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General Research Paper

Microfiltration, Groundwater Remediation and Environmental Engineering Science - A Scientific Perspective and a Far-reaching Review

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ABSTRACT

The environmental engineering paradigm is surpassing one visionary frontier over another. Mankind today stands in the midst of optimism and scientific vision. The world of challenges is befitting to the progress of human civilization. The road to progress in implementation of environmental sustainability is vast, varied and ground-breaking. In such a crucial juncture of history and time, the need of application of environmental engineering science is of immense and effective importance. Microfiltration and other membrane separation processes are the ultimate avenues of scientific and engineering progress. Science and engineering are moving steadfastly towards a newer scientific generation and a newer scientific understanding. The step forward is painstaking as regards zero-discharge norms. Environmental regulations and stringent environmental restrictions have plunged the scientific community to devise paths towards progress. Industrial pollution control, wastewater treatment and application of microfiltration are the primordial issues targeted in this treatise. The focus towards addressing novel separation processes and novel environmental engineering techniques stands today as a formidable challenge in the road towards zero-discharge norms. The author diligently and lucidly brings forward to the scientific community the immense rigorous and effective challenges in the application of microfiltration as an efficient membrane separation process. History of environmental engineering science, history of science and technology needs to be readdressed and reassessed in the future application of membrane science as an efficient separation technique.

INTRODUCTION

Microfiltration has an umbilical cord with environmental engineering science and industrial wastewater treatment. The domain of environmental engineering and environmental sustainability today stands on a strong foothold and a visionary groundwork. Environmental pollution control is the primordial issue which needs to be tackled with the progress of humanity and road to excel in science and engineering. Zero-discharge norms stands today in the midst of immense vision as well as instinctive scientific endeavour. Microfiltration is such a branch of membrane science which is surpassing visionary scientific frontiers.

Microfiltration (abbreviated as MF) is a type of physical filtration process where a contaminated fluid is passed through a special pore-sized membrane to separate microorganisms and suspended particles from process liquid (Cheryan 1998). It is commonly used in conjunction with various other separation processes such as ultrafiltration and reverse osmosis. Microfiltration serves as a pretreatment for other separation processes such as ultrafiltration and a post-treatment as a granular media filtration (Kepa et al. 2008, Zhou et al. 2002, Cheryan 1998). The typical particle size used for microfiltration ranges from 0.1 to 10 µm. In terms of approximate molecular weight these membranes can screen and separate macromolecules generally less than 100,000/mol (Cheryan 1998).

Microfiltration surpasses various and varied challenges-scientific as well as economical. In today's scientific civilization and scientific pursuits, one needs to look at the economy and efficiency of the process. In such a visionary platform, microfiltration rises above other membrane separation processes with its biochemical engineering applications. Microfiltration, membrane science and environmental engineering science in today's scientific world is effectively surpassing visionary frontiers and reaching out to millions with respect to global water shortage, industrial wastewater treatment and provision of clean drinking water. Science and technology applications in human society is opening up new doors and newer visionary avenues in years to come (Cheryan 1998).

VISION BEHIND THE PRESENT TREATISE

Scientific vision and scientific truth today are the primordial issues in progress of today's human civilization. The author clearly delineates the importance of microfiltration in environmental engineering science and biochemical separations. Zero-discharge norms, industrial wastewater treatment and environmental sustainability shapes the future of human civilization and the face of progress of science and technology. With a cogent insight, the world of challenges stands in the distant horizon with immense illusion and in the similar manner sound and purposeful vision. Man's history needs to be re-drafted and revamped with the changing face of time (Cheryan 1998).

The vision behind the present treatise is vast, bright and far-reaching. Challenges, difficulties and path towards progress are immense due to the phenomena of fouling. Research endeavours and research validation will go a long way in evolving new challenges and new avenues of progress. A deep and cogent insight and a strong comprehension on the application areas of microfiltration is addressed and re-envisioned in this treatise.

DEFINITION AND CLASSIFICATION OF MEMBRANE SEPARATION PROCESSES

Definition of membrane separation processes is constructive and is based on particle size to be separated. The vision of the effectiveness of its separation phenomena is purposeful and far-reaching. Scientific advancements, scientific vision and progress of environmental engineering science inevitably depends on the success of separation phenomena (Cheryan 1998). Characteristics of membrane processes are given in Table 1.

Microfiltration and biotechnological applications: Micro-filtration and biotechnology in today's world of innovation and challenge have an unsevered linkage. The major and purposeful vision of microfiltration in today's application domain is its foray into biotechnology. Challenges, difficulties and vision will open a new day and a new era. Micro-filtration and biotechnology are two branches of scientific advancements which is overcoming and surpassing visionary frontiers. Man's scientific prowess and mankind's scientific vision are the torchbearers of tomorrow (Cheryan 1998).

Biotechnology and nanotechnology are the next generation science. The domain of biotechnology is instinctively surpassing visionary frontiers. Applications, validation of scientific endeavour and human societal applications are wide and varied. Membrane science and microfiltration are on the verge of evolving new technology to interface with biotechnology. History of science and engineering and application of membrane science and biotechnology will witness a new dawn (Cheryan 1998).

HISTORICAL DEVELOPMENTS

Historical developments are the focal points of the immense and arduous path to success for the separation phenomena of membrane science. Scientific cognizance, scientific vision and deep scientific understanding will go a long way in opening the windows of innovation in membrane science and technology.

The intricate phenomenon of osmosis, which is the transport of water or solvent through a semi-permeable membrane (defined as a membrane that is permeable to solvent and impermeable to solutes), has been known about since 1748, when Abbe Nollet observed that water diffuses from a dilute solution to a more concentrated one when separated by a semi-permeable membrane. Dutorchet is credited with introducing the term osmosis to characterize spontaneous liquid flow across permeable partitions. In 1855, Fick developed the first synthetic membrane, made apparently of nitrocellulose. Two years later, Traube also prepared artificial membranes, while Pfeffer reported in 1877 the successful manufacture of membranes made by precipitating copper ferrocyanide in the pores of porcelain (Cheryan 1998).

In the early 1950s, Samuel Yuster of the University of California, Los Angeles, had predicted with great vision, that based on the Gibbs adsorption isotherm, it should be possible to produce freshwater from brine. Srinivasa Sourirajan, who also worked in the same university, reported some success with this concept using commercially available homogeneous membranes. He used a hand-operated pump, and it is reported that it took a few days to produce a few millilitres

Table 1: Characteristics of membrane processes (Cheryan 1998).

Process	Driving Force	Retentate	Permeate
Osmosis	Chemical potential	Solutes, water	Water
Dialysis	Concentration difference	Large molecules, water	Small molecules, water
Microfiltration	Pressure	Suspended particles, water	Dissolved solutes, water
Ultrafiltration	Pressure	Large molecules, water	Small molecules, water
Nanofiltration	Pressure acids,water	Small molecules, divalent salts,dissociated water	Monovalent ions, undissociated acids,
Reverse osmosis	Pressure	All solutes, water	Water
Electrodialysis	Voltage/current	Nonionic solutes, water	Ionized solutes, water
Pervaporation	Pressure	Nonvolatile molecules, water	Volatile small molecules, water

of freshwater (Loeb 1981). From 1958 to 1960, Sourirajan, now joined by Sidney Loeb, attempted to modify commercial cellulose acetate membranes by heating them under water, in the apparent hope that this would expand the pores and that the pores would remain open when the membrane cooled, thus increasing the flux (Cheryan 1998).

PHYSICAL CHEMISTRY OF MEMBRANE SEPARATION

Thermodynamic principles govern the physical chemistry of membrane separation. Membrane separation processes are the fountainhead of chemical engineering and environmental engineering science. The success of membrane separation processes lies with immense scientific vision on the physical chemistry of the entire phenomenon. Process design, environmental engineering science and its immense applications are all interlinked and will go a long way in evolving new dimensions of the membrane separation phenomenon (Cheryan 1998).

CHEMICAL POTENTIAL AND OSMOSIS

The success of membrane separation operation lies immensely on the chemical potential of fluid mixtures. Scientific truth and scientific understanding are the immense torch bearers to the application of osmosis which stands as the earliest membrane separation process. Unlike other intensive thermodynamic properties such as pressure and temperature (i.e. those not dependent on the size of the system), chemical potential cannot be physically felt the way heat and force can, which results in some difficulty for the novice when trying to grasp its significance. In simple terms, chemical potential can be envisioned as being to chemical energy what temperature is to heat energy, pressure is to mechanical energy (e.g. flow of fluids), and voltage, or emf, is to pressure energy (Cheryan 1998).

Vapour pressure: Vapour pressure is a primordial parameter in the separation phenomena of a membrane. Challenges and vision needs to be reshaped and scientifically rejudged. The vapour pressure of a solution is always less than that of a pure solvent (Cheryan 1998). This is best expressed according to Raoult's law as follows:

$P = X_1P^0$, where P is the vapour pressure of the solution and P^0 is the vapour pressure of the pure solvent at that temperature.

As mentioned earlier, to prevent passage of solvent from the pure solvent side to the solution side, we need to apply a pressure on the solution side equal to the osmotic pressure difference.

The criterion for osmotic equilibrium is that the chemical potential of the solvent should be the same on both sides of the membrane, rather than the "pressures" being the same (Cheryan 1998).

Osmotic pressure and chemical potential: In order to develop a relationship between osmotic pressure, chemical potential, and parameters that can be easily measured experimentally, we need to make two assumptions : 1) the solvent vapour behaves ideally and Raoult's law applies and 2) the liquid is incompressible. Van't Hoff dealt lucidly and intuitively with the phenomenon of thermodynamics of the separation process (Cheryan 1998).

The physical significance and efficacy of osmotic pressure in biological and clinical situation is widely well known: the osmotic pressure difference is what causes germinating seeds to burst open their protective coat, causes the drawing of water from the soil into the root system of plants, and can burst open cells by immersing them in a solution of much lower osmotic pressure (Cheryan 1998). As far as membrane science and its conditions are concerned, its major significance lies in the fact that the external pressure that must be applied for significant permeate flux must be higher than the osmotic pressure of the solution (Kepa et al. 2008, Zhou 2002, Al-Kdasi 2004).

MEMBRANE SEPARATION PROCESSES DOCTRINES AND IMPORTANCE

Membrane separation science and the doctrine behind it today is in the midst of unimaginable and intense innovation. The immense importance of microfiltration lies in its application in biochemical separations and industrial wastewater treatment. A scientist's as well as a man's vision needs to be re-envisioned and restructured with the immediate and imminent concern of environmental catastrophes. The wider vision of science and engineering is at stake today with the major environmental engineering catastrophes of this century and the past century (Kepa et al. 2008, Cheryan 1998).

The development and application of the Sourirajan-Loeb synthetic membrane in 1960 provided a visionary and valuable tool to the process industries, but it faced a lot of difficulties and barriers in its early days. This model was the torchbearer to the visionary age of membrane science and membrane separation processes. The situation is different in today's realm of membrane science as membranes are more robust, modules and equipment are better designed and fouling phenomenon is well addressed. More important, costs have come down significantly, partly because of the maturing of the technology and partly because of competition from an increasing number of membrane suppliers and original equipment manufacturers (OEM) (Cheryan 1998).

Microfiltration, immense scientific understanding and vision: Microfiltration, intense scientific revamping and the history of difficulties leads towards a newer generation and a newer vision of application of microfiltration in biochemical separations. History needs to be rebuilt and reshaped towards a vibrant future. The environmental engineering plight and the disasters of Three Mile Island, USA, Chernobyl, Russia, and Fukushima, Japan catastrophes have urged the scientific community to strive towards a newer vision and effective challenges.

Microfiltration and other membrane separation processes are surpassing visionary frontiers and overcoming difficult challenges. Difficulties concerning fouling, the urge to excel and the vision for tomorrow have propelled the scientific community to venture new realms and newer areas of scientific pursuit.

The vision of application of microfiltration to the ever-concerning domain is also related to global water shortage. Industrial wastewater treatment should be on the other side of the coin. The progress of human civilization and forays into technological advancements have an unsevered umbilical cord. Immense scientific understanding and instinctive vision will surely open new horizons of innovation.

MEMBRANE CHEMISTRY, STRUCTURE FUNCTION AND FUTURE VISION

Membrane chemistry is the most intricate and most important feature of successful application of membrane separation processes. The inherent barriers lies inside the membrane structure. The vision to excel has helped scientists to strive forward towards newer goal and newer objectives. Membrane chemistry, structure and function is the backbone of analysis of the success of the separation process. The future vision of separation phenomenon is wide and ground breaking. Science and technology is taking a definite step towards newer innovation and newer scientific instinct.

MICROFILTRATION AND MEMBRANE SCIENCE - DEFINITIONS AND CLASSIFICATIONS

Membrane separation processes today stand in the midst of immense optimism, scientific vision and hope. Scientific understanding and the world of challenges are the torch-bearers to a new generation of scientific cognizance and deep comprehension. Membrane separation processes can be classified according to its separation phenomena and the particle size which needs to be separated. Scientific justification and adroitness of science are coinwords of environmental engineering in today's human civilization (Cheryan 1998).

Depth versus screen filters: Filters are manufactured and developed from a variety of materials using several methods, but they can all be classified into two general categories: depth filters or screen filters. Depth filters consist of a matrix of randomly oriented fibres or beads that are bonded together to form a tortuous maze of the flow channels. Common materials of construction include cotton, fibre glass, asbestos, sintered metals, and diatomaceous earth. The intriguing phenomena is that particulates that are insoluble or colloidal in nature are removed from a fluid by entrapment or adsorption to the filter matrix.

A screen filter, in comparison, separates by retaining particles on its surface, in much the same manner as a sieve. The structure is usually more rigid, uniform, and ontinuous, with pore size more accurately controlled during manufacture. The demarcation between depth and screen filters evolves into newer vision and newer technologies in membrane science and its separation phenomenon. The challenge towards effective separation technique depends on membrane technology, microfiltration and ultrafiltration along with improved scientific vision (Cheryan 1998).

Microporous versus asymmetric membranes: Screen filters can be further classified according to their ultrastructure as either microporous or asymmetric (the latter is also referred to as "skinned" membranes) (Cheryan 1998). Microporous membranes are sometimes further classified as isotropic (with pores of uniform size throughout the body of the membrane) or anisotropic (where the pores change in size from one surface of the membrane to the other). Frequently, the terms anisotropy and asymmetry are (incorrectly) used interchangeably. Electron micrographs of microporous membranes show a multilayered screen or sieve of very small mesh size, with passageways in this mesh forming the "pores". Particles are retained on or in the surface mesh-like layer in the membrane (Cheryan 1998).

General methods of membrane manufacture: There are several methods for manufacturing membranes (Table 2). Some of the methods are applicable to a variety of polymers, and others are material specific, e.g., the heating-stretching method used to make pores in microporous polytetrafluoroethylene (PTFE) membranes. Each of these methods results in different ultrastructures, porosity and pore size distribution (Cheryan 1998).

Membrane properties: Membrane properties are the most important visionary alleys of challenge and barriers. The fetters of barriers in science need to be restructured and re-envisioned. Membrane properties shape the future of performance of membranes. Membrane chemistry, its structure and its inherent function lead a world of challenges in the field of membrane separation processes. Properties of membrane are demarcated and defined by two key parameters of

Table 2: Methods of manufacture of synthetic membranes (Cheryan 1998).

Process	Materials
Phase inversion by	Polymers
Solvent Evaporation	Cellulose acetate, polyamide.
Temperature Change	Polypropylene, polyamide
Precipitant Addition	Polysulfone, nitrocellulose
Stretching sheets of partially crystalline polymers	Polymers: PTFE
Irradiation and etching.	Polymers: polycarbonate, polyester
Molding and sintering of fine-grain powders.	Ceramics, metaloxides, PTFE polyethylene.

membrane performance-flux and rejection. Of special importance for ultrafiltration (UF) and microfiltration (MF) membranes are the pore statistics, e.g., pore "size" (usually expressed as pore diameter), pore density (number of pores per unit membrane surface area), and bulk porosity (or void volume), which is the fraction of the membrane volume occupied by the pores (Cheryan 1998).

Performance and engineering models: Several mathematical models can be gleaned from the literature that attempt to describe the mechanism of transport through membranes. Although the operating techniques of microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) are similar, the latter two are almost certainly not separation merely by size alone. Microfiltration and ultrafiltration, on the other hand, due to their relatively large pores, have most frequently been visualized as sieve filtration. Process engineering and performance models define the entire futuristic vision of membrane science. Process engineering phenomena, transport phenomena and separation techniques describe the engineering models of membrane technology. Challenge, validation and vision empowers the success of membrane science and engineering (Cheryan 1998).

Fouling and cleaning: Fouling and cleaning are the vexing and primordial issues of the successful performance of the membrane. Concentration polarization is the visionary barrier of tomorrow. The importance and vision of the success of the separation process is absolutely exemplary. A scientist's as well as a man's vision is emboldened with the future of the world's environment at stake. Environmental sustainability is under a difficult situation in today's human civilization. Challenges, advancement of science and technology and the progress of human race inevitably depend on environmental sustainability (Cheryan 1998).

Fouling and cleaning are the futuristic challenge of the success of membrane operation. Barriers, boundaries and frontiers are wide and many. The challenge of our scientific domain lies in the distant horizon. History of membrane science and technology is revisiting itself at every step of human scientific endeavour. Man's as well as a scientist's challenge needs to be reshaped with the ever increasing concern of environmental sustainability. Successful environmental sustainability has an umbilical cord with the provision of clean drinking water in our present day human civilization. The challenge for remediation of groundwater heavy metal contamination is immense (Cheryan 1998).

PROCESS DESIGN AND FUTURE VISIONARY ASPECTS OF MEMBRANE SEPARATION PROCESSES

Process design and chemical engineering aspects in today's scientific world are the primordial issues in the successful operation of a membrane. Our main vision and focal point in the success of separation, is the choice of the membrane and the relevant membrane technology. The challenges need to be reshaped and re-envisioned (Chiron et al. 2000, Cheryan 1998).

Future of membrane separation processes is moving in a new direction of immense scientific challenge and scientific vision. Environmental sustainability readjudicates itself in a new direction of scientific hope towards the evolution of new innovations in membrane separation processes. A scientist's vision at the age of advancement of science and engineering needs to be reshaped and restructured. Global water crisis has propelled the scientific generation and scientific domain to aim for newer ideas and newer processes. Process design visions are moving towards the new scientific generation and the world of knowledge and cognizance are reshaping the future of chemical and environmental engineering (Cheryan 1998).

Process design in membrane separation processes stands as a primordial issue in the success of the operation. Challenges, barriers and technological advancements will go a long way and improved manner in evolving new avenues of innovation and intuition (Cheryan 1998). Process design is the pillar towards chemical engineering success. The challenges, unsurpassed frontiers and the unmitigated barriers will lead a long way in the true evolution of membrane technology.

MICROFILTRATION AND THE VARIED AND VAST APPLICATION AREAS OF BIOCHEMICAL ENGINEERING

Biochemical engineering and biotechnology in today's human progress strives towards a visionary future. The umbilical cord between microfiltration and biotechnology can never be severed. A scientist's vision ushers in a new generation of scientific hope, scientific grit and scientific generation. Intense scientific pragmatism and immense scientific steadfastness is needed on the path towards progress and the march of history of engineering science. Microfiltration will surely solve many intricate problems of biochemical industrial wastewater treatment. The vision awakens human needs and concerns a holistic global water shortage. Global water shortage will surely and relentlessly usher in a new vision and a new dream. Man's challenges will never be a disgraced dream or a visionary failure. The world of challenges will never be an optical illusion in the field of membrane science if strong scientific vision is pursued (Chiron et al. 2000, Cheryan 1998).

Biochemical engineering and biotechnology today stands amidst immense scientific vision and scientific truth. Membrane science proves itself immensely in its application of biotechnology and biochemical engineering. Scientific challenges, fortitude and vast scientific forbearance will go a long way in proving the importance of membrane science in the biochemical wastewater treatment. Biotechnology and biochemical engineering are the visionary technologies of tomorrow and the next generation. The technique of microfiltration is a miniscule in the vast domain and the immense application of membrane science and technology. Human endeavour, human vision and scientific truth will surely open up new doors of extreme innovation in years to come. The challenge lies in the distant horizon with immense scientific rigour (Cheryan 1998).

INDUSTRIAL WASTEWATER TREATMENT AND APPLICATION OF MICROFILTRATION

Industrial wastewater treatment in today's human civilization is undergoing serious, severe and drastic challenges. Application of microfiltration is steadfastly moving towards a greater scientific vision and immense scientific understanding. Global water shortage is an indomitable disaster for mankind.

The technology of microfiltration is moving very fast along with other membrane separation processes towards a new vision and new challenge. Environmental sustainability, ecological balance and progress of science and engineering will go a long way in opening doors of innovation and windows of immense scientific intuition in years to come.

Industrial wastewater treatment, future of environmental pollution control and the future of mankind are opening up new vistas of challenge and scientific forbearance in years to come. In this era of environmental sustainability and progress of civilization, man's as well as a scientist's vision needs to be restructured and re-envisioned. Application of microfiltration is moving towards a new era of vision and challenge. The application area of microfiltration in industrial wastewater treatment needs to be explored with utmost vision. The challenge and the utmost vision in the scientific understanding of this separation tool has been ever-inspiring. Zero-discharge norms, environmental sustainable development and ecological balance will evolve into a new future dimension. Future and vision of microfiltration are wide and bright.

GLOBAL WATER SHORTAGE, DESALINATION AND VISION BEHIND MICROFILTRATION

Global water shortage, the march of science and engineering and the purposeful vision behind membrane separation process will enhance the immense scientific potential in years to come. Scientific introspection needs to be readdressed and revamped. Challenges and barriers are immense and indomitable but the hope and vision are similarly great and path-breaking. Desalination of seawater is a primordial issue in the success of environmental sustainability. Environmental disasters are looming large over the distant scientific horizon. Groundwater remediation and desalination stands in the midst of immense scientific hope and indomitable optimism. Science will usher in a new era of global water shortage crisis. In such a crucial juncture, the challenges are towards the application of microfiltration to industrial wastewater treatment. History of science and technology will open up a new era for innovation in years and decades to come (Chiron et al. 2000, Cheryan 1998).

Desalination and global water shortage are the forerunners of a greater emancipation of the worldwide phenomenon of environmental engineering science. The vision of microfiltration should be targeted towards desalination. Provision of clean drinking water is an important parameter towards the progress of economy of a nation. It is a basic and visionary amenity. Thus, challenges need to be redrafted and reorganized with the path towards progress of a nation. Man's history and mankind's prowess need a drastic revamping with respect to the issue of the provision of clean drinking water. History of science and technology will repeat itself vehemently with the passage of time (Chiron et al. 2000, Cheryan 1998).

Groundwater contamination and subsequent remediation are the torch bearers to a definitive future and a purposeful vision towards a global water shortage and the provision of clean drinking water. It is a bane to the human development in South Asia. Arsenic groundwater contamination is in the midst of a disastrous stake in South Asia mainly India and Bangladesh. The immediate concern, the intense research pursuit and success of membrane science will surely open up new doors of innovation in alleviating the severe crisis.

Crisis in such a mass-scale environmental disaster is immense and indomitable. Man's history, man's prowess and human cognizance will all gear up to newer avenue of innovation in the application domain of membrane science.

DIFFICULTIES, BARRIERS AND THE IMPORTANCE OF FOULING

Fouling is an impediment to the successful operation of membrane separation process. Scientific vision needs to be addressed and restructured. Scientific challenges need to be targeted to a visionary future direction. Scientific vision and scientific difficulties have an unsevered umbilical cord. Fouling stands in the midst of successful membrane performance and effective scientific rigour. Man's vision will surely usher in a newer hope and challenging visionary frontiers.

Scientific rigour and scientific advancements are the focal points in the road to progress in the field of membrane separation process. The challenges, whether scientific or social in the field of application of membrane science are far-reaching as well as immature. The latent domains of its application need to be explored. Scientific validation should be at its zenith. Fouling and cleaning stand in the path towards progress.

Concentration boundary layer, importance and scientific rigour: Concentration boundary later phenomenon today stands in the midst of scientific rigour and rigorous scientific understanding. Concentration boundary layer also is a major impediment to successful membrane separation. Scientific rigour, scientific vision and the world of challenges today stands in the midst of immense introspection and optimism. Concentration boundary layer is the primordial issue in the success of a membrane operation. Research endeavour has surpassed visionary frontiers. Scientific and academic rigour ushers in a newer age and a newer vision.

PATH-BREAKING AREAS OF MEMBRANE SEPARATION PROCESSES AND THE SCIENTIFIC VISION BEHIND ITS APPLICATION

Scientific vision and scientific rigour will go a long way in opening doors of innovation and path of progress in human civilization. Global water shortage stands in the midst of immense crisis and deep concern. The history of science and technology, global ecological imbalance and global water shortage will usher in a new era of vision. Global ecological imbalance has urged scientists and engineers to be more reassured towards new tools and new innovations (Cheryan 1998).

ADVANCEMENT OF SCIENCE AND TECHNOLOGY, ADVANCEMENT OF ENVIRONMENTAL ENGIEERING SCIENCE AND THE ROAD TO PROGRESS

Man's as well as a scientist's vision is emboldened with the passage of time and the path towards progress. Advancement of science and technology is today in the midst of immense hope and optimism. In the similar vein, advancement of environmental engineering science is showing human civilization a new dawn of innovation. Environmental issues are at a vicious stake in our present day human civilization. The imminent challenges need to be redrawn and restructured. The road to progress is inspiring and will open up new challenges and new visionary future (Cheryan 1998).

NEW DIMENSIONS IN ENVIRONMENTAL ENGINEERING SCIENCE

Environmental engineering science is moving steadily surpassing one visionary frontier over another. Advancement of science and technology, progress of science and engineering and urge to excel has propelled human scientific pursuit to a newer scientific generation and a newer vision.

Environmental engineering science in today's world is surpassing one visionary frontier over another. Global water shortage and groundwater contamination has urged the scientific community to take drastic steps and effective measures. The challenges are immense yet far-reaching. Membrane separation processes and its effective application has ushered in a new era and a newer vision in the progress of human civilization.

HISTORY OF SCIENCE AND TECHNOLOGY, IMMENSE CHALLENGES AND TECHNOLOGICAL DIFFICULTIES

Technology and science need to be upgraded at every step of the progress of human civilization. Immense challenges and difficulties fall in the path of steady growth. Scientific vision and scientific truth are the torchbearers of the future generation. Membrane science, industrial wastewater treatment and the immense barriers ahead will surely act as forerunners for alleviation of global water shortage. A scientist's vision then will be surely reshaped. Every decade in this century is a decade of prominence and a decade of visionary scientific learning and vision. Scientific validation, the world of challenges and a scientist's prowess will surely give new hope to the history of human mankind.

VISIONARY FUTURE, THE WORLD OF CHALLENGES AND THE PROGRESS OF SCIENCE AND ENGINEERING

The future of human civilization is at a disastrous stake and at a devastating focal point. Technology needs to be revamped and restructured. Technological advancements and instinctive innovation will be the only torchbearers to the future progress of mankind. The disastrous clouds of environmental catastrophes loom large over the distant technological horizon. Innovation can only lead through the disaster with scientific forbearance.

GLOBAL WATER SHORTAGE, GROUNDWATER CONTAMINATION AND THE PATH TOWARDS PROGRESS

Global water shortage is a primordial issue and is on the verge of immense disaster. Scientific hope, scientific vision and urge to excel will go a long way in evolving new dimensions in the domain of groundwater remediation. Man's prowess and mankind's surge to excellence are the focal points in today's scientific endeavour. The path towards progress in the application areas of microfiltration is far-reaching and surpassing visionary frontiers. At such a crucial juncture of history, time and vision, environmental engineering science will usher in a new era.

Arsenic groundwater contamination and the future challenges: Arsenic groundwater contamination and its challenges are the torchbearers to a newer path of progress. Scientific doctrine and scientific concern has urged our scientific domain to open up windows of intuition in the field of groundwater remediation. Groundwater remediation is a primordial issue in the scientific advancement of a nation and society. The challenges in South Asia need to be revamped and reshaped with the ushering of a newer scientific era. Groundwater contamination is a bane to human civilization. Challenges, difficulties and barriers are immense and needs to be reorganized with the progress of human society and human civilization.

Arsenic in drinking water, the devastation in South Asia and pragmatic solutions: Future challenges, future strategies and purposeful vision will go a long way in opening new doors of innovation in scientific vision and scientific fortitude. Arsenic contamination of groundwater and drinking water has devastated the environmental engineering paradigm. South Asia is in a visible danger and challenges surmounting. The question of effective remediation needs to be readdressed and re-envisioned. Pragmatic solutions in alleviating the environmental disaster of groundwater contamination need to be reshaped. Environmental engineering tools need to be re-envisioned and revamped with the passage of time and history.

FUTURE CHALLENGES, FUTURE STRATEGIES AND GLOBAL WATER CRISIS

Future strategies and global water shortage are the primordial issues in the path and urge to excel. Man's vision needs to be readdressed with immense excellence in scientific endeavour. The path to excel stands between immense hope and on the other hand scientific pessimism. Future path of strategy should be towards zero-discharge norms in industrial wastewater treatment and the provision of clean drinking water. In such a scientific vision, history of mankind should have a new beginning.

Scientific research validation and the future road to progress: Man's progress, mankind's prowess and the visionary road to progress are all interlinked. The destiny of human civilization lies greatly on effective and purposeful scientific endeavour and subsequent validation. The visionary path towards scientific advancement is inevitable with the future passage of time. Research foray in the field of membrane separation processes is widely effective and can solve problems of industrial wastewater treatment and global water shortage. Groundwater remediation is on the verge of a new era. In such a crucial juxtaposition of history, vision and time, scientific validation will surely open new vistas of research (Chiron et al. 2000, Cheryan 1998).

Future vision and future thoughts in industrial wastewater treatment: Global water shortage and environmental catastrophes are at difficult stake in our present day human civilization. Mankind needs to readdress its importance for environmental pollution control since today's industrial wastewater treatment is on the verge of new era and new future direction. Industrial wastewater treatment today stands in the midst of strong scientific vision and effective scientific steadfastness. Scientific vision does not lag behind in the march of science and technology. The challenges of strong scientific vision need to be redrafted and restructured. History of science and technology will surely usher in a new era of innovation and scientific instinct with years to come (Palit et al. 2012a, Gogate et al. 2004).

Future dimensions of the application areas of microfiltration: Microfiltration and other membrane separation processes redefines environmental engineering science. History of science and technology is moving steadfastly towards a new vision and a new direction. The world of challenges needs to be redrafted and re-envisioned with the march of science and technology. The vision of the future in the application areas of membrane separation needs to be revamped and restructured (Van der Bruggen et al. 2008, Palit et al. 2012b, Kos et al. 2003).

Future dimensions and future directions in the field of microfiltration and membrane separation processes are inspiring and inevitably visionary. The world of challenges will usher in a new generation of scientific hope and determination in years to come. Future challenges, the path towards progress and immense scientific understanding are the harbingers of a new age and a new visionary era (Palit et al. 2012b).

CONCLUSION

Microfiltration and membrane separation processes today stands as the most important and vital separation technique of environmental engineering science. Zero-discharge norms and successful environmental sustainability will go a long way in ushering in a visionary future and effective industrial wastewater treatment. Challenges, difficulties and barriers are the primordial issues of a visionary future. Scientific vision and strong scientific understanding will evolve new areas of research and new dimensions of futuristic technological developments in decades and years to come. Man's as well as a scientist's vision will then be strongly validated if environmental pollution control techniques open up eyes of innovation to the civil society (Kos et al. 2003).

A scientist's vision today stands in the midst of immense rigour and far-reaching objectives. Global water shortage is a visionary issue of tomorrow. Future generations of scientific endeavour surely will look forward to a newer dimension and a newer path of innovation in tackling the global water shortage. Microfiltration as well as other membrane separation processes will be inspiring solutions to achieve the visionary objectives in the solution of global water shortage. The vision is wide and bright. New technologies, new research development and urge to excel will open up new generations of scientific understanding and purposeful vision. The concern of validation of scientific research and the improved scientific vision in the applications of environmental engineering tools will usher in a newer visionary scientific era.

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REFERENCES

Al-Kdasi, Idris, A., Saed, K. and Guan, C.T. 2004. Treatment of textile wastewater by advanced oxidation processes: a review. Global Nest, The International Journal, 6(3): 222-230.

Cheryan, M. 1998. Ultrafiltration and Microfiltration Handbook. Technomic Publishing Co. Inc.

Chiron, S., Fernandez-Alba, A., Rodriguez, A. and Garcia-Calvo, E. 2000. Pesticide chemical oxidation: state of the art. Water Research, 34(2): 366-377.

Gogate, P.R. and Pandit, A.B. 2004. A review of imperative technologies for wastewater treatment I: oxidation technologies at ambient conditions. Advances in Environmental Research, 8: 500-551.

Kepa, U., Stanczyk-Mazanek, E. and Stepniak, L. 2008. The use of advanced oxidation process in the ozone + hydrogen peroxide system for the removal of cyanide from water. Desalination, 223: 187-193.

Kos, L. and Perkowski, J. 2003. Decolouration of real textile wastewater with advanced oxidation processes. Fibres and Textiles in Eastern Europe, 11(4): 43.

Palit, S. 2012a. Membrane separation processes and advanced oxidation processes of dyes in bubble column reactor-a keen and far reaching overview. International Journal of Chem. Tech. Research, 4(3): 862-866.

Palit, Sukanchan 2012b. Ozone treatment as an effective advanced oxidation process for the degradation of textile dye-effluents. International Journal of Chemical and Analytical Science, 3(1): 1293-1295.

Van der Bruggen, B., Manttari, M. and Nystrom, M. 2008. Drawbacks of applying nanofiltration and how to avoid them: a review. Separation and Purification Technology, 63: 251-263.

Zhou, H. and Smith, D.W. 2002. Advanced technologies in water and wastewater treatment. Journal of Environmental Engineering Science, 1: 247-264.