

# Environmental and Energy Sustainability in India and Arsenic Groundwater Remediation – A Vision for the Future

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## Abstract

The world is moving steadily at a drastic pace and human civilization is surpassing visionary frontiers. Challenges, barriers and future planning are the ultimate crux of the progress of human civilization. Environmental degradation is at its vicious helm. At such a critical juncture of human history and time, man's vision should be targeted towards successful energy and environmental sustainability. Mankind's vision and civilization's prowess will go a long way in the emancipation of human progress and environmental scientific endeavor. Frontiers of scientific truth and scientific vision are surpassed with every step of scientific endeavor. Environmental engineering science and energy scenario are opening up new vistas of development in the Indian perspective in years to come. India today is one of the fastest growing economies. Challenges, grit and scientific determination are the coinwords of future. The vision for the future of the nation needs to be reshaped and reorganized as the nation propels into twenty first century. Environmental and energy sustainability needs to move at a rapid pace in a developing country like India. The progress of the world order, the unsurpassed barriers of a developing economy and scientific vision needs to be readdressed at every step of human endeavor.

**Keywords:** Sustainability; Energy; Environment; Vision; Arsenic; Groundwater; Remediation

## Introduction

Environmental sustainability and energy sustainability in today's world have an unsevered umbilical cord. The future of Indian nation is in the verge of a new generation of scientific understanding and scientific vision. Environmental engineering science and its application in Indian perspective is moving towards a visionary realm. Environmental sciences in today's world stand in the midst of immense scientific truth and scientific forbearance. Sustainability issue in India is devastated and is at a difficult situation. Arsenic groundwater contamination has led human civilization to its greatest human catastrophe. In such a crucial juncture of science and engineering, process technology, environmental engineering and water technology needs to be envisioned. Sustainability whether it is energy or environmental

needs to be restructured and rebuilt in the Indian context. Sustainable infrastructural development and the primordial issue of provision of basic human needs to be reshaped with the passage of history and time [1,2]. Challenges, difficulties and scientific barriers are veritably surpassing visionary frontiers. Man's vision and its challenges are opening up new windows of innovation in the domain of energy and environmental sustainability. In a similar vein, arsenic groundwater remediation should be the futuristic goal of India. Eastern India is troubled with the catastrophe of arsenic groundwater contamination. The vision of groundwater contamination needs to be rebuilt with innovation in scientific endeavor. The world of scientific challenges and scientific barriers are befitting to the progress of human life and innovative endeavor. The primordial question of provision of clean drinking water stands as a major issue in South

Asian countries. Scientific vision, intense scientific endeavor and the path towards future progress will lead a long way in alleviating the issue of arsenic groundwater contamination in South Asia [3,4].

## Vision of the Present Treatise

The domain of environmental engineering is moving at a drastic and devastating pace with the passage of time and history. Environmental regulations and stringent restrictions are the torchbearers of a definitive vision of tomorrow. Environmental and energy sustainability is at a disastrous state in our present day human civilization. Provision of clean drinking water today stands in the midst of immense pessimism and grave concern. Arsenic and heavy metal contamination of groundwater is the largest and major human disaster in our present century. South Asia today stands in the midst of an inimitable disaster [3]. The challenge and difficulties in scientific endeavor needs to be reshaped. Challenges to environmental sustainability should be re-envisioned at every step of human scientific progress. Environmental and energy sustainability is moving slowly through difficult trials and tribulations. History of human scientific progress is at a difficult stake. Man's vision as well as a scientist's prowess is in the midst of immense catastrophe with the burgeoning concern for environmental sustainability. Science, engineering and human progress will all lead towards a greater emancipation. The author with cogent insight and deep introspection brings forward to the scientific forefront the immense vision of energy and environmental sustainability in India and the future progress of arsenic groundwater remediation in India [5,6]. Energy demands, sustainable development and environmental regulations should go a long way in alleviating barriers of sustainability. Arsenic groundwater contamination will open up new areas of innovation and new visionary vistas of heavy metal groundwater remediation. The challenge, the unsurpassed barriers and the path towards sustainability will lead a long and visionary way in the true realization of environmental and energy sustainability in India and other developing countries.

## The scope of the study

The world of challenges, challenges of scientific truth and the vision for tomorrow in the field of Indian sustainability is wide, versatile and far-reaching. The scope of the study is targeted towards arsenic groundwater remediation and the future of global sustainability and the intricate details of global water shortage. Human history and human mankind is in the midst of visionary challenges. Science and technology are witnessing a new challenge- the challenge of global sustainability. Science is revamped with every step of technological history. Human sufferings, the defunct technologies of provision of clean drinking water and the immense road towards progress all will go a long way in the true emancipation of human scientific endeavour. Arsenic groundwater contamination needs to be alleviated with each step of scientific rigour. Energy engineering and environmental engineering are in the path of immense intellect and a giant vista of scientific rigour. The scope of the vision of this study enumerates the instinctive and innovative world of sustainability and arsenic groundwater remediation in

India. Technology and science needs to be restructured and re-envisioned at every step of endeavour and rigour. The world of immense challenges as well as opportunities in the pursuit of science and technology is gearing towards a newer dimension. Provision of clean drinking water is the pillar of sustainability in today's civilization. From Prime Minister Gro Harlem Brundtland of Norway's vision, sustainable development is ushering in a new era of infrastructural development. In such a critical situation, man's vision as well as a scientist's progress needs to be restructured with respect to energy and environmental sustainability. Scientific progress is in the beginning of a visionary era. Scope and vision is wide and versatile. The history of science is awakening to a new dawn of energy and environmental sustainability. Prime Minister Brundtland's vision is the ultimate and immediate vision of tomorrow. The vision of sustainability needs to be restructured with India's as well as South Asia's progress. Vision of science and infrastructural development is ushering in a new era of development.

## Scientific truth, scientific doctrine and progress of technology

Scientific truth and scientific cognizance are in the midst of immense distress and inimitable disaster. Water science and water technology needs to be re-envisioned and restructured at every step of scientific rigour and progress. Progress of technology is defunct in the present day human civilization. Deep and immense comprehensions are the pillars of human scientific rigour and progress. A nation's economy depends on the successful scientific validation. Vision, purpose and scientific enlightenment will surely and inevitably cross scientific frontiers. Scientific vision is at a state of human disaster with the immense plight of human civilization. The world of groundwater remediation and provision of clean drinking water is in a state of deep distress and immense introspection. Progress of clean technology and road towards green chemistry will surely and inevitably usher in a new dawn of human progress.

## An introspective understanding into the science of groundwater contamination and bioremediation

Bioremediation is the scientific rigour and vision of our times. The primordial issue of present human step of life is the provision of basic needs. Groundwater contamination is at a disastrous state of affairs. Basic human needs are in a state of immense disaster. Human history as regards to environmental engineering science needs to be re-envisioned. Teeming millions in the state of West Bengal in India and Bangladesh are in a state of distress. Man's history, mankind's history and the progress of civilization are ushering in a new era of sustainable development. Only scientific progress and deep scientific introspection can bring in innovative wonders in the field of water science. Bioremediation is one of the many plausible solutions of global drinking water shortage and the future of environmental sustainability. The vision of arsenic sustainability is in the midst of deep scientific vision and deep scientific understanding. In such a crucial juncture, man's progress, human scientific endeavor and comprehensive solutions will open up new windows of innovation in years to come.

### Scientific endeavor, scientific truth and the present and future state of sustainable development

Scientific endeavor, infrastructural development and sustainability will go a long way in evolving new vision in years to come. Environmental as well as energy sustainability are the torchbearers to the future progress and growth of a nation. Scientific truth and scientific vision are the two parameters of an effective planning scenario. Vision is befitting to the progress of science and progress of human civilization. The question of sustainability is inevitably linked to the march of science and engineering. Indian progress after liberalization era has been significant and far-reaching. The nation is moving drastically and steadily towards a newer scientific generation and newer scientific vision. The scenario of provision of basic needs, alleviation of poverty and the progress of science and technology will all go a long way in achieving successful sustainability [7,8].

### Progress towards green chemistry and the success of heavy metal groundwater remediation

The world of green chemistry is a veritable challenge to human progress and every step of human life. Green technology and heavy metal groundwater remediation are the challenges of human progress. Arsenic groundwater remediation is a bane to human civilization and an incomprehensible calamity to human progress. Endeavour of science, future of green chemistry and the challenge of mankind are ushering in a new avenue of technological advancements. The next generation technology of arsenic and heavy metal groundwater remediation needs to be re-emphasized and re-addressed at every step of human life. Heavy metal groundwater remediation is in the midst of immense distress and deep comprehension. The challenge of life needs to be revitalized and the progress of science needs to be re-envisioned at every step of human endeavor. Green chemistry is in the path of newer vision and wide avenues of scientific truth. The grave concerns, the inevitable scientific truth and stringent environmental regulations are opening up new challenges in the path towards progress in green chemistry and green engineering.

Heavy metal is a general collective term, which applies to the group of metals and metalloids with atomic density greater than  $4000 \text{ kg m}^{-3}$ , or 5 times more than water and they are natural components of the earth's crust. Although some of them act as micro-nutrients for leaving beings, at higher concentrations they can lead to severe poisoning. The most toxic forms of these metals in their ionic species are the most stable oxidation states e.g.  $\text{Cd}^{2+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Hg}^{2+}$ ,  $\text{Ag}^{2+}$  and  $\text{Ag}^{3+}$  in which they react with the body's biomolecules to form extremely stable biotoxic compounds which are difficult to dissociate.

In human's surrounding environment, the heavy metals are generally more persistent than organic contaminants such as pesticides or petroleum by-products. They can become mobile in soils depending on soil pH and speciation. So a fraction of the total mass can leach to the aquifer or can become bio-available to living organisms. Heavy metal poisoning can result from drinking water contamination (e.g. Pb pipes, industrial and consumer wastes), intake via the food chain or high ambient air concentrations near emission sources.

Over the past, many remediation technologies were applied all over the world to deal with the contaminated soil and aquifers. Intense scientific endeavor has surpassed visionary boundaries. Removal of heavy metal removal from wastewaters is published recently. Apart from the report by USEPA, no document reviewing the heavy metal remediation technologies for groundwater in the recent times has been investigated.

The crux of a scientific endeavor lies in the fact that technology is varied and versatile. The scientific understanding and scientific vision leads to a general overview. The author, with great caution, investigates the present and future technologies of wastewater treatment and a holistic view of sustainability. The author reviews the only removal of heavy metals from groundwater, i.e., the water which is located in soil pore spaces and the fractures in rock units. The immense vision, the willful challenges and the wide urge to excel has geared up the scientific community to create a wider vision.

### Environmental and Energy Sustainability in India

India as a developing economy is moving fast towards a newer vision and newer scientific forbearance. Science, technology and engineering are surpassing one frontier over another. Holistic human development depends on successful environmental and energy sustainability. Infrastructural foray into economic progress depends veritably on vision towards sustainability. Basic needs provision and development of infrastructure is the catalysts of the greater vision of tomorrow. Scientific fortitude and immense scientific vision will surely usher in a new era of human development for Indians. India is gaining strides in economy and development of its infrastructure. Infrastructural development is the eye of the nation and vision of tomorrow. The present subtle treatise widely delineates the challenges and future trends of application of science and technology along with the road towards sustainable development. Infrastructural developments in India as well as throughout the world are veritably linked with basic human needs like provision of clean drinking water. Science, vision for the future and the immense urge to move forward will all go a long way in redefining sustainability. Economic progress in India should not be a barrier to progress in environmental sustainability. Indian vision for the remaining part of this century needs to be redefined for greater challenges. Successful sustainability, ecological balance and grave concern about environment will move the nation forward. These parameters of development are veritably linked with success of infrastructural development in India. India today is in the path towards visionary progress and glory. Mankind's prowess, civilization's vision and environmental concerns will surely shape India's development [9-12].

### Vision for the Future, Immense Challenges and the Road Ahead in Successful Sustainability

Challenges, barriers and hurdles are immense torchbearers to a new generation of hope and determination for an Indian.

Environmental sustainability and future of human civilization have an unsevered umbilical cord. Environmental pollution control and history of environmental engineering science are in a disastrous state of affairs. Mankind's history is at a devastating stake. Challenges and forbearance are the only decisive parameters to the future progress of the nation. The road ahead in successful environmental and energy sustainability is a path of thorns. The country is moving forward from the post-liberalization era. Progress of science and engineering in the Indian paradigm is visionary and far-reaching [13-16].

## Global Water Crisis, Environmental Sustainability and the Immediate Concern

Global water crisis today is in great distress. Global water crisis today stands in the midst of immense pessimism and inimitable concern. Environmental sustainability stands as a virtual torchbearer to provision of clean drinking water. The role of environmental sustainability to the future of human progress and human scientific progress is unimaginable. Science and technology is in the new path of emancipation. Groundwater remediation is the primordial issue of the present scientific generation. Sound infrastructural development needs to be envisioned at every step of human progress [3].

Over the past two or three decades, occurrence of high concentrations of arsenic in drinking water has been recognized as a major public-health concern in several parts of the world. There have been a few review works concerning the arsenic contamination scenario throughout the world. Visionary details are deliberated concerning this grave environmental issue. Arsenic groundwater research in today's scientific panorama is surpassing visionary barriers. The intricate concern, the feasible solutions and the scientific urge to excel has revolutionized the panorama of environmental engineering science. In today's vicious world of environmental catastrophes, the ultimate and instinctive vision of science needs to be veritably realized. With the discovery of newer sites in the recent past, the arsenic contamination scenario around the world, especially in Asian countries changed dramatically. The vision of groundwater remediation needs to be changed considerably. Before 2000, there were five major incidents of arsenic groundwater contamination in Asian countries: Bangladesh, West Bengal, India and sites in China. Between 2000 and 2005, arsenic related groundwater problems have emerged in different Asian countries including new sites in China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, DPR Korea and Pakistan. There are reports of arsenic contamination from Kurdistan province of Western Iran and Vietnam where several million people may have a considerable risk of chronic arsenic poisoning [13-16].

## Heavy Metal Contamination of Groundwater and its Visionary Remediation Strategies

"Heavy metal" is a general collective term, which applies to the group of metals and metalloids with atomic density greater

than 4000 Kg m<sup>-3</sup>, or 5 times more than water and they are natural components of the earth's crust. Although some of them act as essential micro-nutrients for living beings, at higher concentrations they can lead to severe poisoning [15]. The most toxic form of these metals in their ionic species are the most stable oxidation states e.g. Cd<sup>2+</sup>, Pb<sup>2+</sup>, Hg<sup>2+</sup>, Ag<sup>+</sup> and As<sup>3+</sup> in which they react with the body's bio-molecules to form extremely stable biotoxic compounds which are difficult to dissociate [15].

The toxicity, mobility and reactivity of heavy metals depend on its speciation, which again depends upon some conditions e.g., pH, Eh, temperature, moisture etc. Several technologies exist for the remediation of heavy metals – contaminated groundwater and soil and they have some definite outcomes such as 1) complete or substantial destruction / degradation of pollutants, 2) extraction of pollutants for further treatment or disposal, 3) stabilization of pollutants in forms less mobile or toxic, 4) separation of non-contaminated materials and their recycling from polluted materials that require further treatment and 5) containment of polluted material to restrict exposure to the wider environment [13-16].

## Arsenic Groundwater Remediation and the Visionary Future

Human disaster with respect to arsenic groundwater contamination is apparent in the scientific scenario. Advancement of science and technology, the path towards progress and the vision to excel are stunted. The disaster of provision of drinking water is unimaginable. Man's vision as well as a scientist's progress has ushered in a new era of green chemistry and successful environmental sustainability. South Asia and some parts of the developed world are witnessing one of the greatest environmental disasters of groundwater contamination. The visionary future is feeble yet the perspectives are immensely resurgent. History of human civilization at this crucial juncture is passing through difficult phase. Scientific research pursuit is not able to surpass the wide frontiers of arsenic groundwater remediation. Environmental sustainability is drastically moving through a difficult phase of history and time. The primordial issue to target for the future is scientific research endeavor in alleviating environmental catastrophes and realizing sustainability. South Asia and many developed and developing countries are in the state of immense environmental catastrophes. The vision of groundwater remediation techniques needs to be readdressed at every step of human civil society. The caution, the immediate action and the vision of application of science needs to be readdressed to the extreme and of utmost importance. In today's world sustainability and drinking water issues needs to be re-envisioned. The visionary future is in a state of immense distress and unimaginable calamity. Emancipation of science and technology will inevitably usher in a new dawn of human civilization and a deep and comprehensive human progress. Industrial wastewater treatment, drinking water issues and the future road towards progress are the ultimate challenges in the progress of human life. Heavy metal groundwater remediation is in the process of new challenge. Mankind's vision and civilization's

progress are today ushering in a new era of human challenges and difficulties. Arsenic groundwater remediation will be the focal point of human scientific endeavor and the world of human progress and difficulties. The frontier needs to be surpassed and the futuristic vision needs to be realized to the utmost.

## Groundwater Contamination and Environmental Sustainability

Groundwater remediation and decontamination today stands in the midst of immense scientific vision and optimism. Scientific fortitude and forbearance are the pallbearers towards a new visionary frontier. Environmental sustainability and water pollution control is drastically moving towards a newer realm and a newer era. Arsenic groundwater contamination and drinking water shortage is burgeoning towards a newer goal and new vision. Groundwater contamination and its remediation today stand as a major impediment to the vision and goal of sustainability in a country like India. The environment is in deep peril. Human civilization and its growth and prowess is in serious catastrophe due to the serious and grave concern of arsenic groundwater contamination in South Asia. Environmental sustainability at this critical juncture needs to be restructured. Scientific endeavor, vision and validated research pursuit needs to be rebuilt at every step of life. The ravages and disaster are immeasurable. Scientific grit and scientific vision is at its utmost at every step of environmental engineering science as regards arsenic remediation. Feasible solutions are still feeble yet the scientific vision is immense. Vision for scientific greatness in research pursuit needs to be emboldened at every step of human progress [3].

The contamination of groundwater by heavy metal, originating either from natural soil sources or from anthropogenic sources is a matter of serious as well as a grave concern to the public health. Remediation and decontamination of groundwater is of highest priority since billions of people all over the world use it for drinking purpose. Selection of a suitable technology stands today as a major challenge due to extremely complex soil chemistry and aquifer characteristics and there is no thumb rule regarding this issue. Science of environment is immensely complex in this regard. In the past decade, iron based technologies, microbial remediation, biological sulphate reduction and various adsorbents played versatile and efficient remediation roles. Keeping sustainability issues and environmental ethics in mind, the technologies encompassing natural chemistry, bioremediation and biosorption are recommended to be adopted and applied in appropriate cases [3].

## Future Vision, Future Directions and Future Perspectives

Future vision and future directions in the field of environmental and energy sustainability are surpassing visionary frontiers of scientific truth and true scientific research pursuit. Challenges, infrastructural development and the path towards progress are ushering towards a newer inspiring era. Sustainable development needs to be re-envisioned at every step of history and human progress. Future perspectives should be towards realization of the scientific truth of environmental and energy sustainability. Vision, challenges and targets of scientific endeavor should be towards ensuring the immense truth about the concept of environmental sustainability. Water pollution control is at a disastrous state of affairs today. Arsenic and heavy metal contamination of drinking water is a bane to human civilization. Future directions and future imaginations are ushering in a new vision of scientific fortitude [3].

## Conclusion

Advancement of science and technology in today's world has an umbilical cord with sustainable development of human planet. The immense difficulties and barriers needs to be revisited in the alleviation of drinking water crisis and arsenic groundwater contamination. Future directions in environmental engineering research pursuits should be towards realizing environmental sustainability. Sustainable infrastructural development and the provision of basic needs are the coinwords of future. The author successfully delineates the importance of environmental and energy sustainability to the future of human mankind. Scientific vision in today's world is of immense proportions. Scientific doctrine, scientific fortitude and deep scientific understanding are ever growing facets of progress towards future. The emancipation of science is emboldened and realized in today's world of environmental engineering science. The wide world of energy and environmental sustainability is opening up new dimensions of scientific research endeavor in decades to come. Vision of science is witnessing new resurgence and drastic challenges. Successful sustainable development will surely advance Indian nation and our human civilization towards a new scientific vision and understanding.

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