

## Review Article

# Nanotechnology, Water Remediation and Sustainability- A Far-Reaching Review and a Broad Scientific and Technological Perspective

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**Abstract:** The world of science and engineering of sustainability and nanotechnology are in today's scientific fabric are in the aisles of newer scientific divination. Environmental, energy and socio-economic sustainability are the utmost needs of the hour. In the similar vision, nanotechnology needs to be aligned with diverse areas of natural sciences, applied sciences and engineering sciences. The definition of "sustainability" as described by Dr Gro Harlem Brundtland, former Prime Minister of Norway needs to be re-envisioned, rethought and rejuvenated with the passage of scientific history and time. Human struggles, human scientific and engineering challenges and human impact needs to be rethought as environmental protection and environmental disasters are in the path of immense scientific contemplation. In this paper, the author deeply discusses with verve and validation the integration of nanotechnology and sustainability. Human race today stands in the middle of deep scientific disaster and also scientific contemplation. Loss of ecological biodiversity and frequent environmental disasters are urging the scientific and engineering community to move towards newer scientific innovations and newer environmental engineering tools. Thus the need of a comprehensive treatise in the field of nanotechnology and sustainable development. Nanotechnology has vast and varied applications in the field of environmental pollution control. The author deeply targets these areas of scientific and engineering research endeavor. A newer era in the field of nanotechnology, nano-engineering and sustainability will surely usher in if a concerted effort is taken in the proper implementation of United Nations Sustainable Development Goals and the vision of Brundtland Commission Report. A new generation of scientists and engineers will move towards positive research directions if man and mankind innovates and envisions the basics and fundamentals of environmental engineering science, chemical process engineering, sustainable engineering and nanotechnology.

**Keywords:** Water, sustainability, environment, drinking, water, industrial, energy, vision.

## INTRODUCTION

Human society and human race today stands in the middle of vast and varied scientific and engineering introspection and vision. Heavy metal groundwater contamination and industrial wastewater pollution are truly ravaging the entire human planet and the very human existence. The domain of nanotechnology needs to be integrated with the domain of environmental engineering and chemical process engineering if environmental pollution can be mitigated. Industrial wastewater treatment and drinking water treatment are ravaging the human civilization and human habitat. The authors deeply elucidate the recent scientific advancements in the field of nanotechnology and sustainability. This is a comprehensive and ground-breaking review which mainly targets different environmental engineering and nanotechnology tools. Environmental engineering techniques involve both conventional and non-conventional environmental engineering tools. Novel separation processes such as membrane science and desalination are today the marvels of science and engineering today. In water scarce countries around the world, desalination is the only scientific and engineering alternative. Engineering and scientific profundity, vision and ideas will go a long and visionary way in truly uncovering the intricacies and difficulties of diffusion processes in membrane separation phenomenon, fouling and barriers of novel

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separation processes. The authors deeply stresses these areas of engineering vision in the field of nanotechnology and sustainable development. The world of science and technology today stands firm in the middle of deep scientific introspection, contemplation and vivacity. The author in this paper deeply reiterates the scientific needs of both nanotechnology and sustainability in the proliferation of global research and development initiatives. A new research dimension in the field of nano-science and nano-engineering will surely evolve if human civilization re-envision and re-thinks the needs of environmental pollution and water sustainability with the passage of global scientific and engineering history. A remarkable avenue will open in future if scientists, engineers and policy makers across the globe takes effective and visionary steps in the integration of nanotechnology and environmental and energy resources sustainability.

### **The Aim and Objective of this Study**

Human race and human mankind are in the process of newer engineering marvels, divination and scientific determination. Global environmental biodiversity and ecological adaptation are today in a state of disaster. There is an immediate need of deep scientific introspection and vast scientific understanding and discernment in the field of nanotechnology and sustainability. This is the main aim and objective of this study. Human struggles and human sufferings are immense in today's world with the ever-growing concerns for climate change and environmental degradation. Today the challenges and difficulties are immense in the field of environmental engineering science and chemical process engineering. Circular economy is the need of the hour today. Human scientific stance in the field of water sustainability and green sustainability are facing immense scientific difficulties and engineering challenges. Thus there is a growing need of innovative technologies in the field of drinking water treatment and industrial wastewater treatment. Nations around the world are today replete with one environmental catastrophe over another. There is an absolutely no respite for human struggles, human sufferings and human poverty. Struggles, trials and tribulations in the field of environmental protection are surmounting day by day. Thus there is a growing need of a deep scientific introspection and scientific and engineering revival in the field of environmental pollution control. Industrial growth and mass urbanization are destroying the human habitat today. The global scientific landscape is in a state of utter disaster. The vision of this study is to elucidate the vast interface of nanotechnology and environmental and energy sustainability.

A newer dawn in the field of renewable energy and energy resources sustainability will surely usher in as man, mankind and vision of science and engineering trudges towards carbon sequestration. Carbon storage, utilization and storage are the visionary areas of scientific research endeavor today. The author deeply elucidates on the newer technologies in the field of nanotechnology and sustainability. Nano-science and nanotechnology, sustainable development and environmental management are the frontier areas of global science and technology today. There is today an immediate need of research introspection in the field of drinking water treatment and industrial wastewater treatment. The areas of water and wastewater treatment should be interspersed with the field of nanotechnology. The author deeply urges the scientific community and governments across the world the integration of heavy metal groundwater remediation and application of nanotechnology.

### **What do you mean by Sustainability?**

Sustainability is a visionary phenomenon coined by Dr Gro Harlem Brundtland, former Prime Minister of Norway in the Global Report – Our Common Future. Sustenance of human civilization with respect to energy, environmental and socio-economic are the primordial pillars of the concept of sustainability. Human scientific and social regeneration today depends on sustainable development and United Nations Sustainable Development Goals. The United Nations Sustainable Development Goals are today directly linked with the pillars of sustainability. The primordial issues of human civilization are the concerns of sustainability, environmental pollution control and water sustainability. Nano-science, nano-engineering and nanotechnology will lead a long and visionary way in true emancipation of global research and development initiatives in diverse areas of science and engineering. People, planet and profit are the fundamentals and basics of circular economy today. Reuse, recycle and regeneration are also the main pillars of circular economy in the global scientific landscape today. The pillars and zenith of Global Sustainable Development Goals are vast and visionary. Climate change mitigation and alleviation of poverty are the cornerstones of sustainability today. In the similar vision, man, mankind and civilization should move towards provision of clean drinking water. Surely energy resources sustainability and renewable energy will be the path breaking areas of science and engineering.

### **The Vast Scientific Doctrine of Nanotechnology and Nano-Engineering**

In today's global scientific firmament, nanotechnology and nano-engineering are the needs of the hour in the field of mechanical engineering and manufacturing engineering. Nanotechnology should be integrated with diverse areas of science and engineering such as technology management and operations management. Today is the age of Fourth Industrial Revolution which involves application of artificial intelligence, machine learning and data analytics towards the success of human mankind and human scientific progress. Science and technology of nanotechnology are huge colossus with a deep purpose and vision of its own. The vast doctrine of nanotechnology and nano-engineering needs to be re-envisioned and re-invented as man and humankind moves forward. In the similar vision, industrial wastewater treatment, integrated water resource management and air quality management needs to be aligned with different areas of nanotechnology and

nano-engineering. Drinking water and industrial wastewater treatment today needs a larger scientific introspection. Thus the need of the application of nanotechnology. The triumph of science and technology today depends on environmental protection science, climate change mitigation and the global needs for drinking water and industrial wastewater treatment. Scientific vision, scientific imagination and scientific adjudication in the field of climate change science and water science and technology today needs to be revamped as man and mankind gears forward. This is an age of nano-engineering. Nanotechnology and nano-engineering should be today integrated with the wide vision of sustainability. A newer dawn in the field of nanotechnology and sustainability will surely usher in if scientific and academic rigor moves in the right direction.

### **Recent Scientific Advancements in the Field of Nanotechnology**

Nano-science and nanotechnology are the fountainhead of human scientific initiatives today. A newer dawn in the field of nanotechnology will emerge if nanotechnology is combined with human scientific progress. In this section, the author describes the recent scientific advancements in nanotechnology. A new scientific rethought and engineering introspection are the needs of the hour. At this moment the science of nanotechnology is in the middle of vision and scientific truthfulness. The author stresses on this issues. Palit *et al.*, (2021) [1] discussed in minute details minerals and metals in the global scenario and environmental sustainability. Today environmental and green sustainability are intertwined with diverse areas of science and engineering. The authors deeply discussed the vast vision and scientific doctrine of environmental sustainability, sustainable resource management, integrated water resource management and the vast vision for the future. The other areas of scientific research pursuit are today's mineral and metal industry and the needs of environmental sustainability. Recent scientific advancements in the field of environmental sustainability are the other cornerstones of this article. The authors also discussed recent scientific prowess and research endeavor in the field of environmental sustainability, wastewater treatment and mineral and metal industry. Future scientific recommendations and the future flow of scientific thoughts are the other areas of research pursuit. Today nanotechnology should be integrated with Global Sustainable Development Goals. The authors in this article deeply elucidates the need of nanotechnology and sustainability in mineral and metal industry. Surely a newer era in the field of sustainability will emerge if global scientific pursuit treads towards zero-carbonization and nanotechnology [1]. Hajian *et al.* (2021) [2] deeply discussed evolution of the concept of sustainability from Brundtland Report to sustainable development goals. The authors in this article discussed with vision, scientific grit and scientific determination the definition of sustainable development, the trend of sustainable development, the evolution of sustainable development concepts, and sustainable development goals. Today scientific provenance and scientific ingenuity open newer avenues in the field of nanotechnology and sustainability. The authors in this deeply trudges through these nanotechnology areas. The authors deeply also discussed indicator developments in the field of sustainability. Surely human scientific regeneration in the domain of nanotechnology will widen human futuristic vision of sustainability [2]. Majernek *et al.* (2021) [3] discussed and elucidated with deep scientific vision areas of sustainability and environment, economy and society. The pillars of social responsibility such as social, economic and environmental are the other scientific issues deeply discussed in this article. Different areas of the sustainability pillars and corporate philanthropy are discussed in minute details. Interconnections between economic growth, energy consumption, social welfare and sustainable quality of life are discussed in minute details [3]. Applications of nanotechnology in diverse areas of human life are true visionaries of global landscape of science and engineering. The author deeply elaborated in this entire article the needs of both nanotechnology and sustainability in the futuristic emancipation of science, technology, engineering and medicine.

### **Recent and Significant Advancements in the Field of Sustainability**

Sustainability issues need to be reframed and re-envisioned as human civilization moves forward. Mankind and man's vision are today dependent on the advancements of sustainability. Circular economy and sustainability are today integrated to each other. The author deeply with lucid insight describes recent progress in the field of sustainability. Without sustainable development, science and civilization cannot move forward. Thus arises the need of energy and environmental sustainability. Palit *et al.* (2021) [4] described with lucid and cogent insight green sustainability and the application of polymer nanocomposites. Human scientific regeneration and advancements in the field of green and environmental sustainability are the needs of the hour. In today's world, science and technology begets science and technology domain. The authors deeply elucidates the scientific doctrine of environmental sustainability, the vast scientific applications of nanocomposites and the vast domain of sustainable development and nanotechnology. Today man and mankind stands in the crossroads and confluence of industrialization and sustainability. The author deeply touches upon these areas of scientific research pursuit. The other areas of scientific endeavor are recent advancements in the field of green and environmental sustainability, and recent scientific advances in the field of nanocomposites. Nanocomposites and nanomaterials applications in the field of environmental pollution control stands as major pillars of this treatise. The scientific truth and vision of environmental sustainability are the other hallmarks of this article. The authors in this chapter reiterates and urges the scientific community and domain the needs of integration of nanocomposites and green sustainability [4]. Science, technology, engineering and medicine stands today in the midst of scientific ingenuity and scientific forbearance. Mankind and human civilization needs to rethink and re-envision the paths and avenues of

sustainable development goals. The author in this treatise deeply elucidates on these intriguing areas of research pursuit [5-21].

### **Nanotechnology and Industrial Pollution Control**

Industrial pollution abatement today stands in the middle of deep scientific thought and scientific reinvention. In this section the authors deeply elucidates on the major applications of nanotechnology in industrial pollution control. In distant future, nanotechnology and nano-engineering will be the primordial pillars of human civilization's progress and the advancement of science. Science, technology, engineering and medicine are in today's world in the process of vast scientific rejuvenation. Industrial pollution control is truly a newer area of global scientific endeavor. The author deeply explores and elucidates the needs of the science of nanotechnology in environmental remediation, water sustainability and water integrity [5-21].

### **Nanotechnology and Water and Wastewater Treatment**

Today nanotechnology and nano-engineering are extensively used in drinking water and industrial wastewater treatment. So there is a growing need for a comprehensive treatise in the field of application of nano-science and nanotechnology in the scientific progress and scientific vision of water treatment and environmental integrity. This is an age of Fourth Industrial Revolution. Circular economy, green economy and ocean economy stands as primordial pillars of civilization's progress. Man's vision and mankind's immense technological and engineering prowess are the needs of the hour. Scientific verve and validation will surely one day open new windows of innovation and scientific instinct in nanotechnology applications in decades to come. Reuse, regenerate and recycle will one day be the pillars of human progress. The pillars of science and engineering today are the applications of nanotechnology and nano-engineering in diverse areas of scientific research pursuit. Industry 4.0 and Internet 4.0 will surely embark on a revolutionary phase in global science and engineering [5-21].

### **The Scientific Ingenuity of Heavy Metal and Arsenic Groundwater Remediation and the March of Human Civilization**

Heavy metal and arsenic groundwater and drinking water contamination are today social trauma and are burning issues troubling human race today. Membrane science and membrane filtration tools are the utmost needs of the hour as science and humankind moves forward. In the similar vein, desalination needs to be aligned with water conservation and water sustainability. Sustainability issues in the global scientific landscape needs to be envisioned and reframed with the passage of scientific and engineering history and time. Science of heavy metal and arsenic groundwater and surface water remediation in the similar vein needs to be reframed. Water and wastewater treatment should be at the forefront of all global water science research and development initiatives. Human mankind is today replete with many water science and water technology scientific and engineering blunders. The need of the hour is a strong and positive research direction in the field of water and environmental sustainability. The march of human civilization today depends on the proper global implementation of United Nations Sustainable Development Goals which includes provision of clean drinking water, proper sanitation and greater emancipation of global public health engineering. Today public health engineering and global infrastructural development are in a state of immense scientific and technological distress. The author deeply reiterates the success and challenges of drinking water and industrial wastewater treatment. The scientific ingenuity and scientific vision in arsenic groundwater remediation in developing countries are the utmost needs of the hour. The author deeply reiterates the immediate needs of nanotechnology in the futuristic vision of drinking water treatment and industrial wastewater treatment [5-21].

### **Futuristic Vision and the Futuristic Flow of Scientific Thoughts in the Field of Nanotechnology and Environmental Pollution Control**

Futuristic vision and futuristic flow of scientific thoughts should be targeted towards sustainability and United Nations Sustainable Development Goals. Both nanotechnology and sustainability are today intertwined with each other. The scientific vision, provenance and ingenuity in the application of sustainability are clear and envisioning. Science and engineering of nanotechnology are today moving at a rapid pace. One scientific frontier over another are deeply surpassed. Today, biotechnology and genetic engineering are the marvels and wonders of science and technology. Sustainable development and the march of science are today opposite sides of the visionary coin. United Nations Sustainable Development Goals should be integrated with scientific and engineering progress. Nanotechnology research pursuit should be at the zenith of scientific and academic rigor today. Biological sciences, biological engineering, biotechnology, clinical chemistry, agriculture and forestry should be also integrated with global science and technological initiatives. A newer beginning and a newer research direction in the field of nanotechnology and sustainability will veritably open up new dimensions of scientific grit, hope and perseverance. The world of science and technology are today replete with deep scientific understanding, scientific discernment and scientific ingenuity. Natural hazards and risk management is in the path of new scientific vision. In the similar way, integrated water resource management and air quality management are the immediate needs of the hour. In this article, the author deeply reiterates these scientific issues. Human race's trials and tribulations are immense as regards achievement of Sustainable Development Goals. Thus a deeper scientific introspection



and scientific vision are the absolute needs of the hour. Implementation of United Nations Sustainable Development Goals will go a long and visionary way in unraveling the scientific truth of environmental protection, nanotechnology and sustainability [5-21]. The world of challenges in the field of industry and academia are immense and visionary. A newer aisle in the field of nanotechnology, nano-engineering and water treatment will be the futuristic pillars of scientific and engineering emancipation globally [5-21].

### Conclusion, Environmental Perspectives and Future Outlook

Technology and engineering science are in the crucial juncture of vision, scientific perseverance and scientific grit. Future environmental engineering perspectives needs to be re-envisioned and revisited as humankind moves from one barrier towards other. Future outlook of environmental engineering and nanotechnology should be directed towards a newer visionary eon in the field of water and environmental integrity. Environmental, green and water sustainability are the utmost needs of human civilization and human scientific proliferation today. A new day and a new dawn in the field of environmental engineering science and nanotechnology will veritably usher in as humankind overcomes one scientific frontier over another. Environmental engineering perspectives today needs to be widened if civilization needs to be saved. Ecological resilience, environmental resilience and economic growth today are linked with each other in every nations around the world. Thus the future scientific and engineering outlook in the field of nanotechnology and sustainable development needs to be revamped and reinvented as man and humankind moves forward. The authors in this article deeply discusses with purpose and persuasiveness the need of both nanotechnology and sustainability in the path and avenues of scientific regeneration. Today there are immense needs of sustainability and nanotechnology in future human scientific progress. Only deep scientific divination and scientific and engineering reinvention will widen human scientific ideas. This is the main aim and objective of this paper. The author deeply discusses with verve and alacrity these scientific needs of both nanotechnology and sustainable development. Surely a new era will emerge in global science and engineering if nanotechnology and nano-engineering are implemented in diverse areas of allied sciences, natural sciences and engineering sciences. Civilization, science and engineering are today at the crossroads of scientific advancements in the field of nano-science and nano-engineering. In this review article, the author deeply pronounces the need of nanotechnology, nanomaterials and engineered nanomaterials in different avenues of science and engineering such as water and energy nexus. A newer revolution in the field of Industry 4.0 will surely open newer dimensions of research and development in decades to come. Scientific provenance and scientific benediction will then surely be the hallmarks of human civilization.

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