Recent Advances in Green Nanotechnology and the Vision for the Future

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Abstract
Nanotechnology today is moving from one visionary paradigm towards another. Green synthesis and green nanotechnology are a totally integral part of the domain of sustainable nanotechnology. According to the Brundtland Commission Report, sustainability can be defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Humankind’s immense scientific prowess, scientific advancements and futuristic vision will all lead to a long and visionary way towards the true realization of sustainable development. The challenges, vision and intricacies of scientific endeavors in green nanotechnology are opening new windows of innovation in nanoscience and nanotechnology as a whole. Nanotechnology for green innovation—green nanotechnology—aims for products and processes that are safe, energy efficient, reduce industrial wastes and lessen greenhouse gas emission. This chapter delves deep into the murky depths of scientific vision and scientific innovation in green synthesis and green nanotechnology. Green nanotechnology veritably and definitely addresses global water shortage and drinking water issues. The authors repeatedly address the issue of drinking water provision and heavy metals and arsenic groundwater contamination. Other areas of scientific endeavors are nanotechnology-based water treatment problems, better and more efficient renewable energy technologies, environmental and waste remediation and

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the application of nanotechnology in sustainable production. This chapter targets the wide and visionary domain of environmental sustainability and its vital and pivotal need in a nation's growth.

*Keywords:* Nanotechnology, green, synthesis, sustainability, process, advances

### 1.1 Introduction

Science and technology are moving at a rapid pace today. Environmental engineering science is witnessing drastic changes. In a similar manner, nanotechnology and green nanotechnology are moving from one visionary paradigm towards another. Environmental regulations, frequent environmental catastrophes and loss of ecological biodiversity have urged the scientific community to move forward towards a newer vision and newer innovations. Green nanotechnology is the frontier of science and engineering today. Human civilization's immense scientific prowess, wide futuristic vision and vast scientific and academic rigor all lead along a long and visionary path towards the true realization and emancipation of green nanotechnology. In this chapter, the authors focus deeply on recent scientific endeavors and scientific advances in the field of green nanotechnology with the sole objective of furthering science and engineering. Today the domain of nanotechnology needs to be re-envisioned and redefined with scientific rigor. The vision and challenge of environmental engineering science and nanotechnology are broadly combined in the evolution of a new branch of scientific endeavor known as green nanotechnology. This chapter also focuses on global water issues—mainly heavy metal groundwater contamination and subsequent remediation. Scientific research pursuit today is replete with vision and scientific profundity. The authors in this chapter have strived to open new windows into innovation in the field of green nanotechnology, which will continue to take place in decades to come.

### 1.2 The Objective of this Study

Today the scientific vision of nanotechnology, green nanotechnology and green synthesis are surpassing wide and visionary scientific frontiers. Technological vision and scientific validation are today's foundation stones of scientific endeavors in the field of nanotechnology and green nanotechnology. The endeavors in this chapter are replete with deep scientific contemplation and scientific introspection. Global nanotechnology applications
and their health risks are challenging the scientific landscape, hence the importance of green synthesis, green nanotechnology and green chemistry. This chapter pointedly focuses on the recent scientific research pursuits in green nanotechnology, especially on the vast domain of groundwater remediation and its vision for the future. Today global nanotechnology initiatives are targeted towards green chemistry, sustainable chemistry and green engineering. The vast scientific potential of green nanotechnology is delineated with scientific precision in this chapter. Deep scientific understanding, wide scientific contemplation and the vision of green science and technology are the basic foundations of this well-observed chapter [1, 2].

1.3 The Rationale for this Study

The rationale for this study surpasses vast scientific imagination and deep scientific discernment. Technology is moving at a rapid pace today. The global water shortage, frequent environmental disasters and stringent regulations have urged the scientific and engineering communities to be geared towards a newer visionary era of green technology. Today, humankind stands in the midst of a global water crisis. Heavy metal and arsenic groundwater contamination are the vexing issues of this century. Thus, the need for this well-observed study. Technological vision and scientific motivation are greatly needed as civilization wearily trudges a scientific path in this century. Scientific comprehension, the deep scientific avenues of this century and a futuristic vision are the forerunners of the recent emancipation of green nanotechnology today. Groundwater remediation and prevention of arsenic and heavy metal drinking water contamination are the futuristic vision of this chapter. Scientific success, scientific potential and wide scientific forbearance are of utmost importance as science and engineering moves into the second half of this visionary century. The rationale of this study goes beyond scientific imagination and scientific fortitude. Humankind and scientific endeavor today stands in the midst of deep vision and contemplation. Today green nanotechnology is a burgeoning area of science. This study pointedly focuses on the vast applications of green nanotechnology with the sole aim of furthering science and engineering.

1.4 What is Meant by Green Nanotechnology?

Today, nanotechnology can alleviate major sustainability issues. Sustainable development is the utmost need of the hour. The framework of green
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nanotechnology involves the production and processes to make nanomaterials, green chemistry, green engineering, direct and indirect environmental applications; and also encompasses the production of nanomembranes, nanocatalysts and the greater emancipation of harnessed energy. Broadly speaking, green nanotechnology refers to the use of nanotechnology to enhance the environmental sustainability of processes, producing verifiable negative externalities [1, 2]. It also encompasses the use of products of nanotechnology to enhance sustainability. It includes green nanoproducts and using nanoproducts in support of sustainability. Technological challenges, deep scientific vision and scientific insight are the pivotal elements of scientific rigor in green nanotechnology today. Green nanotechnology has been described as having a major pivotal role in the development of clean technologies.

1.5 The Scientific Doctrine and Truth Behind Nanotechnology Applications

Today, nanotechnology needs immense scientific vision and deep scientific forbearance. Green engineering and green science are the order of today’s scientific research pursuits. Scientific doctrine, scientific truth and futuristic vision are all forerunners to a greater emancipation of green nanotechnology. The water shortage crisis is challenging the scientific fabric of today. Heavy metal and arsenic groundwater contamination are changing the face of civilization and the scientific endeavor of humans. The doctrine of the science of green nanotechnology and nanotechnology needs to be re-envisioned and redefined with every step of human life today. Technological vision and scientific validation are reframing the world of green nanotechnology and sustainable chemistry. The vision of environmental and energy sustainability and its immediate needs are forerunners to a greater realization of environmental engineering science today. Environmental engineering and green nanotechnology are the two opposite sides of the visionary coin.

Today scientific doctrine and scientific cognizance are the pathway to newer scientific regeneration and rejuvenation. Global water challenges and environmental engineering issues are veritably changing the face of scientific research pursuits today. Arsenic and heavy metal groundwater contamination are the vexing issues of scientific empowerment today. Technological validation and scientific vision are the definite rules of today’s scientific research pursuit. Human civilization’s immense scientific rigor, the academic rigor behind today’s environmental engineering research and
the wide avenues of nanotechnology will all lead along a long and visionary path towards the true emancipation and realization of green nanotechnology and green chemistry. Scientific innovation and scientific advancements are on the pathway to immense rejuvenation and forbearance. This chapter emphasizes the success of application of green nanotechnology with the sole objective of furthering science and engineering [1, 2].

1.6 Recent Research Pursuit in the Field of Nanotechnology

Nanotechnology and nanoscience are the revolutionary avenues of scientific endeavor. The challenge and vision of science and engineering need to be redefined and re-envisioned in relation to scientific history and scientific vision with the passage of time. Today nanotechnology is the visionary domain of scientific research pursuit. The vision and challenge of this domain will be to open new windows of innovation in the field of nanotechnology in years to come.

The European Commission Report of 2011 [3] clearly discusses successful European nanotechnology research. According to the report, nanotechnology is an outstanding science and technology endeavor which matches the future needs of society. The fruits of nanotechnology are vast and versatile and cross visionary scientific frontiers. Nanotechnology is the new frontier of science and technology in Europe and around the world. Validation of nanoscience and nanotechnology are of utmost importance in the future of scientific and academic rigor. Setting up appropriate methodologies is a relevant and uphill task in the future of nanotechnology [3]. This report gives a sharp glimpse into the application of nanotechnology in energy and the environment, electronics and ICT, industrial applications, textiles, nanomaterials, nanomedicine and a wider approach towards ethical, legal and social aspects [3]. The avenues of nanotechnology are far-reaching and well-researched today. Technology barriers need to come down as nanoscience enters a newer era [3].

The United States Environmental Protection Agency White Paper of 2007 [4] provides a deep insight into mainly the environmental benefits of nanotechnology. Technology and engineering science are surpassing vast scientific boundaries. Humankind’s immense scientific prowess is redefined as engineering and technology that ushers in a newer era in the field of nanotechnology. The authors touch upon the environmental benefits of nanotechnology, risk assessment of nanomaterials, EPA’s research needs for nanomaterials and future recommendations [4]. The vision of
nanotechnology, the futuristic vision of science and the world of academic and scientific rigor will lead to the true realization of environmental protection and nanotechnology. The science of nanotechnology according to this report needs to be veritably re-envisioned and readdressed with the passage of scientific history and time.

1.7 Scientific Endeavors in the Field of Green Nanotechnology

Green technology and sustainability engineering are the path to immense scientific regeneration and scientific forbearance. Today, the avenues of scientific endeavor are ushering in a newer visionary era in green nanotechnology. Global water issues, global drinking water crisis and groundwater contamination by heavy metals are challenging the wide scientific frontier. This chapter pointedly focuses on the immense scientific vision and forbearance needed in the pursuit of green technology research.

Nanotechnology for green innovation was widely redefined by OECD Science, Technology and Industry Policy Paper No. 5 (2013) [5]. This paper brings together widespread and vital information collected through discussions and projects undertaken by the OECD Working Party on Nanotechnology (WPN), which is absolutely relevant to the development and use of nanotechnology for green sustainable development and vast innovation [5]. The aim and objective of this paper is to provide background information for future work by the WPN on the application of nanotechnology for green engineering and innovation. Green nanotechnology is today ushering in a new era in the furtherance of science and technology [5]. Technological vision, scientific motivation and vast academic rigor are forerunners to a greater emancipation of nanoscience and nanotechnology. Humankind today is in a state of immense scientific distress due to vast challenges. In their paper, the authors gleaned the tremendous challenges, deep scientific crisis and the success of nanoscience and nanotechnology today. The entire treatise is divided into three sections; 1) a thorough introduction to nanotechnology, 2) strategies for green innovation and green engineering through nanotechnology, and 3) the impact of green nanotechnology [5]. The immediate need for sustainable development of affordable and safe methods of addressing global challenges in areas, such as energy, the environment and health, has never been so pressing as in this century. Energy and environmental sustainability are the pillars and pivotal elements of today’s scientific and engineering endeavors [5]. The global demand for energy is expected to
increase by more than 30% between 2010 and 2035 [5]. More than 800 million people throughout the world are currently without proper access to drinking water. Such challenges have changed the scientific mindset of scientists, engineers, policymakers and politicians in developed and developing economies. Scientific self-control and deep insight are the supports of a larger vision for a greater emancipation of green nanotechnology [5]. Green innovation targets the reduction of environmental impacts by increasing energy efficiency, reducing waste or greenhouse gas emissions and by minimizing the consumption of nonrenewable raw materials. Scientific research pursuits in green nanotechnology are today ushering in a new era of sustainable development and green engineering. The technology and science of green nanotechnology and engineering are highly advanced today. Scientific success, a visionary path and overcoming obstacles will all go a long way towards environmental sustainability and environmental engineering science today. Since it began its work in 2007, the OECD Working Party on Nanotechnology (WPN) developed a number of feasible projects addressing emerging and far-reaching policies of science, technology and innovation related to the cogent development of nanotechnology [5]. Nanotechnology of green innovation, or green nanotechnology, aims for wide-ranging scientific products and processes that are immensely safe, energy efficient, reduce waste and deeply lessen greenhouse gas emissions. Technological validation is of utmost importance in the progress of scientific and academic rigor. The WPN treatise widely researches the success of green nanotechnology and the authors pointedly focus on the immense scientific potential and deep scientific vision behind green engineering [5].

Karn and Bergeson [6] clearly present thoughtful insights into the immense promises and uncertainties in the vast world of green nanotechnology today. The technology and engineering science of nanoscience and nanotechnology are highly advanced today, ushering in a new technological era [6]. Green nanotechnology today is redefining the world of success in the field of application of nano-enabled products to human society. The article of Karn and Bergeson describes green nanotechnology and discusses the many feasible reasons why traditional chemical assessment and management approaches may not be enough in the pursuit of scientific research [6].

A project report by the Woodrow Wilson International Center for Scholars [7] describes green nanotechnology with immense clarity. Technological advancements, the vision to move forward and the targets of science will all lead towards the true realization of nanotechnology for green innovations [7]. In this report, clean and green nanotechnology,
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Nano-enhanced green technology and the global green nanopolicy are well observed. According to this report, the principles of green chemistry encompass prevention of waste, design of safer chemicals, design of less hazardous materials and less hazardous process syntheses. Also, this wide scientific frontier involves use of catalysts, avoids chemical reagents, maximizes atom economy and visualizes reuse of used products. Green chemistry also involves the minimization of the potential of accidents and the success of chemical process safety. This paper rigorously points out the scientific success and the deep scientific forbearance behind green nanotechnology [7]. Scientific vision is in a state of immense distress today as science and technology moves forward. The challenge of this research pursuit goes beyond scientific imagination and opens up new areas of endeavor and vision. This insightful report investigates the endeavors of research and educational institutions in North America [7].

Nath and Banerjee [8] provide clear insight into the success of green nanotechnology and its interfaces with medical biology. The development of eco-friendly technologies in material synthesis is of vital importance to extend their biological and biomedical applications. Today, technological splendor and depth are in a state of immense regeneration due to newer thoughts [8]. Their review highlights the classification of nanoparticles, giving vital emphasis to the biosynthesis of metal nanoparticle by viable organisms [8]. The science of nanoparticles is always growing and crossing visionary boundaries. Biomedical engineering is also surpassing far-reaching scientific frontiers today. Technological validation and profundity are of utmost need as green nanotechnology ushers in a new era in the field of nanoscience and nanotechnology. This treatise also focuses on the applications of the biosynthesized nanoparticles in a wide spectrum of potential areas of medical biology, including catalysis, targeted drug delivery, cancer treatment, antibacterial agents and as biosensors [8]. Nanomaterials, with characteristic dimensions in the range of 1–100 nm, are at the leading edge of the scientific research pursuit in nanotechnology [8]. Nano vision and nanotechnology, especially metal nanoparticles, have received immense scientific interest in diverse fields of applied science, ranging from materials science to biotechnology. Because of the extremely small size and high surface volume ratio of nanoparticles, the physicochemical properties of nanoparticles-containing materials are quite different to those of the bulk materials. Scientific vision and scientific forbearance are the pillars of scientific research pursuit today. The authors touched upon classification of nanoparticles such as liposomes, superparamagnetic nanoparticles, fullerenes such as buckyballs and carbon nanotubes, dendrimers, quantum dots and liquid crystals [8]. The authors rigorously dealt with synthesis of metal
nanoparticles by traditional physical and chemical methods. The methods encompass laser ablation, inert gas condensation, sol-gel method, hydrothermal synthesis, and a wide range of colloidal methods. The authors also described bio-inspired green nanomaterial synthesis [8].

Virkutyte and Varma [9] intently discussed green synthesis of metal nanoparticles with more research forays into biodegradable polymers and enzymes in stabilization and surface functionalization. Engineering science and technology of green synthesis are ushering in a new era of scientific vision and scientific sagacity. Current scientific breakthroughs in green nanotechnology are intensely capable of transforming many of the existing processes and diverse products that enhance environmental quality, reduce pollution, and conserve natural resources. Science is moving through difficult terrains today. Scientific research avenues, the futuristic vision and the intense academic rigor of metal nanoparticles and biodegradable polymers are opening up new avenues of scientific and engineering research pursuit today [9].

Schwarz [10] presented a clear discussion of green nanotechnology with its tremendous vision and scientific forbearance. Nanotechnology has recently been identified along with principles of sustainability and with “green agenda” [10]. Schwarz's paper discusses and argues that deeper lying societal and cognitive structures are at work to target the true realization and true emancipation green nanotechnologies [10]. Green nanotechnology is today understood as a boundary concept in which wide and disparate discourses are dealt with immense scientific vision. This treatise also pointedly focuses on green nanotechnology and sustainability with the sole objective of furtherance of science and engineering. His paper gives a wider view of the relevance of green nanotechnology in the German-speaking countries in Europe. Green nanotechnology today is replete with scientific vision and encompasses technological validation and scientific fortitude [10].

Yehia et al. [11] dealt with immense lucidity the structural and magnetic properties of nanocrystalline spinel ferrite powders. These are synthesized by a novel green nanotechnology derivative of the sol-gel method. Nickel ferrite (NiFe$_2$O$_4$) has an inverse spinel structure. The science of nanotechnology and its wide scientific vision are documented with forbearance and deep scientific understanding in this treatise [11].

Shawkey et al. [12] presented an immensely insightful discussion of green nanotechnology and the anticancer activity of silver nanoparticles using *Citrullus colocynthis* aqueous extracts. Green nanotechnology and biotechnology are the two opposite sides of the visionary coin today. Green synthesis of metal nanoparticles is a growing research avenue because of
their potential applications in nanomedicines [12]. The science of nanomedicines is wide-ranging and far-reaching. The green synthesis of silver nanoparticles (SNPs) is a comparatively convenient, cheap and environmentally safe approach compared to chemical synthesis [12]. Technology is highly advanced today, crossing wide scientific frontiers. The engineering science of green nanotechnology today is replete with scientific vision and deep scientific cognizance. In their study, the authors synthesized SNPs from AgNO₃ using aqueous extracts (AEs) of fruits, leaves, roots and seeds of C. colocynthis as reducing and capping agents [12]. Nanoparticles of free metals have been extensively investigated because of their unique physical properties, chemical reactivity, biological labeling, biosensing, drug delivery, antibacterial activity, antiviral activity, detection of genetic disorders, gene therapy and DNA sequencing [12]. Green nanotechnology is opening new windows of scientific innovation today and deep scientific instinct in years to come. The present study explores the potential antitumor activity of greenly synthesized SNPs on cancer cells [12]. The wide world of green nanotechnology, the futuristic vision of cancer biology and the deep academic and scientific rigor will all lead to a long and visionary way towards the true emancipation of nanoscience today [12].

With immense foresight and clarity, Hutchison [13] discussed greener nanoscience as a proactive approach for advancing applications and reducing the implications of nanotechnology. Scientific cognizance, scientific sagacity and deep scientific understanding are the forerunners of research pursuit today [13]. A wide futuristic vision and overcoming the challenges of science and engineering will lead to the true realization and application of green nanotechnology. Nanotechnology continues to offer new materials and applications that will highly benefit human society, yet there is an ever-growing concern about the potential health and environmental impacts of the production and widespread use of nanoproducts [13]. The focus of this treatise is on the nanomaterial complexities through coordinated research on the applications and implications of new materials. Greener nanoscience is a revolutionary area of nanoscience today. Technological profundity and the scientific vision of the domain of green nanotechnology are veritably changing the face of scientific research pursuit today. Hutchison’s treatise pointedly focuses on the research agenda in minimizing global nanomaterials and green technology issues [13].

Albrecht et al. [14] lucidly described green chemistry and the health implications of nanoparticles. Spectacular developments in nanotechnology have taken place in nanotechnology with disregard towards the veritable health issues involved in it. There are practically no specific regulations on nanoparticles except for existing regulations covering the same...
material in bulk form [14]. Technology and engineering science are today faced with immense scientific obstacles and barriers. This review focuses on potential health effects of nanoparticles along with medical applications of nanoparticles, including imaging, drug delivery, disinfection and tissue repair. Validation of science and technology are slowly gearing up today towards a newer visionary scientific future in green chemistry and green nanotechnology [14].

Fagan et al. [15] discussed green nanotechnology with deep and cogent insight, along with the development of nanomaterials for environmental and energy applications. The technology and engineering science of green nanotechnology are highly advanced today and cross visionary boundaries. Fagan et al. discuss the synthesis of various nanomaterials for green nanotechnology applications in incisive detail. Special attention is focused on the development of emerging areas such as environmental and energy areas [15]. The challenge and vision of the technology and science of green nanotechnology are reaching immense scientific heights as human civilization enters into a newer scientific era. In this treatise, various approaches for preparing nanostructured photocatalysts, such as titanium dioxide, zinc oxide, iron oxide, and metal sulfides, and different conventional methods and novel methods, including sol-gel, hydrothermal, microwave-assisted and sonochemical methods, are discussed in deep detail [15]. The futuristic vision of nanotechnology, targets of scientific rigor and scientific passion and cognizance will all lead to a long and visionary way towards the true realization of nanotechnology science today [15].

### 1.8 Challenges and Opportunities in the Field of Green Nanotechnology

Today the challenges and opportunities in the field of green nanotechnology are surpassing vast and versatile scientific frontiers. The wide futuristic vision of nanotechnology, the technological challenges and the vision to move forward will all lead to a long and visionary way towards the true emancipation of nanoscience today. Human scientific endeavors in green nanotechnology and sustainable chemistry are transforming the visionary world of nanoscience and nanoengineering. In this chapter, the authors pinpoint the scientific success, immense scientific potential and future research trends in the field of green nanotechnology. Humankind’s immense vision and scientific prowess and the girth of scientific endeavor are forerunners of newer scientific research pursuits and innovations. Today, science and engineering are colossal with a definite vision and willpower of their own.
Science, engineering and technology are transforming the scientific genre of nanotechnology today.

1.9 Environmental Sustainability, Humankind’s Progress and Vision of Science

Environmental sustainability and humankind’s progress are in a state of immense scientific contemplation and deep scientific introspection today. Today, the progress of human beings is stalled and re-envisioned as regards sustainable development and environmental sustainability. The vision of the science of nanotechnology needs to be reframed and restructured regarding application and scientific potential. Green nanotechnology is in a state of immense scientific restructuring and scientific revamping today. Environmental sustainability and human scientific research pursuit are two opposite sides of the visionary coin today. Dr. Gro Harlem Brundtland, the former Prime Minister of Norway, defined and envisioned the science of sustainability. While the modern concept of sustainable development is derived mostly from the 1987 Brundtland report, it is also rooted in earlier ideas about sustainable forest management and twentieth century environmental concerns. Technological vision, deep introspection and scientific candor will all lead to a long and visionary way towards the true emancipation of green nanotechnology and green engineering today. Environmental sustainability today stands amid immense scientific revamping and, in a similar vein, deep crisis due to frequent environmental disasters and wide environmental hiatus periods. The question of sustainability today stands widely challenged and is deeply entwined with past scientific history and vision and the passage of time.

1.10 Scientific Cognizance, the Greatness of Research Pursuit and Green Nanotechnology

Scientific awareness is highly challenged today, with green nanotechnology standing amid immense scientific comprehension and deep introspection. Environmental and energy sustainability are in a state of deep crisis today due to untold environmental catastrophes. The greatness of scientific research pursuits needs to be veritably overhauled as science and technology enters a new visionary age. Green nanotechnology and sustainable development are the two opposite sides of the visionary scientific coin today.
1.11 Global Water Crisis – The Vision and Challenge of Science

The global water crisis and the visionary world of water research and development initiatives today stand in the midst of deep scientific introspection and wide scientific girth. The vision and the challenge of science are the pillars of scientific endeavor today. Global water shortage, drinking water contamination and industrial wastewater treatment will all lead to a long and visionary way towards the true emancipation of global sustainability science and the true realization of environmental sustainability. The success and vision of science today are immense and groundbreaking. Technological validation and scientific candor are the pathway to scientific regeneration and scientific revamping. Many developing nations as well as developed nations are in the throes of a deep disaster regarding groundwater contamination and a drinking water crisis. Science and engineering has no answers to the immense questions and vexing issues of arsenic and heavy metal groundwater contamination. The success of scientific endeavors is in a state of deeply entrenched global water crisis. The immense scientific prowess of human beings and their civilization's scientific achievement along with the scientific girth and determination are the veritable forerunners of a newer scientific and technological age. Water scarcity and global water hiatus periods are reaching immense heights and taking on disastrous proportions today.

1.12 Heavy Metal and Arsenic Groundwater Contamination – The Vision for the Future

Heavy metal and arsenic groundwater contamination is a primordial issue, which has continued to pose a vexing problem over the course of scientific history and in the pursuit of scientific research in today’s day-to-day civilization. Technological profundity today stands in the midst of deep catastrophe with the rising issues of global water shortage and contamination of drinking water. Developing and developed economies are in a veritable quagmire of arsenic groundwater contamination. Green nanotechnology and green chemistry are in the throes of a vicious scientific struggle to control their destiny. Yet environmental engineering science has a wide range of answers to this grave global water concern. The vision for the future needs to be reframed and redefined following the course of scientific history, scientific vision and time. Developing countries like India or
Bangladesh are in a veritable quagmire because of the scientific disaster brought about by the global water crisis. In this chapter the authors bring to the forefront the success of new technologies and innovations such as membrane science, advanced oxidation processes and the wide domain of nanoscience and nanotechnology. The crisis of drinking water contamination goes beyond scientific imagination and scientific adjudication. This chapter gives a veritable glimpse into the success of scientific endeavors in the field of green nanotechnology, green chemistry and sustainable chemistry.

Hashim et al. [16] discussed with immense lucidity remediation technologies for heavy metal contaminated groundwater. The contamination of groundwater by heavy metal is of grave concern for the progress of science and the vast progress of human civilization. Remediation of contaminated water is of highest priority since billions of people throughout the world use it for survival. Today, engineering science and technology are revamping the broad scientific panorama and vast scientific vision. Humankind’s immense scientific prowess, scientific stature and futuristic vision are fore-runners to the true realization of groundwater remediation technologies. In their paper, a large number of approaches for groundwater treatment have been reviewed, which are mainly classified under three large categories: chemical, biochemical/biological/biosorption, and physical-chemical absorption processes.

1.13 Groundwater Remediation and Water Purification Technologies

Groundwater remediation and removal of arsenic or heavy metal from drinking water stands as a major imperative to the furtherance of environmental engineering science today. Despite scientific progress, the questions concerning arsenic groundwater contamination have remained unanswered up till now. Technological profundity and scientific success are the pillars of environmental engineering science and nanotechnology today. Water purification technologies are in the throes of a deep crisis and an unimaginable scientific catastrophe. The scientific and academic rigor of groundwater remediation are being challenged today due to the intricacies of the pursuit of wide scientific research. Humankind today stands on the threshold of deep scientific vision and scientific introspection. Today, water technologies and environmental engineering science are replete with scientific forbearance and technological profundity. Drinking water contamination is in a state of immense scientific contemplation. Science and
the vision of humankind need to be readdressed and re-envisioned as scientific forbearance and profundity progresses.

### 1.14 Application of Nanotechnology in Industrial Wastewater Treatment

Nanotechnology applications are changing the face of human scientific endeavor. The crisis of environmental engineering science is highly inevitable, as the loss of ecological biodiversity and frequent environmental catastrophes are changing the face of human civilization. Industrial wastewater treatment, drinking water treatment and groundwater remediation are of utmost importance in today’s world of scientific and academic rigor. Nanotechnology is a veritable answer to the numerous questions of industrial wastewater treatment. Environmental catastrophes and stringent environmental restrictions are challenging the scientific landscape and the deep technological vision. Scientific candor, scientific forbearance and deep scientific understanding are the forerunners to a newer scientific genre and scientific vision. Nanoscience and nanoengineering are changing the face of scientific endeavors today. The global water shortage and global water catastrophe are the primordial scientific issues of today.

Nanotechnology has been called the Second Industrial Revolution. Its seemingly limitless potential will continue to inspire innovations and discoveries in a wide array of beneficial applications and briskly transform human society. Despite the hope and definite promise nanotechnology brings, engineered nanomaterials, the tiny engines driving this new transformative technology, also generate a widely held apprehension due to their largely unknown implications on human health and the environment. Thus ushers in green nanotechnology, an approach to managing the potential environmental, health, and safety (EHS) risks associated with the manufacture and use of nano-enabled products while veritably fostering their responsible development and application.

Karn et al. [6] delineated with great lucidity the widely held promise and uncertainty in green nanotechnology. Their article describes green nanotechnology and discusses the reasons why traditional chemical-assessment and management approaches may not be adequate in all cases when applied to nanomaterials. Technological vision, the wonders of science and the futuristic vision of green nanotechnology will all lead to a long and visionary way towards the true transformation of nanovision today. Nanotechnology encompasses the science of nanomaterials, forms of matter in a particular size range, roughly between 1 and 100 nanometers (nm).
Nanomaterials are bigger than most molecules and smaller than bacteria cells. They can consist of groups of single elements such as metals, groups of compounds such as metal oxides, tubes or wires of elements, soccer ball structures, branching structures, and infinite combinations of these. Science and technology is highly advanced today as green nanotechnology surpasses visionary frontiers. This chapter widely researches the scientific success, the deep scientific potential, and the wide scientific vision in the field of application of green nanotechnology and green engineering. Sustainable chemistry, environmental sustainability and sustainability engineering are in the path of immense scientific regeneration and scientific rejuvenation today. Humankind today is on the path to deep scientific vision and rejuvenation as nanotechnology enters a new phase of scientific achievement and determination. While nanomaterials are intentionally designed to be unique, what is common to all is their super small size, which imparts properties that are surprising and special. The science and engineering of nanomaterials are entering a new phase of technological challenges and scientific profundity. This chapter widely observes the immense scientific potential, the scientific understanding and the scientific contemplation behind nanomaterials, engineered nanomaterials and the wide domain of nanotechnology. Electric properties also can change at the nanoscale. The rolled-up carbon chicken-wire structure of carbon nanotubes (CNTs) is a conductor when the chicken wire falls in a straight line.

According to Karn et al. [6], there are two aspects to green nanotechnology. The first involves nanoproducts that provide solutions to environmental challenges. These green nanoproducts are used to prevent harm from known pollutants and are incorporated into environmental technologies to remediate hazardous waste sites, clean up polluted streams, and desalinate water, among other applications. Technology needs to be revamped and restructured with the progress of scientific history, scientific vision and time.

1.15 The Vision of Renewable Energy Technologies

Renewable energy technologies are the visionary technologies of today and tomorrow. Energy sustainability and renewable energy technology are the two opposite sides of the visionary coin. Humankind today stands amid deep scientific hope and optimism. Technological challenges and scientific vision need to be re-envisioned with the passage of scientific history and time. Renewable energies are the next generation technologies. The path of science and the vision of scientific endeavor are immensely far-reaching today in the domain of renewable energy technologies. Today, green nanotechnology and sustainable engineering are linked with
renewable energy technologies in a visionary way. This chapter gives a wide vision and this section treads a visionary path in the direction of newer and futuristic trends in the field of renewable energy technologies such as solar energy, wind energy and wave energy. Technology is highly advanced today. The progress of humankind, the immense scientific and academic rigor and the future path of alternate energy sources will all lead to a long and visionary way towards the true emancipation of renewable energy technology today. Human civilization and scientific research pursuits are in a state of immense distress and unimaginable catastrophe, as environmental disasters, industrial pollution and loss of ecological biodiversity is destroying the deep scientific fabric [17]. Science and its pursuit and deep vision needs to be readdressed and re-envisioned with the passage of human history and time. Green nanotechnology and the wider domain of nanoscience and nanotechnology are rewriting scientific history today. This chapter explores the wider vision and vast challenges facing technology in order to have proper and true emancipation of nanotechnology today [18].

1.16 Future Research Trends and Flow of Thoughts

Future research trends are veritably opening new avenues of scientific thought and scientific vision. Nanoscience and nanotechnology are ushering in a new era in the field of scientific vision and forbearance. The scientific and technological truth needs to be re-envisioned as regards application of nanotechnology and green nanotechnology. The future of human civilization and human research pursuit lies in the hands of scientists and engineers. The science of green nanotechnology is witnessing a new beginning with the advent of sustainable chemistry and the wide domain of sustainable engineering. The question of energy and environmental sustainability is creating immense scientific obstacles and barriers. Future scientific endeavors lie in unfolding the unknown areas of the science and technology of green nanotechnology. Green engineering and green chemistry are ushering in a new era in the field of nanotechnology today. Global water research and development initiatives also encompass green chemistry and sustainable engineering. This chapter gives a wide glimpse of the scientific success and scientific potential of application of green nanotechnology. Today green nanotechnology is surpassing wide scientific frontiers. The immense visionary scientific and academic rigor of nanoscience and nanotechnology are the forerunners to a greater emancipation of green engineering and green nanotechnology today. Humankind’s immense scientific prowess and the progress of science will be opening new windows of
scientific innovation and scientific instinct for decades to come. The future perspectives of science are immensely bright and far-reaching [19].

1.17 Conclusion and Future Perspectives

The science and engineering of green nanotechnology are moving towards newer knowledge dimensions and are crossing visionary boundaries. Environmental engineering science and environmental sustainability are veritably changing the scientific landscape [17–19]. The future progress of science and academic rigor lies in nanotechnology or green nanotechnology in particular. Technological vision, scientific splendor and futuristic vision are all forerunners to a newer visionary era in the field of sustainable development and green nanotechnology. Green chemistry, sustainable chemistry and green nanotechnology are challenging the wide scientific panorama today. This chapter gives a wider glimpse of the science of green nanotechnology with a greater emphasis on sustainable development and green engineering. Scientific success, scientific vision and scientific forbearance are changing the face of the pursuit of scientific research today. Chemical process engineering and environmental engineering science veritably need to be re-envisioned and re-envisioned with the progression of scientific history, scientific vision and time. Scientific fortitude and grandeur are on the path to scientific regeneration today, as this century moves towards a new era of space technology and nuclear science. Today science is a colossus with a wide and definite vision and stature of its own. Technological validation and scientific profundity needs to be restructured with the definite vision of nanotechnology, green engineering and environmental engineering science today. The scientific success and scientific splendor of nanotechnology will surely bear new and definite fruits with the progress of scientific and academic rigor. The challenge of green nanotechnology is just as immense and far-reaching. The targets of science and the immense success of nanotechnology applications will surely open windows of innovation for the furtherance of science in years to come.

References

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