NANOTECHNOLOGY FOR SUSTAINABLE WATER RESOURCES

Edited By
Ajay Kumar Mishra and Chaudhery Mustansar Hussain

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Nanotechnology for Sustainable Water Resources
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The main purpose of nanotechnology is to improve and develop materials, devices, and systems with fundamentally different properties by exploiting unique properties of molecular and supramolecular systems at the nano level. Nearly all the tools have inspired every field of science and technology, and the ideas of nanotechnology and innovation it brings continues to be made in medical technology, lab-on-a-chip, sensor technology, energy resources, and environmental protection and preservation. The continuous use of nanotechnology and nanomaterials in most of the disciplines is beginning to mature. This current book introduces the reader to the use of nanotechnology to preserve water resources, improve water quality and the social inferences therein that may affect approval or extensive usage.

Nanomaterials are nano-sized structures and have extraordinary physical and chemical properties, such as the unique optical, electrical, thermal, magnetic and adsorption characteristics, etc, due to their ultra-small size. Large specific surface areas of nanomaterials can improve the detection sensitivity and miniaturize the devices. In addition, these nanomaterials of various compositions and morphologies provide powerful tools for improving water quality. Therefore, the nanomaterials-based techniques can play vital roles in many water resources. Moreover, freedom to functionalize the nanomaterials with various chemical groups can also increase their affinity toward target contaminants, which is very much desirable for selective cleaning and detection of target contaminants in urban and industrial waters. In this book, we will summarize recent progresses due to novel nanomaterials for sustainable water resources.

The present book has been divided into four sections. Part 1: “Nanotechnology for Natural Resources” contains the details of preservation of natural resources especially water and long-term sustainable development. Recently, nanomaterials and polymer nanocomposites are researched as one of the prime materials for sustainable development. This section is an overview of the latest development and potential that nanotechnology has generated for water resources. Part 2: “Nano Sensor as Tools for Water Resources” has been described where sensors can be deployed as a standalone unit. One of its creators says that the technology
may one day be adapted for use in deployable water chemistry labs and could help scientists working in pollution cleanup operations. This section presents nanosensors to detect contaminations in water at concentration levels of significance to human health and regulatory compliance. Part 3: “Nanoseparation Techniques for Water Resources” describes the separation technologies and capabilities including a range of techniques, test environments, and related expertise to separate different waste fractions in a form in which they can be used effectively for other applications or disposed of. The techniques range from membrane technologies electrochemically assisted nutrient recovery to sludge treatment and hydrothermal carbonization. Finally, Part 4: “Sustainable Future with Nanotechnology” where water has been presented as core sustainable development and is very critical for environment, healthy ecosystems, and for human survival itself. It is vital to reduce the global burden of disease and improving the health, welfare, and productivity of populations. It is central to the production and preservation of a host of benefits and services for people. Water is also at the heart of adaptation to climate change, serving as the crucial link between the climate system, human society, and the environment. Overall, this book provides a summary of the state-of-the-art knowledge to scientists, engineers, and policy maker, about recent developments in nanotechnology and the sustainable water resources arena. Moreover, up-to-date knowledge on the economy, toxicity, and regulation related to nanotechnology have been presented in detail. In the end, the role of nanotechnology for green and sustainable future has also been briefly discussed.

Ajay Kumar Mishra and Chaudhery Mustansar Hussain
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Part I

NANOTECHNOLOGY FOR NATURAL RESOURCES
Application of Nanotechnology in Water Treatment, Wastewater Treatment and Other Domains of Environmental Engineering Science – A Broad Scientific Perspective and Critical Review

Sukanchan Palit

Department of Chemical Engineering, University of Petroleum and Energy Studies Dehradun, Uttarakhand, India

Abstract
Industrial wastewater treatment and drinking water treatment are today witnessing immense scientific challenges. Global vision towards environmental protection and ecological biodiversity has urged the scientific domain to move towards newer innovations and technologies. In this chapter, the author focuses on the research pursuit in nanotechnology in environmental engineering, the vast domain of membrane science and the future trends in water and wastewater treatment. The cornerstones of this chapter are the areas of research pursuit in desalination, advanced oxidation processes, and water treatment. Human civilization and human scientific endeavor are today highly challenged as environmental protection ushers in a new era in science and engineering. Membrane science is opening up new windows of innovation. This chapter delineates the vast scientific success, the scientific landscape and the scientific potential behind nanofiltration and application of nanotechnology in industrial pollution control and water treatment.

Keywords: Water, nanotechnology, vision, desalination, membranes

Corresponding author: sukanchan68@gmail.com; sukanchan92@gmail.com
1.1 Introduction

Science and engineering in today’s visionary world are moving at a vast and drastic pace. Ecological imbalance, global climate change and environmental engineering concerns have geared the scientific domain to yearn for newer realms and surpass visionary frontiers. Man’s wide vision, mankind’s definitive prowess and civilization’s progress will lead a long way in the true emancipation of environmental and energy sustainability. Environmental sustainability today stands in the crossroads of drastic challenges and deep introspection. In such a crucial juncture, application of nanotechnology in water and wastewater treatment is of utmost importance in the future progress of environmental engineering science. This treatise delineates with cogent insight the success of environmental sustainability, the research pursuit of nanotechnology in environmental engineering and the future trends in research areas of water and wastewater treatment. Membrane science and other tertiary treatments such as advanced oxidation processes stands as a major backbone of this scientific research endeavour. The challenge, the vision and the purpose of this treatise widely observes the success of application of nanotechnology in water and wastewater treatment and also discusses the visionary avenues in the field of nanofiltration and other membrane separation processes. The world of engineering science is moving forward towards a newer visionary eon. The challenge of this treatise discusses certain critical scientific questions in membrane science such as fouling phenomenon and the immense scientific barriers linked with it. The world of environmental engineering science and the wide domain of nanotechnology are passing through a challenging phase. Nanotechnology today is surpassing visionary boundaries. The author skillfully attempts with immense foresight the recent trends and future path of scientific endeavour in the field of water and wastewater treatment specifically the domain of application of nanotechnology. This treatise widely observes the success of application of membrane science in the wide avenues of environmental engineering science. A new chapter in the history of application of membrane science is revealed with every step of human life.

Environmental engineering science today stands in the midst of deep introspection and immense crisis. The fate of environment in our human civilization is at an immense distress. March of human civilization today has become retrogressive. Chemical process engineering and environmental engineering are witnessing newer challenges and vast and versatile innovations. Mankind and its scientific research pursuit in the field of water and wastewater treatment need to be re-envisioned with each step of human life. Environmental concerns, the deep challenges of industrial
pollution control and widespread ecological imbalance have brought a new revolutionary change in global scientific research pursuit. The author with cogent insight observes and informs to the wider scientific audience the world of challenges in the success of application of nanotechnology in water and wastewater treatment. The challenge and the vision need to be re-envisioned with each step of human life and each stride of scientific endeavour. Environmental concerns, environmental degradation and the success of environmental sustainability will lead a long way in the true emancipation of science and engineering today.

1.2 The Vision of the Study

The vision behind this well-informed study is wide and versatile. Science and engineering in today’s human civilization and human realm are moving at a drastic pace. Industrial pollution control and environmental degradation are the burning issues facing the scientific domain today [33, 34]. The vision and the challenge need to be readdressed at each step of human scientific research pursuit. Ecological imbalance and success of application of environmental engineering tools will lead a long way in the true emancipation and true realization of environmental sustainability. The vision of this treatise is wide and versatile. The author skillfully delineates the immense success of application of nanotechnology in water and wastewater treatment and the future realization of environmental sustainability. In this treatise, the author also discusses the application of advanced oxidation processes and other non-traditional techniques of wastewater treatment. This area of scientific pursuit is termed as tertiary treatment of industrial wastewater. The other visionary area of endeavour is novel separation processes especially membrane separation processes. Desalination and water treatment are the vexing and enigmatic areas of scientific research endeavour. The vision and purpose of this study widely revisits the murky depths of membrane science and technology. The main areas of thrust in this study are microfiltration and ultrafiltration, both are unexplored and robust areas of membrane science [33, 34].

Providing clean and affordable water to meet human needs is a formid-able challenge of the twenty-first century. Globally, water supply struggles to keep up with the fast growing demand, which is aggravated by immense population growth, global climate change and water quality deterioration. Science of groundwater quality needs re-envisioning. The need for technological innovation to address integrated water quality management cannot be overstated. Globally, a revamping of integrated water quality
management system is the need of the hour. This discussion covers can-
didate nanomaterials, properties and mechanisms that enable the applica-
tions, advantages and limitations as compared with existing processes, and
difficulties and research needs for commercialization. This vision and the
immense scientific candour will lead a long way in the true realization of
environmental sustainability [33, 34].

1.3 The Need and the Rationale of the Study

The world of environmental engineering science and chemical process
engineering today stands in the midst of deep introspection and unimag-
inable challenges. Global water shortage and water crisis have plunged
human civilization to murky depths. The author pointedly attempts to
bring forward to the scientific domain the immense potential of applica-
tion of nanotechnology in water and wastewater treatment. The visionary
prowess of mankind, man’s immense vision and the progress of science
are all the torchbearers towards a greater realization of environmental
sustainability. Global water challenges are the backbone of this vast and
versatile study. Scientific vision and deep scientific understanding are
the pillars of human scientific research pursuit today. The immense need,
the rationale and the importance of this study are to discuss the future
of global water crisis and its alleviation with the help of novel environ-
mental engineering techniques and novel separation processes. Novel
separation processes connote to membrane science. Non-traditional
environmental engineering techniques imply the advanced oxidation
processes. The author pointedly focuses on these two broad areas of
science [33, 34].

Science and technology are moving fast in today’s human civilization.
The road to success is arduous and groundbreaking. Global water crisis,
grave concerns for environment and the cause for scientific validation
will go a long way in the true emancipation of environmental sustain-
ability. The challenge and the vision of science are immense and awe-
some. Environmental protection has a definite cause and vision today.
The rationale of the study unfolds a newer beginning and moves towards
the path of a visionary era of science. Engineering is witnessing one par-
adigmatic shift after another. Global water initiatives are the need of the
hour due to growing concerns over provision of pure drinking water.
The success of human scientific endeavour should reach all people.
Thus, the imminent need of a global water research and development
initiative [33, 34].
1.4 The Scope of the Study

The scope of this visionary study is wide and purposeful. Global water crisis and the concerns of environmental sustainability are witnessing drastic challenges. This study envisions the wide applications of membrane science and advanced oxidation processes to the water and wastewater treatment. In today’s world, technological vision is opening up new vistas of scientific research endeavour. The other facet of this study is to open up new avenues of scientific application of nanotechnology in water and wastewater treatment. The challenge is immense, yet the vision is wide. The author with deep intuition focuses on the application of nanofiltration and other vistas of nanotechnology in water and wastewater treatment. Science and engineering are moving at a rapid pace in this century. Sustainable development is of immense concern. The cause of energy and environmental sustainability need to be re-addressed and re-envisioned at each step of human scientific endeavour. This treatise opens up new challenges and new directions in the futuristic applications of nanotechnology to tackle global water issues.

1.5 Environmental Sustainability, the Vision to Move Forward and the Immense Challenges

Technological and scientific visions are at their helm in today’s scientific generation. Global concern for climate change, the ecological imbalance and the scientific urge to excel are all the pallbearers towards a greater emancipation of environmental sustainability. Water science and water technology in today’s scientific world are linked by an unsevered umbilical cord. Today’s science is a colossus without a definite will of its own. The challenges of environmental engineering techniques are immense today. Industrial water pollution control stands in the midst of deep introspection today. The vision to move forward is arduous and requires immense scientific understanding and scientific astuteness. Environmental sustainability is the backbone of environmental paradigm today. Scientific vision needs to be immensely re-envisioned with the alleviation of global water shortage and global water crisis.

1.6 Water and Wastewater Treatment – The Scientific Doctrine and Immense Scientific Cognizance

The science of water and wastewater treatment needs to be re-envisioned at each step of scientific endeavour. The scientific doctrine and immense
scientific cognizance are paving the path towards a new visionary future. Membrane science and technology is the only answer to the intricate problems of global water crisis and industrial water pollution control. The scientific vision, the scientific fortitude and the scientific astuteness are the pallbearers towards a greater understanding of membrane science. Nanotechnology and its application in water and wastewater treatment are surpassing wide visionary frontiers. The advancement of science and engineering in today’s world is unimaginable. Scientific truth and scientific fortitude need to be re-envisioned and re-addressed at each step of scientific pursuit. This well-informed and well-observed treatise discusses the difficulties and barriers of the applications of nanotechnology in drinking water and industrial wastewater treatment. The challenge of human scientific research pursuit and scientific vision is awesome. In a similar manner, the scientific doctrine and scientific cognizance of nanotechnology and nanofiltration are gaining immense grounds in the wide horizon of chemical process engineering.

1.6.1 Nanotechnology and Drinking Water Treatment

Nanotechnology in today’s scientific world has an unsevered umbilical cord with drinking water treatment. Human civilization and human scientific endeavour are in today’s world moving towards a newer direction. Green chemistry applications, the success of nanotechnology and the visionary world of membrane science will lead a long and positive way in deep emancipation of water science and technology. Provision of clean drinking water stands in the midst of deep crisis. Global water shortage and climate change are the bane of present day human civilization. The author with deep and cogent insight brings to the scientific forefront the intricacies of nanotechnology applications in drinking water treatment. Industrial wastewater treatment is another wide facet of this present scientific endeavour. Technological vision is at its helm at each step of human scientific research pursuit. Drinking water treatment and industrial water pollution control today stand in the midst of deep comprehension and introspection. The challenge of nanotechnology applications in drinking water treatment is veritably widening the scope of science and technology.

1.6.2 Nanotechnology and Industrial Wastewater Treatment

Industrial wastewater treatment is a burning issue in today’s human civilization. The grave concerns of environmental engineering catastrophes have urged human scientific endeavour to gain immense grounds in its path