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General Research Paper

Arsenic Groundwater Remediation in South Asia and the Visionary Technologies for the Future

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ABSTRACT

The world of environmental engineering science is moving from one paradigmatic challenge towards another. The paradigm of global water shortage is moving from one visionary and drastic challenges over another. Man's vision, civilization's prowess and the target of the provision of clean drinking water has urged human civilization to target new and innovative technologies. Arsenic and heavy metal groundwater contamination has evolved into a true emancipation of science and technology. Arsenic water pollution is the largest human disaster in this century. Environmental restrictions, environmental regulations and the urge of successful scientific endeavour are the need of the hour. Tools and environmental engineering innovations are gearing up for alleviating global water shortage. Human scientific research pursuit and the vision to excel has geared environmental engineering science to a new degree of awareness. The vision for the tomorrow is to gear towards a new dawn of environmental engineering techniques to alleviate this monstrous crisis. The incidence of this crisis is of monstrous proportion in South Asia and high concentrations of arsenic has emerged as a public health problem. The situation in the state of West Bengal, India and Bangladesh is grave. The contamination is due to both natural and anthropogenic sources. Concrete finding shows the vulnerability of the crisis. The study with deep comprehension focuses on the future perspectives of the world's largest environmental crisis. The author delineates with cogent insight, the state of environment, and the paper presents an overview of the current scenario of arsenic contamination in across the globe with special emphasis on South Asia. Heavy metal groundwater contamination is a bane to human civilization and human endeavour. The author brings forward along with the present situation in severely affected countries in Asia such as India and Bangladesh. Along with these countries, recent instances from Pakistan, Myanmar, Afghanistan, Cambodia etc. are presented. Challenges, barriers and catastrophes have urged the civil society to gear up for drastic and far-reaching challenges. Concrete findings suggest that the source of arsenic is geogenic. Arsenic is found in alluvial sediment of the Ganges Delta in India. This has led to much alarm and grave concern. Social isolation of the arsenic affected human beings, the society's unmitigated concern and the future of disastrous challenges has urged the scientific community to surge and gear forward in innovations. The author with incisive insight delineates the remediation technologies, the visionary future of scientific research pursuit in groundwater remediation and the future of advancement of science.

INTRODUCTION

Arsenic and heavy metal contamination of ground water is a disaster for the future of global water shortage. Vision of science, technological advancements and the avenues of progress are the forerunners of greater scientific understanding and immense scientific vision. The world of challenges in the global water crisis are multiplying without any proper feasible solution. History of civilization is in a defiant defeat and a defiant state of crisis. Human scientific emancipation is gearing up from one paradigmatic crisis after another. The paradigm of science is at a definite crisis. Human mankind, the face of human civilization and the road towards immense progress are the torchbearers towards a newer vision of the global water crisis. Heavy metal groundwater contamination is a bane to human civilization. The progress of science, the immense vision of alleviation of water crisis and the tools of environmental engineering science will go a long way in surpassing frontiers of global water crisis. The author with deep comprehension and cogent insight delves deeply into the future of global water shortage and the inherent challenges which lie before it (Byrne 1996, Hanley 2009, Banerjee 2003, Goodland 1995, Mukherjee 2006).

Over the past two or three decade, occurrence of high concentrations of arsenic in drinking water has become a major public health concern in several parts of the world. There have been a few review works containing arsenic concentration scenario around the world. With the discovery of new sites around the world, the arsenic affected scenario has changed dramatically and alarmingly over the years. Vision of science, the glory of human scientific endeavour and the darkness and human agony due to arsenic contamination will go a long way in the greater emancipation of human progress and alleviation of the ever-ending human crisis. Crisis, grave concerns and the futuristic challenges are the forerunners to a new dimension of scientific hope and scientific optimism. Man's vision as well as a scientist's prowess are in the path of a new scientific regeneration. The immense scientific endeavour and the world of difficulties and challenges are in the way of practical regeneration. History is repeating itself at each step of environmental engineering progress. The ultimate choice and the utmost importance rely on strong concept of environmental sustainability and strong and steady road towards successful environmental engineering tools. The author with visionary emphasis deals lucidly on the success of environmental engineering techniques and also the coherent world of environmental sustainability. The vision of the author is decisive and greatly glorifying with every step of environmental progress (Byrne 1996, Hanley 2009, Mukherjee 2006, Goodland 1995, Banerjee 2003).

VISION OF THE PRESENT TREATISE

Environmental engineering progress today stands in the midst of immense challenges and unmitigated disaster. The future of environment is at a deeper and disastrous state of affairs. A scientist's challenge, mankind's prowess and the progress of human mankind are the forerunners of a new chapter of arsenic and heavy metal groundwater remediation. The vision of heavy metal groundwater remediation and bioremediation in particular are surging ahead in the pursuit of greater emancipation. The scientific challenges behind groundwater remediation are immense, visionary and wide. The vision behind this treatise evolves in a holistic manner and glorified attitude the future of global water shortage and the tools and technologies behind the imminent crisis. Arsenic and heavy metal groundwater contamination will open up new challenges and innovative roles for the scientific community. It is of utmost importance for the future of mankind. Human civilization can never go ahead without the realization of the provision of clean drinking water and the vision towards environmental sustainability. In such a crucial juxtaposition, man's vision as well as a civilization's power to excel, will lead a glorified way in realizing the success of environmental sustainability. The vision is bright, versatile and clear. The world of challenges are the forerunners towards a newer future dimension of global water shortage and the concept of environmental sustainability. The vision and the challenge of this study focuses on the immense catastrophe of arsenic groundwater contamination in South Asia, the challenges behind it, the remediation technologies which are envisioned and the futuristic success behind the alleviation of global water shortage and crisis (Masters 2013, Goodland 1995, Jenkins 2013, Mukherjee 2006).

SCOPE OF THE STUDY

The scope and vision of the study are opening up new dimensions of research in water technology and global water shortage. Future thoughts and future vision are ushering in a new dimension of challenges. Water science and groundwater remediation are moving towards an innovative direction. The scope of this study is vast and versatile. Arsenic groundwater technology is moving towards a newer future direction. The greatest human disaster, the unmitigated challenges and the wide road towards a visionary future will all lead a glorified way in the future emancipation of the science and engineering of global water crisis. History of human civilization, history of human mankind and the urge to excel in science and engineering are the torchbearers to human progress and human step of life (Nair 2009, Newell 2011, Palit 2013, Mukherjee 2006).

Worldwide concern of arsenic crisis is grave and devastating. The challenge, the vision and the target of science and engineering should be towards research and development in water science and technology. The fruits of civilization needs to be re-envisioned. The ultimate vision and the veritable scope of the study aims at realization of environmental sustainability with the ultimate and inevitable goal of heavy metal groundwater remediation. History will repeat itself with each step of human scientific pursuit. The challenges to groundwater remediation are unimaginable and insurmountable. The scope of this present study will open up new vision and innovative vistas of life in the scientific horizon of groundwater remediation research in years to come. The future direction and scope of the study in heavy metal groundwater remediation is far-reaching and evergrowing. Health issues, the world of ailments and the vision of the health sector should be kept in mind in tackling global water issues. Arsenic infected areas in eastern India and Bangladesh has taken monstrous proportions. Environmental engineering techniques are paving the way for successful realization of environmental sustainability. The vision of scientific research pursuit, the wide road ahead and the success of research endeavour will lead a visionary avenue in the successful emancipation of alleviation of global water crisis. The scope, the vision and the challenges are vast, versatile and visionary. A scientist's vision is re-addressed and reorganized at every step of scientific progress in the vast domain of heavy metal groundwater remediation. This treatise goes ahead towards a visionary future in groundwater remediation and global water crisis. The scope unfolds and unravels the vast and varied issues of global water crisis (Renewable Energy Report 2009, Sarkar 2010, Wisner 2011, Kalam 2011, Mukherjee 2006).

HUMAN SOCIETY, THE VISION FOR THE FUTURE AND THE GLOBAL WATER SHORTAGE

Human society, as regards global water shortage, is in the dawn of a new and drastic challenges. Global water shortage and the crisis of civilization is the midst of tremendous instinctive challenges and the visionary road ahead (Mukherjee 2011). Society needs such challenges with the progress and betterment of civilization. Global energy and environmental scenario is in the avenue of great distress. Man's progress needs to be re-envisioned at each step of life. Global water shortage is a serious crisis. History of human scientific endeavour is in a distressful situation. The question of health issues due to arsenic infected human beings brings up new challenges and newer answers. Human society is in deep peril. The crisis, the vision of human health and the wide road to successful sustainability will all lead a long way in the immense visionary path of human progress. Arsenic groundwater contamination ground reality and global water crisis in today's world are linked by an unsevered umbilical cord. Road ahead for human society, the vistas of scientific progress and the innovative scientific research pursuit will lead a visionary way in the true realization of environmental sustainability and the successful sustainable development. Global water shortage is a parameter for a nation's negative economic growth. Successful and positive sustainable development can only be achieved when the question of provision of basic needs is re-envisioned. Vision of science, the human progress and the vistas of science ahead will veritably open up new doors of innovation and future directions in years to come (Mukherjee 2011).

ARSENIC AND HEAVY METAL GROUNDWATER CONTAMINATION AND THE FUTURE OF GLOBAL WATER CRISIS

Global water crisis is ushering in a new dawn of environmental research. Progress of civilization, the challenges ahead and the ushering in a new era of environmental engineering paradigm. Occurrence of arsenic in groundwater and its presence in drinking water has been recognized as a major health concern in major parts of the world. With the discovery of newer sites in the recent past, the arsenic contamination scenario is in the midst of major distress. The world of technology and the world of water engineering needs to be revisited and rebuilt at every step of human progress. Human civilization is in a state of immense challenges. Heavy metal groundwater remediation will be the ultimate focus of today's scientific endeavour and tomorrow's challenges. Arsenic crisis and its alleviation will be the vision and technology of tomorrow. The vision of arsenic and heavy metal groundwater remediation needs to be rebuilt and restructured. Global water crisis and the future of technology are in the path of deep comprehension as well as deep crisis. Advancement of science and the technology and the vision of tomorrow will go a long way in the true emancipation of technological advancements in heavy metal groundwater remediation. The future of global water crisis is in a crucial juxtaposition of deep introspection and deep scientific vision. True vision is in the midst of difficulties and immense catastrophes in global water crisis. Concerted effort from civil society, the battle against scientific validation and the advancement of technology are the torchbearers of a new generation of scientific forbearance. Tremendous effort, immense technological advancements and the forward visionary technologies will lead a long way in the true evolution and true emancipation of water science and water technology. Arsenic crisis needs to be re-envisioned and rebuilt (Mukherjee 2006).

SOCIETY, TRUE EMANCIPATION OF SCIENCE AND THE FUTURE OF WATER TECHNOLOGY

Impact of groundwater and drinking water contamination on human civilization is immense and path breaking. Arsenic contamination of drinking water in South Asia is a bane to human scientific progress. In such a crucial juncture, visionary technologies will pave the path towards alleviation. South Asia is in a truly deep crisis. Human development, human progress and human vision are a difficult stake. Man's vision is in a state of disaster. True emancipation of science is greatly stunted. Human history is in the midst of a veritable disaster. The scale of devastation in an arsenic infected region is immense and catastrophic. South Asia, particularly India and Bangladesh are in the throes of immense and unmitigated devastation. Vision of science, the scientific urge to excel and the world of challenges over disaster will lead a visionary way in the true alleviation of the world's greatest human disaster (Kumar 2011). Water technology is in deep distress. Human society is in a devastating blunder. The future of water science and water engineering are experiencing a culpable blunder. Scientific understanding and scientific vision are in total disaster. Scientific endeavour is facing a bane of human life and a disaster to the progress of every step of human life. Science and engineering in South Asia and some parts of the world are in the throes of severe and awesome challenge. Man's scientific prowess, civilization's urge for scientific creation and the unmitigated challenges to human civilization will veritably reassure the fundamentals of science and engineering of remediation. South Asia's challenges will open new doors of fundamental science of heavy metal groundwater remediation and subsequent bioremediation. The doors of science and human life are wide open. History of engineering will usher in a new beginning with every step of drinking water crisis. Society and its urge to excel will predominate a new beginning. The future of groundwater remediation is moving towards a disastrous era. The challenges, the futuristic vision and the success of science is ushering in a new era. Man's vision, mankind's challenges and visionary frontiers of engineering will lead a long way in greater emancipation of water technology and drinking water treatment. The chemistry of groundwater heavy metal contamination is challenging and replete with barriers. Visionary frontiers need to be surpassed with immediate effect with every step of human progress. The basic needs of human civilization such as provision of clean drinking water need to readdressed and re-envisioned with each step of human history. South Asia is in great and immense distress. The society needs to plunge forward in addressing the issue. Arsenic remediation and drinking water issues are devastating the scientific horizon of human mankind. Disaster and catastrophes are replete in the futuristic vision of innovative remediation technologies (Kumar 2011).

ADVERSE HEALTH EFFECTS DUE TO ARSENIC GROUNDWATER CONTAMINATION

Devastating health effects of arsenic depend on the dose and duration of the exposure. Specific dermatological effects are characteristics of chronic exposure to arsenic. Salient dermatological features are melanosis (pigmentation) and keratosis (rough, dry, papular skin lesions), both may be spotted or diffuse. Chronic exposure to arsenic may also cause reproductive, neurological, cardiovascular, respiratory, hepatic, haematological and diabetic effects in humans. Ingestion of inorganic arsenic is an established cause of skin, bladder and lung cancer (Mukherjee 2006, Kumar 2011).

Health issues due to arsenic contamination are disastrous and ever-increasing. Cancer is a common ailment which needs to be addressed veritably in the path towards scientific progress towards remediation. Vision of science needs to be rebuilt and restructured at every step of human life and scientific progress. Human health should be of prime concern which is veritably linked with successful environmental sustainability. Arsenic groundwater contamination is causing immense havoc to the horizon of science and the entire environmental engineering scenario. Vision of science needs to usher in a new dawn and a new beginning in years to come. Successful sustainable development is in a new path of glory and effective scientific progress. Environmental sustainability can only be realized veritably when the human civilization progresses forward in the area of heavy metal decontamination along with the ushering in of a new vision of science and engineering. South Asia's catastrophe is devastating the scientific horizon and the scientific conscience of human progress. The challenge, the vision and the future perspective of the advancement of science and technology are opening up new doors of innovation in the field of scientific research pursuit in arsenic and heavy metal groundwater contamination.

A CRITICAL REVIEW OF VISIONARY TECHNOLOGIES FOR GROUNDWATER REMEDIATION

Visionary technologies are the urge of science as human society moves forward towards a newer scientific vision. In the environment, the heavy metals are generally more persistent than organic contaminants such as pesticides or petroleum byproducts. They can become mobile in soils depending on soil pH and their speciation. So a fraction of the total mass can leach to aquifer or can become bioavailable to living organism. 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 (Hashim 2011).

Over the past few decades, many remediation technologies were applied all over the world to deal with contaminated soil and aquifers. A technology and visionary science functioning successfully under some operating conditions, inherently possess some limitations by virtue of which it may not function as effectively in other conditions. So this treatise elucidates all the applied and emerging technologies for heavy metal groundwater and soil remediation, along with their scopes, advantages, limitations and vision (Hashim 2011).

In the past, some technologies were applied for removing only petroleum products, some for inorganic solvent removal, while some were earmarked for heavy metal removal. Of late, this barrier has been diminishing as scientists around the world are combining various technologies for groundwater remediation. Technology should be indigenous and reach the teeming millions of South Asia in particular. The huge gap between discovery and scientific validation should be decreased in opening new doors of scientific innovation and scientific instinct in decades to come.

HEAVY METALS IN GROUNDWATER, ITS VISIONARY TECHNOLOGIES AND THE POSITIVE FUTURE

Heavy metals occur in the earth's crust and may get solubilized in groundwater through natural processes or by change in soil pH. Moreover groundwater can get contaminated with heavy metals from landfill leachate, sewage, leachate from mine tailings, deep-well disposal of liquid wastes, seepage from industrial waste lagoons or from industrial spills and leaks. Vision of science and engineering is stunted at each step of history and time with the evergrowing concern of arsenic groundwater remediation. West Bengal state of India and Bangladesh are in the throes of a deep disaster. Instinctive introspection, the state of groundwater contamination and the future thoughts of technology will lead a long way in the true realization of vision of pure drinking water provision. Technologies defeated and challenges are in the path of an worldwide disaster (Hashim 2011).

A variety of reactions in soil environment e.g. acid/base, precipitation/dissolution, oxidation/reduction, sorption or ion exchange processes can influence the speciation and mobility of contaminants. The rate and extent of these reactions will depend on factors such as pH, Eh, complexation with other dissolved contaminants, sorption and ion-exchange capacity of the geological materials and organic matter content. Groundwater flow characteristics is vital in influencing the transport of metal contaminants (Hashim 2011).

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. (Hashim 2011.

VISION OF REMEDIATION TECHNOLOGIES FOR HEAVY METAL CONTAMINATED GROUNDWATER

Vision of remediation technologies are in the path of an evergrowing concern and unmitigated introspection. Scientific knowledge and scientific truth are in the midst of deep retrospection and unimaginable comprehension. The devastation in human health due to arsenic groundwater contamination is shockingly alarming (Hashim 2011). Today's technology stands in the midst of immense calamities. Environmental and energy sustainability is moving towards a greater shocking phenomena. The challenge only lies in the true vision of drinking water treatment. Bangladesh and West Bengal, India needs to gear up towards unmitigated challenges, (Hashim 2011). The challenge of successful groundwater remediation and the future of environmental sustainability is immense as well as far-reaching. Scientific efforts, scientific doctrine and cognizance needs to be re-envisioned at this critical juncture of human progress.

Several technologies exist for the remediation of heavy metals contaminated groundwater and soil and they have some definite outcomes such as i) complete or substantial destruction/degradation of the pollutants ii) extraction of pollutants for further treatment or disposal, iii) stabilization of pollutants in forms less mobile or toxic, iv) separation of non-contaminated materials and their recycling from polluted materials that require further treatment, v) containment of the polluted material to restrict exposure of the wider environment (Hashim 2011). Thus, in such an environmental engineering crisis, vision needs to be greatly re-addressed with each step of human scientific progress. Technological solutions will go a long way in alleviating this global water crisis. Success of human civilization, the progress of mankind and the immense potential of today's technology will enhance the powers of application of today's technological progress. The challenges of groundwater remediation are varied, visionary and versatile. The main thrust area of today's vistas of science and engineering is environmental sustainability. In today's world environmental sustainability has an umbilical cord with global drinking water issues. Science is ushering in a new era. Remediation technologies including bio-remediation will veritably bring in a new era of environmental sustainability in years to come. Science, engineering and technological advancements will lead a visionary way in the true realization of successful environmental sustainability (Hashim 2011).

Chemical treatment technologies: Groundwater contaminants are often dispersed in plumes over large areas, deep below the surface, making conventional types of remediation technologies difficult to apply. In those cases, chemical treatment technologies may be the best choice. Chemicals are used to decrease the toxicity or mobility of metal contaminants by converting them to inactive states. Oxidation, reduction and neutralization reactions can be used for this purpose. Reduction is the method commonly used (Hashim 2011).

In-situ treatment by using reductants: When groundwater is passed through a reductive zone or a purpose-built barrier, metal reductions may occur. Based on both laboratory and field studies, an appropriately created reduced zone can remain in reducing conditions for up to a year. Manipulation of sub-surface redox conditions can be implemented by injection of liquid reductants , gaseous reductants or reduced colloids (Hashim 2011).

Reduction by dithionite: Dithionites can substantially reduce redox sensitive metals such as Cr, U and Th to less oxidation states. Dithionites can be injected downstream of the contaminant plume to create a reduced treatment zone formed by reducing Fe (III) to Fe (II) within the clay minerals of the aquifer sediments. The flowing contaminants will either be degraded or be immobilized while passing through the zone. Vision of science of chemistry will veritably open up new thoughts and newer future directions (Hashim 2011).

Reduction by gaseous hydrogen sulphide: Gaseous hydrogen sulphide (H_2S gas) was tested for in-situ immobilization of chromate contaminated soils by Thornton & Jackson

(1994), although the delivery of H_2S gas to the contaminated zone posed to be somewhat difficult. Nitrogen could be used as a carrier gas for the delivery and control of H_2S gas during treatment and also for removal of any unreacted agent from the soil after treatment (Hashim 2011).

Reduction by using iron based technologies: Iron based technologies for remediation of contaminated groundwater and soil is a well documented arena. The ability of iron as Fe(0) and Fe(II) to reduce the redox sensitive elements have been demonstrated at both laboratory scale and field tests (Hashim 2011).

Zero-valent colloidal iron (colloidal ZVI): ZVI (Fe^0)was found to be a strong chemical reductant and was able to convert many mobile oxy anions and oxy cations into immobile forms. Colloidal ZVI of micro-nanometer particle size can be injected into natural aquifers and this was advantageous than a treatment wall filled with ZVI since no excavation of contaminated soil was needed, human exposure to hazardous materials was minimum and injection wells could be installed much deeper than trenches. Furthermore, the treatment barrier created this way could be renewed with minimal cost or disturbance to above-ground areas (Hashim 2011).

Removal of chromium by ferrous salts: The toxic or carcinogenic Cr(VI) was reduced to the less toxic Cr(III) form , which readily precipitated as $Cr(OH)_3$. One researcher in the past reported a case, where, at the site of a former paper mill on the Delaware river, USA ,the in-situ application of an acidified solution of ferrous sulphate heptahydrate, via a combination of wells and trenches, reduced concentrations of Cr(VI) in groundwater from 85000 µg/L to 50 µg/L by reductive precipitation (Hashim 2011).

Soil washing: This technique involves washing of contaminated soil by water and other extracting agents, i.e. acid or chelating ligands added to the water to leach out the reactive contaminants from the soil. According to Sikdar et al. (1998), two approaches are taken for soil washing. In the first approach, soil washing as is considered as a fractionating technique for isolating the finer particles i.e. clay, silt or humic substances which captivates the contaminants in the soil. The second approach is based on washing the entire soil with a fluid that extracts the contaminants from all size fractions. The in-situ soil washing and surfactant or solvent assisted soil washing techniques use organic solvents, such as alcohols, polymers, poly-electrolytes, chelants, inorganic acids, or surfactants depending on site-specific circumstances (Hashim 2011).

In-situ soil flushing: The flushing liquid (water or chemical extractant solutions) is applied on the surface of the site or injected into the contaminated zone. The resultant leachate can then be recovered from the underlying groundwater by pump and treat methods (Hashim 2011).

In-situ chelate flushing: Injecting chelating agents in contaminated soils may give rise to very stable soluble metal-chelate complexes pulling out the metals from solid phase to the solution phase. The most frequently used chelating agents are EDTA, citric acid and diethylene triamine pentaacetic acid (DTPA) (Hashim 2011).

In-situ remediation of heavy metals by selective ion exchange methods: An important class of ion-exchange resins includes solvent-impregnated resins (SIRs). These materials combine the advantages of liquid-liquid extraction and ion-exchange involving a separate solid phase. SIRs removed very low concentration of contaminants in the presence of high concentration of microelements (e.g.. calcium, magnesium, sodium, potassium and chloride) present in water at nearly neutral pH and the presence of other anions, all of which compete for available sites on the SIRs (Hashim 2011).

Heavy metal groundwater contamination is in the path of new dawn of human civilization. Human scientific progress is in the threshold of a new scientific regeneration. In today's world, scientific vision and scientific truth are in the path of newer success vistas. In-situ groundwater remediation is in the path of new success, innovation and newer scientific imagination.

BIO-REMEDIATION- THE NEXT GENERATION ENVIRONMENTAL ENGINEERING TOOL

The term bioremediation has been introduced to describe the process of using biological agents to remove toxic waste from environment. Bioremediation is the most effective management tool to manage the polluted environment and recover contaminated soil. Bioremediation has been used at a number of sites worldwide, including Europe, with varying degrees of success. Scientific vision has ushered in both in-situ and ex-situ strong scientific growth. Future of bioremediation is in the path of visionary scientific endeavour (Kumar 2011). Vision of science is moving towards a definite direction. Bio-remediation is a next generation environmental engineering technique. Scientific discovery and scientific validation will lead a long and visionary way in the true emancipation of science and engineering of bioremediation. Bioremediation and natural attenuation are also seen as a solution for emerging contaminant problems, e.g.: endocrine disrupters, landfill stabilization, mixed waste biotreatment and biological carbon sequestration. Microbes are helpful to remediate the contaminated environment (Kumar 2011). Number of microbes including aerobes, anaerobes and fungi are involved in the bioremediation process (Kumar 2011). History of bioreme-diation, vision of science and the road towards progress in groundwater remediation will veritably go a long way in the true emancipation of remediation technology in decades to come (Kumar 2011).

TRUE VISION OF SCIENCE OF WATER TECHNOLOGY

True vision of science and engineering of water technology is alarming and shocking in today's world in South Asia. Targets towards scientific future, the challenges of science and the future directions needs to be re-envisioned at each step of human history and time. Water science and water engineering is in today's world in the midst of unmitigated calamity. Vision of science is today touching newer paradigm with each step of human history, successful sustainability and the technologies for groundwater remediation. Successful environmental sustainability ushers in from tremendous scientific vision and concerted effort from the civil society. Water technology is gearing up from one visionary challenge over another. Technology and engineering is moving from one future dimension over another. Arsenic and heavy metal groundwater remediation is gearing up from one scientific challenge over another. The teeming millions in South Asia are the disastrous sufferers and the world needs to address the drinking water crisis vehemently.

History of human civilization's progress is challenging. Groundwater remediation will gain ground if the concept of environmental sustainability is envisaged. The vision of technological advancements in today's world is far-reaching and stands on the inevitable spectrum of environmental sustainability. Forays of engineering, vision of science and the arduous road ahead will surely open up new challenges and new vistas of scientific vision (Cheryan 1998, McCutcheon 2005, Fritzmann 2007, Lattemann 2008).

FUTURE RECOMMENDATIONS OF STUDY IN THE FIELD OF GROUNDWATER REMEDIATION IN INDIA AND SOUTH ASIA

Future vision of water science and heavy metal groundwater remediation are in the avenue of immense scientific success and unmitigated vision. Scientific blunder and the stunted scientific understanding and vision are in the path of future dimensions of human progress. Human future thoughts and the awe-inspiring rational approach of vision of science is ushering in a new day. Future vision and future recommendations in the study of heavy metal groundwater remediation are wide and far-reaching. Human progress is slowly moving out of deepening crisis.

Strong future recommendations of the study are the veritable challenges in new innovations in remediation technologies. Scientific vision will inevitably usher in a new era of scientific judgement and challenges. Research is intense but replete with failure. At such a crucial juxtaposition of human scientific progress, research endeavour are ushering in a new dawn of science and vision.

Groundwater heavy metal and arsenic remediation is the path of serious and veritable challenges. Concerted effort from civil society, the scientific urge to excel and the wide and arduous path to alleviation of drinking water crisis are the today's challenges. Science and engineering are in the midst of immense vision. Human civilization's greatest environmental disaster is in the midst of ever-deepening crisis. Future challenges and future directions today stands in the midst of scientific optimism and scientific forbearance. South Asia is in the midst of veritable changes in provision of basic needs. Future recommendations of drinking water crisis is to target environmental pollution control and successful environmental sustainability.

FUTURE VISIONARY THOUGHTS AND FUTURE TRENDS IN GROUNDWATER SCIENTIFIC PURSUIT

Future vision of heavy metal groundwater remediation needs to be re-addressed. South Asia is in the midst of immense challenges. Scientific fortitude and scientific vision will move forward towards a new era of visionary future. The challenges, vision of science and the newer and innovative technologies are ushering in a new generation of future scientific vision. The avenues of science are in the course of unimaginable disaster. Groundwater heavy metal contamination is in the path of unmitigated disaster. A deep scientific understanding and an instinctive innovative idea are the future of the alleviation of this problem.

CONCLUSION

Environmental engineering science is, in today's world, in the path of great distress. Heavy metal groundwater contamination is a catastrophe to the human civilization. Vision of technology, road towards visionary challenges and mitigation of the drinking water crisis will go a leading way in the true emancipation of environmental engineering tools. Arsenic and heavy metal groundwater remediation will open new doors of innovation and instinct. The future of South Asia is in deep crisis. Scientific frontiers and scientific innovation are the orders of this century. A deep understanding and a deep scientific concern will veritably lead the world of environmental engineering science to a new dawn of human civilization. Arsenic contamination of drinking water is of major concern in India and Bangladesh specifically. Vision of science and engineering and the wide road of unimaginable technological progress will surely evolve new and frontier technologies into the world of global drinking water crisis. Global water shortage, drinking water crisis and the human progress of civilization will lead a long way in opening wide doors of scientific innovation in years to come. The veritable progress of mankind will lead human scientific endeavour to a new future direction and innovative future dimension.

REFERENCES

Byrne, J. and Shen, Bo. 1996. The challenge of sustainability, balancing China's energy, economic and environmental goals. Energy Policy, 24(5): 455-462.

Hanley, N., Mcgregor, P.S., Swales, J.K. and Turner.K. 2009. Do increases in energy efficiency improve environmental quality. Ecological Economics, 68(3): 692-709.

Masters, G.M. and Wendell, P.E.2013. Environmental Engineering and Science, Prentice Hall India Learning Private Limited.

Banerjee, A. and Solomon, B. 2003. Eco-labeling for energy efficiency and sustainability-a meta evaluation of US programs. Energy Policy, 31: 109-123.

Goodland, R. 1995. The concept of environmental sustainability. Annual Review of Ecology and Systematics, 26: 1-24.

Jenkins, D. 2013. Renewable Energy Systems-The Earthscan Expert Guide to Renewable Energy Technologies for Home and Business. Routledge-Taylor and Francis Group (First Edition).

Nair, J. 2009. Impending Global Water Crisis. Pentagon Press, New Delhi, India.

Newell, Peter, Jon Phillips and Dustin Mulvaney 2011. Human Development Research Papers, Pursuing Clean Energy Equitably. United Nations Development Programme, November.

Palit, S. 2013. Concept of sustainability and development in Indian perspective: a vision for the future. Journal of Environmental Research and Development, 8(1).

Research and Development on Renewable Energies 2009. A global report on photovoltaic and wind energy. International Science Panel on Renewable Energies.

Sarkar, A.N. 2010. Global Climate Change. Pentagon Press, New Delhi, India.

Wisner, B., Gaillard, J.C. and Kelman, I. 2011. The Routledge Handbook of Hazards and Disaster Risk Reduction. Routledge, Taylor and Francis Group.

Kalam Abdul, A.P.J. and Singh, S.P. 2011. Target 3 billion, PURA: Innovative solutions towards sustainable development. Penguin Books.

Mukherjee, A., Sengupta, M.K., Amir Hossain, M., Ahamed, S., Das., B., Nayak, B., Lodh, D., Rahman, M.M. and Chakrabarti, D. 2006. Arsenic contamination of groundwater: A global perspective with emphasis on Asian scenario. Journal of Health, Population, Nutrition, 24(2): 142-163.

Cheryan, M. 1998. Ultrafiltration and micro filtration handbook. Technomic Publishing Company Inc.

McCutcheon, J.R., McGinnis, R.L., Elimelech.M. 2005. A novel ammonia-carbon dioxide forward (direct) osmosis desalination process. Desalination, 174: 1-11.

Fritzmann, C., Lowenberg, J., Wintgens, T. and Melin, T. 2007. State-of-the-art of reverse osmosis desalination. Desalination, 216: 1-76.

Lattemann, S. and Hopner, T. 2008. Environmental impact and impact assessment of seawater desalination. Desalination, 220: 1-15.

Kumar, A., Bisht, B.S., Joshi, V.D. and Dhewa, T. 2011. Review on bioremediation of polluted environment: A management tool. International Journal of Environmental Sciences, 1(6): 1079-1093.

Hashim, M.A., Mukhopadhaya, S., Sahu, J.N. and Sengupta, B. 2011. Remediation technologies for heavy metal contaminated groundwater. International Journal of Environmental Management, 92: 2355-2388.

Sikdar, S.K., Grosse, D. and Rogut, I. 1998. Membrane technologies for remediating contaminated soils: a critical review. Journal of Membrane Science, 151: 75-85.

Thornton, E.C. and Jackson, R.L. 1994. Laboratory and field evaluation of the gas treatment approach for in-situ remediation of chromate contaminated soil. Prepared for the Department of Energy, USA.