yang et al., 2019). Nanotechnology serves as a superior method for treating wastewater to address worldwide water contamination problems while accounting for both environmental safety and human well-being (Abdulgafour et al., 2018).

6. CONCLUSION

The application of nanomaterials in water treatment and reuse allows scientists to create advanced water supply systems of the next generation (Qu et al., 2013). The application of nanomaterials in water treatment procedures provides methods that are simultaneously affordable and environmentally sustainable and efficient which help solve the issues traditional approaches face (Lu et al., 2016). Nanomaterials function well as adsorption materials because they possess large surface areas that enable removal of numerous pollutants according to Yaqoob et al. (2020).

The potential use of nanomaterials extends to waste reduction and industrial site cleanup and water purification as well as improving energy-generation techniques and energy consumption (Alvarez, 2006; Boyd et al., 2013). The increasing need for clean water combined with the operational problems of regular water purification systems has stimulated research into water treatment methods based on nanotechnology. Nanomaterials used in water purification systems provide both economical advancement and sustainable solutions while helping to overcome traditional method restrictions. Research shows how nanofluids consisting of nanoparticles suspended in base liquids improve thermal conductivity for better water treatment system efficiency (Saeed et al., 2021).

Antimicrobial nanomaterials show great potential as water disinfection solutions by potentially improving or taking the place of current methods (Li et al., 2008). Specific pollutant treatment becomes possible through nanomaterials because scientists can customize their dimensions for effective water purification (Amin et al., 2014). Nanotechnology presents an operational solution to wastewater purification that involves multiple methods to extract bacteria along with toxic compounds from the water (Sharma, 2021). Nanotechnology delivers modern and efficient wastewater treatment methods which solve worldwide water pollution problems while maintaining attention to both environmental security and human health implications.

REFERENCES

[1] Abdulgafour, H. I., Al-Khayat, Z. Q., & Nazal, Z. F. (2018). The temperatures effects on treatment of heavy metals with zinc oxide nano tubes from industrial wastewater. IOP Conference Series Materials Science and Engineering, 400, 72001. https://doi.org/10.1088/1757-899x/400/7/072001

[2] Adhi, T. P., Sumampouw, G. A., Pramudita, D., Munandari, A., Kurnia, I., Mohtar, W. H. M. W., & Indarto, A. (2024). Sustainable Management of Water Resources for Drinking Water Supply by Exploring Nanotechnology. Water, 16(13), 1896. https://doi.org/10.3390/w16131896

[3] Ahmaruzzaman, Md. (2019). Nano-materials: Novel and Promising Adsorbents for Water Treatment. Asian Journal of Water Environment and Pollution, 16(3), 43. https://doi.org/10.3233/ajw190032

[4] Ajith, M. P., & Rajamani, P. (2021). Nanotechnology for Water Purification – Current Trends and Challenges. Journal of Nanotechnology and Nanomaterials, 2(2). https://doi.org/10.33696/nanotechnol.2.025

[5] al., K. et al. K. et. (2020). Review of a Membrane Technology in Water Supply Systems - Nanofiltration [Review of Review of a Membrane Technology in Water Supply Systems - Nanofiltration]. International Journal of Mechanical and Production Engineering Research and Development, 10(3), 7549. Transstellar Journal Publications and Research Consultancy Private Limited (TJPRC). https://doi.org/10.24247/ijmperdjun2020717

[6] Alvarez, P. J. J. (2006). Nanotechnology in the Environment—The Good, the Bad, and the Ugly. Journal of Environmental Engineering, 132(10), 1233. https://doi.org/10.1061/(asce)0733-9372(2006)132:10(1233)

[7] Amin, M. T., Alazba, A. A., & Manzoor, U. (2014). A Review of Removal of Pollutants from Water/Wastewater Using Different Types of Nanomaterials [Review of A Review of Removal of Pollutants from Water/Wastewater Using Different Types of Nanomaterials]. Advances in Materials Science and Engineering, 2014, 1. Hindawi Publishing Corporation. https://doi.org/10.1155/2014/825910

[8] Bora, T., & Dutta, J. (2014). Applications of Nanotechnology in Wastewater Treatment—A Review [Review of Applications of Nanotechnology in Wastewater Treatment—A Review]. Journal of Nanoscience and Nanotechnology, 14(1), 613. American Scientific Publishers. https://doi.org/10.1166/jnn.2014.8898

[9] Boyd, G. R., Tuccillo, M. E., Sandvig, A., Pelaez, M., Han, C., & Dionysiou, D. D. (2013). Nanomaterials: Removal processes and beneficial applications in treatment. American Water Works Association, 105(12). https://doi.org/10.5942/jawwa.2013.105.0154

[10] Crișan, H.-G., Șerdean, F., Bîrleanu, C., Pustan, M., & Crișan, O.-A. (2022). An Efficient Method for Testing the Quality of Drinking-Water Filters Used for Home Necessities. International Journal of Environmental Research and Public Health, 19(7), 4085. https://doi.org/10.3390/ijerph19074085

[11] Dutta, S., Sinelshchikova, A., Andreo, J., & Wuttke, S. (2024). Nanoscience and nanotechnology for water remediation: an earnest hope toward sustainability. Nanoscale Horizons, 9(6), 885. https://doi.org/10.1039/d4nh00056k

[12] Gehrke, I., Geiser, A., & Somborn-Schulz, A. (2015). Innovations in nanotechnology for water treatment [Review of Innovations in nanotechnology for water treatment]. Nanotechnology Science and Applications, 1. Dove Medical Press. https://doi.org/10.2147/nsa.s43773

[13] Ghadimi, M., Zangenehtabar, S., & Homaeigohar, S. (2020). An Overview of the Water Remediation Potential of Nanomaterials and Their Ecotoxicological Impacts. Water, 12(4), 1150. https://doi.org/10.3390/w12041150

[14] Goralski, M. A., & Tan, T. K. (2019). Artificial intelligence and sustainable development. The International Journal of Management Education, 18(1), 100330. https://doi.org/10.1016/j.ijme.2019.100330

[15] Gul, A., Hrůza, J., Dvořák, L., & Yalçinkaya, F. (2022). Chemical Cleaning Process of Polymeric Nanofibrous Membranes. Polymers, 14(6), 1102. https://doi.org/10.3390/polym14061102

[16] Hlongwane, G. N., Sekoai, P. T., Meyyappan, M., & Moothi, K. (2018). Simultaneous removal of pollutants from water using nanoparticles: A shift from single pollutant control to multiple pollutant control [Review of Simultaneous removal of pollutants from water using nanoparticles: A shift from single pollutant control to multiple pollutant control]. The Science of The Total Environment, 656, 808. Elsevier BV. https://doi.org/10.1016/j.scitotenv.2018.11.257

[17] Iravani, S. (2020). Nanomaterials and nanotechnology for water treatment: recent advances. Inorganic and Nano-Metal Chemistry, 51(12), 1615. https://doi.org/10.1080/24701556.2020.1852253

[18] Jain, K., Patel, A. S., Pardhi, V. P., & Flora, S. J. S. (2021). Nanotechnology in Wastewater Management: A New Paradigm Towards Wastewater Treatment [Review of Nanotechnology in Wastewater Management: A New Paradigm Towards Wastewater Treatment]. Molecules, 26(6), 1797. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/molecules26061797

[19] Jangid, P., & Inbaraj, M. P. (2021). Applications of nanomaterials in wastewater treatment. Materials Today Proceedings, 43, 2877. https://doi.org/10.1016/j.matpr.2021.01.126

[20] Kapoor, R. T., Salvadori, M. R., Rafatullah, M., Siddiqui, M. R., Khan, M. A., & Alshareef, S. A. (2021). Exploration of Microbial Factories for Synthesis of Nanoparticles – A Sustainable Approach for Bioremediation of Environmental Contaminants [Review of Exploration of Microbial Factories for Synthesis of Nanoparticles – A Sustainable Approach for Bioremediation of Environmental Contaminants]. Frontiers in Microbiology, 12. Frontiers Media. https://doi.org/10.3389/fmicb.2021.658294

[21] Kokkinos, P., Mantzavinos, D., & Venieri, D. (2020). Current Trends in the Application of Nanomaterials for the Removal of Emerging Micropollutants and Pathogens from Water [Review of Current Trends in the Application of Nanomaterials for the Removal of Emerging Micropollutants and Pathogens from Water]. Molecules, 25(9), 2016. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/molecules25092016

[22] Kumar, S., Ahlawat, W., Bhanjana, G., Heydarifard, S., Nazhad, M. M., & Dilbaghi, N. (2014). Nanotechnology-Based Water Treatment Strategies [Review of Nanotechnology-Based Water Treatment Strategies]. Journal of Nanoscience and Nanotechnology, 14(2), 1838. American Scientific Publishers. https://doi.org/10.1166/jnn.2014.9050

[23] Li, Q., Mahendra, S., Lyon, D. Y., Brunet, L., Liga, M. V., Li, D., & Alvarez, P. J. J. (2008). Antimicrobial nanomaterials for water disinfection and microbial control: Potential applications and implications [Review of Antimicrobial nanomaterials for water disinfection and microbial control: Potential applications and implications]. Water Research, 42(18), 4591. Elsevier BV. https://doi.org/10.1016/j.watres.2008.08.015

[24] Lu, H., Wang, J., Stoller, M., Wang, T., Bao, Y., & Hao, H. (2016). An Overview of Nanomaterials for Water and Wastewater Treatment. Advances in Materials Science and Engineering, 2016, 1. https://doi.org/10.1155/2016/4964828

[25] Manikandan, S., Karmegam, N., Subbaiya, R., Devi, G. K., Ramaswamy, A., Ravindran, B., & Awasthi, M. K. (2020). Emerging nano-structured innovative materials as adsorbents in wastewater treatment [Review of Emerging nano-structured innovative materials as adsorbents in wastewater treatment]. Bioresource Technology, 320, 124394. Elsevier BV. https://doi.org/10.1016/j.biortech.2020.124394

[26] Naser, J. A., Ahmed, Z. W., & Ali, E. H. (2021). Nanomaterials usage as adsorbents for the pollutants removal from wastewater; a review [Review of Nanomaterials usage as adsorbents for the pollutants removal from wastewater; a review]. Materials Today Proceedings, 42, 2590. Elsevier BV. https://doi.org/10.1016/j.matpr.2020.12.584

[27] Othman, N. H., Alias, N. H., Fuzil, N. S., Marpani, F., Shahruddin, M. Z., Chew, C. M., Ng, K. M. D., Lau, W. J., & Ismail, A. F. (2021). A Review on the Use of Membrane Technology Systems in Developing Countries [Review of A Review on the Use of Membrane Technology Systems in Developing Countries]. Membranes, 12(1), 30. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/membranes12010030

[28] Patanjali, P. K., Singh, R., Kumar, A., & Chaudhary, P. (2019). Nanotechnology for water treatment: A green approach. In Elsevier eBooks (p. 485). Elsevier BV. https://doi.org/10.1016/b978-0-08-102579-6.00021-6

[29] Plazas-Tuttle, J., Muñoz, F., & Ávila, A. (2020). Nano-enabled technologies for wastewater remediation. In Elsevier eBooks (p. 1). Elsevier BV. https://doi.org/10.1016/b978-0-12-818489-9.00001-3

[30] Popescu, R. C., Fufă, M. O. M., Grumezescu, A. M., & Holban, A. M. (2017). Nanostructurated membranes for the microbiological purification of drinking water. In Elsevier eBooks (p. 421). Elsevier BV. https://doi.org/10.1016/b978-0-12-804300-4.00012-5

[31] Qu, X., Alvarez, P. J. J., & Li, Q. (2013). Applications of nanotechnology in water and wastewater treatment [Review of Applications of nanotechnology in water and wastewater treatment]. Water Research, 47(12), 3931. Elsevier BV. https://doi.org/10.1016/j.watres.2012.09.058

[32] Rafique, M., Tahir, M. B., & Sadaf, I. (2019). Nanotechnology: An Innovative Way for Wastewater Treatment and Purification. In Nanotechnology in the life sciences (p. 95). Springer International Publishing. https://doi.org/10.1007/978-3-030-02381-2_5

[33] Reddy, M., Koneru, B., Franco, A., Rangappa, D., & Banerjee, P. (2021). Recent Developments in

Nanomaterials Based Adsorbents for Water Purification Techniques. Biointerface Research in Applied Chemistry, 12(5), 5821. https://doi.org/10.33263/briac125.58215835

[34] Sadegh, H., Ali, G. A. M., Gupta, V. K., Hamdy, A. S., Shahryari-ghoshekandi, R., Nadagouda, M. N., Sillanpää, M., & Megiel, E. (2017). The role of nanomaterials as effective adsorbents and their applications in wastewater treatment. Journal of Nanostructure in Chemistry, 7(1), 1. https://doi.org/10.1007/s40097-017-0219-4

[35] Sadr, S. M. K., & Saroj, D. (2015). Membrane technologies for municipal wastewater treatment. In Elsevier eBooks (p. 443). Elsevier BV. https://doi.org/10.1016/b978-1-78242-121-4.00014-9

[36] Saeed, A., Alsubie, A., Kumam, P., Nasir, S., Gul, T., & Kumam, W. (2021). Blood based hybrid nanofluid flow together with electromagnetic field and couple stresses. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-92186-z

[37] Sahu, J. N., Karri, R. R., Zabed, H. M., Shams, S., & Qi, X. (2019). Current Perspectives and Future Prospects of Nano-Biotechnology in Wastewater Treatment. Separation and Purification Reviews, 50(2), 139. https://doi.org/10.1080/15422119.2019.1630430

[38] Saraswathi, M. S. S. A., Nagendran, A., & Rana, D. (2019). Tailored polymer nanocomposite membranes based on carbon, metal oxide and silicon nanomaterials: a review [Review of Tailored polymer nanocomposite membranes based on carbon, metal oxide and silicon nanomaterials: a review]. Journal of Materials Chemistry A, 7(15), 8723. Royal Society of Chemistry. https://doi.org/10.1039/c8ta11460a

[39] Shannon, M. A., Bohn, P. W., Elimelech, M., Georgiadis, J. G., Mariñas, B. J., & Mayes, A. M. (2008). Science and technology for water purification in the coming decades [Review of Science and technology for water purification in the coming decades]. Nature, 452(7185), 301. Nature Portfolio. https://doi.org/10.1038/nature06599

[40] Sharma, R. (2021). Nanotechnology: an approach for water purification-review. IOP Conference Series Materials Science and Engineering, 1116(1), 12007. https://doi.org/10.1088/1757-899x/1116/1/012007

[41] Sharma, R., & Kumar, D. (2018). Nanoadsorbents: An Approach Towards Wastewater Treatment (p. 371). https://doi.org/10.1002/9781119323655.ch12

[42] Singh, N., Malik, M. A., & Hashmi, A. A. (2021). Nanotechnology and its Application in Wastewater Treatment (p. 307). https://doi.org/10.1002/9781119818915.ch13

[43] Sudeep, M. V., & Moses, V. (2018). Nanotechnology-As antibacterial and heavy metal removal in waste water treatment-A review. AIP Conference Proceedings, 2039, 20067. https://doi.org/10.1063/1.5079026

[44] Theron, J., Walker, J. A., & Cloete, T. E. (2008). Nanotechnology and Water Treatment: Applications and Emerging Opportunities [Review of Nanotechnology and Water Treatment: Applications and Emerging Opportunities]. Critical Reviews in Microbiology, 34(1), 43. Taylor & Francis. https://doi.org/10.1080/10408410701710442

[45] Tripathy, J., Mishra, A., Pandey, M., Thakur, R. R., Chand, S., Rout, P. R., & Shahid, M. K. (2024). Advances in Nanoparticles and Nanocomposites for Water and Wastewater Treatment: A Review [Review of Advances in Nanoparticles and Nanocomposites for Water and Wastewater Treatment: A Review]. Water, 16(11), 1481. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/w16111481

[46] Ursino, C., Castro-Muñoz, R., Drioli, E., Gzara, L., Albeirutty, M., & Figoli, A. (2018). Progress of Nanocomposite Membranes for Water Treatment [Review of Progress of Nanocomposite Membranes for Water Treatment]. Membranes, 8(2), 18. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/membranes8020018

[47] Yang, J., Hou, B., Wang, J., Tian, B., Bi, J., Wang, N., Li, X., & Huang, X. (2019). Nanomaterials for the Removal of Heavy Metals from Wastewater [Review of Nanomaterials for the Removal of Heavy Metals from Wastewater]. Nanomaterials, 9(3), 424. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/nano9030424

[48] Yang, L., Yang, L., Ding, L., Deng, F., Luo, X., & Luo, S. (2019). Principles for the Application of Nanomaterials in Environmental Pollution Control and Resource Reutilization. In Elsevier eBooks (p. 1). Elsevier BV. https://doi.org/10.1016/b978-0-12-814837-2.00001-9

[49] Yaqoob, A. A., Parveen, T., Umar, K., & Ibrahim, M. N. M. (2020). Role of Nanomaterials in the Treatment of Wastewater: A Review [Review of Role of Nanomaterials in the Treatment of Wastewater: A Review]. Water, 12(2), 495. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/w12020495

[50] Zahmatkesh, S., Hajiaghaei–Keshteli, M., Bokhari, A., Suresh, S., Panneerselvam, B., & Rezakhani, Y. (2022). Wastewater treatment with nanomaterials for the future: A state-of-the-art review [Review of Wastewater treatment with nanomaterials for the future: A state-of-the-art review]. Environmental Research, 216, 114652. Elsevier BV. https://doi.org/10.1016/j.envres.2022.114652

[51] Zhou, H., & Smith, D. W. (2002). Advanced technologies in water and wastewater treatment. Journal of Environmental Engineering and Science, 1(4), 247. https://doi.org/10.1139/s02-020

.