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Nanofiltration and Ultrafiltration- the next generation Environmental engineering tool and a vision for the future

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Abstract : Environmental engineering science is moving towards the newer scientific realm at a drastic pace. The vision, aim and the purpose of membrane separation processes is wide, far-reaching and scientifically inspiring. Environmental restrictions and stringent regulations are transforming the environmental engineering scenario. In such a critical juncture of human scientific progress, the author delineates novel separation processes and subsequently membrane separation processes. The author strives forward towards the intricacies and barriers towards membrane science particularly nanofiltration and ultrafiltration. In today's scientific world, environmental engineering techniques and environmental sustainability have an unsevered umbilical cord. Loeb- Sourirajan model revolutionized the field of membrane science. The author with deep comprehension also delineates the barrier of concentration polarization to membrane separation processes. The state of environment in today's world is disastrous and catastrophic. Novel separation processes are the torchbearers of the new environmental engineering world order. Scientific vision, scientific truth and deep scientific understanding stands in the midst of visionary world order. The author strives to bring forward towards the scientific horizon the efficacy of membrane separation processes especially nanofiltration and ultrafiltration. Vision of science, the wide vistas of engineering science and the human scientific progress all will lead a long way in true emancipation of environmental engineering. Membrane science such as nanofiltration, ultrafiltration and reverse osmosis are the forerunners of a new world order in environmental engineering. The author with deep comprehension also lucidly delineates the future vision arsenic and heavy metal groundwater remediation and the relevant novel separation techniques associated with it.
Keywords : environment, membrane, nanofiltration, ultrafiltration, sustainability, engineering, science, vision.

1. Introduction

The vistas of environmental engineering science today stands in the midst of immense scientific vision and deep comprehension. Environmental regulations and restrictions have urged the human scientific progress to opt for newer scientific endeavour such as innovation of novel separation processes such as membrane science. The vision of science is inspiring and far-reaching in today's world of environmental engineering. Science and human endeavour in today's scientific horizon have an unsevered umbilical cord. Novel separation processes and advanced oxidation techniques are in the newer innovative realm of environmental engineering science. Science and engineering of environmental techniques are moving at a drastic and visionary pace. In such a critical juncture of history and time, the vision of environmental engineering techniques such as

membrane science or other novel separation processes are the torchbearers of a newer future dimension of environmental sustainability and successful sustainable development. Technological vision is of utmost importance in today's path of scientific life. Environmental engineering science in the same vein should have a clear cut aim and vision. This treatise indentifies the challenges and prospects of the applications of membrane science especially targeting nanofiltration and ultrafiltration. Science and technology will surely usher in a new era of vision and emancipation in years to come.[1],[2]

2. Purpose and Aim of the Study

Membrane science is moving towards a visionary realm and a true visionary future. The purpose and aim of the study is to delineate the future insight of application of membrane science in solving environmental engineering problems. The world of chemical engineering and environmental engineering is witnessing immense surge in scientific endeavour. Vision of science and engineering , the progress of human civilization and the forays of scientific pursuit are the forerunners towards a newer realm of environmental science and technology. The author with deep and cogent insight brings forward in the scientific horizon the true efficacy of membrane science and its visionary future. Global water shortage and ground water remediation are of utmost importance in today's visionary world of science and engineering. The vision and the target of environmental engineering should be towards provision of basic human needs and alleviation of global water crisis. History of technology, progress of human civilization and the wide vistas of science will go a long way in the true realization of environmental sustainability. The author elucidates upon the future of global water shortage and global environmental sustainability. [1],[2]

Filtration is defined as the separation of two or more components from a fluid stream based primarily on size differences. In conventional usage , it veritably refers to the separation of solid immiscible particles from liquid or gaseous streams. Membrane filtration extends this application further to include the separation of dissolved solutes in liquid streams and for separation of gas mixtures. The primary role of a membrane is to act as a selective barrier. It should permit passage of certain components and retain certain other components of a mixture. By implication, either the permeating stream or the retained phase should be enriched in one or more components. In its widest and broadest sense, a membrane could be defined as "a region of discontinuity interposed between two phases"(Hwang Kammermeyer,1975), or as a "phase that acts as a barrier to prevent mass movement but allows restricted and/or regulated passage of one or more species through it"(Lakshminarayanaiah,1984)[1],[2] .

3. Scope of the Study

Membrane science in today's world is witnessing visionary challenges. Application areas are diverse. Science and engineering are surpassing visionary frontiers in today's human civilization. Nanofiltration and ultrafiltration are two branches of membrane which has tremendous potential in its application in environmental engineering science. The vision of the study encompasses the wide vistas of application of nanofiltration and ultrafiltration and the barriers of membrane separation processes. The author delineates the intricacies of concentration boundary layer and the ultimate vision of membrane separation processes in alleviating global water crisis. Arsenic and heavy metal groundwater contamination are at a devastating state in today's human civilization. Human scientific progress needs to be re-envisioned at each step of human history and life. The scope of the study unravels and unveils the deep intricacies of concentration boundary layer. The immense application areas of nanofiltration , ultrafiltration and other membrane separation processes and deep insight into the visionary boundaries of concentration boundary layer unveils the wide scope of this short study.[1],[2]

The vision and the scope of the study in the domain of membrane science or novel separation processes are wide and versatile. Science today stands in the midst of immense futuristic introspection and deep crisis due to the disbalance of ecology. The author meticulously brings forward to the scientific audience the present and future status of membrane science especially nanofiltration and ultrafiltration. Nanofiltration, ultrafiltration and other membrane separation processes today stands in the forefront of the scientific horizon of chemical process engineering and environmental engineering science. The vision of science and engineering of novel separation processes is veritably explored to its utmost in this short treatise. The author with visionary insight delineates the struggle of science towards the realization of environmental sustainability and successful environmental engineering paradigm.

4. Doctrine and Science of Membrane Science and Nanofiltration

Vision of membrane science and technology are surpassing wide and visionary frontiers. Technology and scientific validation are the torchbearers of the future vision of membrane and novel separation processes. Man's distinct vision, civilisation's deep scientific comprehension and mankind's prowess are opening up wide avenues in water technology. Global water crisis is at a devastating state today. Nanofiltration and ultrafiltration will inevitably open up new doors of scientific innovation.

A membrane can be gaseous, liquid, or solid or combinations of these. Membranes can be further classified by a)nature of the membrane – natural versus synthetic; b)structure of the membrane-porous versus non-porous, its morphological characteristics, or as liquid membranes; c)application of the membrane – gaseous phase separations, gas-liquid, liquid-liquid , etc; d) mechanism of membrane action-adsorptive versus diffusive, ion-exchange, osmotic, or non-selective(inert) membranes.[1],[2]

Nanofiltration is a relatively new process that uses charged membranes with pores that uses charged membranes with pores that are larger than RO membranes , but too small to allow permeation of many organic compounds such as sugars. They also have an useful property in that they can separate dissociated forms of a compound from the undissociated form;e.g., organic acids such as lactic, citric , and acetic pass through easily at low pH but are rejected at higher pH when in their salt forms(Raman et al.1994). Ultrafiltration deals with the separation of fairly large molecules , such as natural polymers like proteins, starch and gums, and colloidally dispersed compounds such as clays, paints, pigments , latex particles, etc. The osmotic pressures involved in ultrafiltration processes are fairly low.[1],[2]

5. Scientific Endeavour in the Field of Membrane Separation Processes

Scientific endeavour in the field of membrane science are wide and visionary. Vision of science, validation of science and the future human progress are the torchbearers of tomorrow's world. Scientific challenges , the progress of science and the vision for the future are the forerunners of a new environmental engineering world order. Science is a huge colossus without a will of its own. Membrane separation processes will surely and inevitably open up new vistas of challenges and surely realize new dimensions of environmental sustainability in decades to come. Human scientific progress in today's world depends on immense and visionary scientific validation. Membrane science is a mature yet latent branch of novel separation process. The efficacy of application is wide, inspiring and far-reaching. Membrane separation processes in today's environmental engineering world stands as a trailblazer and definite innovator towards newer solutions to global water crisis. Vision of science , progress of technology and the wide scientific world ahead will go a long way in opening visionary doors of scientific instinct in water technology in years to come. Technological and engineering vision in today's scientific world needs to be validated at every step of research pursuit. Water science and technology needs to be re-envisioned. A scientist's quest for knowledge will surely be an eye opener to the human mankind and the global water situation.[1],[2]

6. Scientific Research Endeavour in the Field of Nanofiltration and Ultrafiltration

Scientific research pursuit in the field of nanofiltration and ultrafiltration are surpassing visionary boundaries. Scientific challenges, scientific vision and scientific forbearance will go a long and decisive way in the true emancipation of membrane science and environmental engineering science. The author delineates with deep and true comprehension the fundamental scientific research pursuit in the field of nanofiltration and ultrafiltration.

Hilal et al(2004)[3] dealt lucidly in a comprehensive review of nanofiltration membranes the treatment, pretreatment , modeling and atomic microscopy. Nanofiltration membranes(NF) have wide applications. One of the main applications has been in water treatment for drinking water production as well as wastewater treatment. The introduction of NF as a pretreatment is considered a true breakthrough for the desalination process. NF membranes have been shown to be able to remove turbidity, microorganisms and hardness, as well as a fraction of the dissolved salts. The authors reviewed the application of AFM in studying the morphology of membrane surfaces as a part of membrane characterization. The authors delineated with deep and cogent comprehension the science of Atomic Microscopy as a future tool to characterize membranes. Vision of science, progress of membrane science and application of membranes are the torchbearers of the larger emancipation of global drinking water crisis.

Childress et al(2000)[4] on an experimental work dealt deeply on nanofiltration membrane performance to membrane charge (electrokinetic)characteristics. The performance (i.e. the water flux and solute rejection)of a thin-film composite aromatic polyamide nanofiltration membrane and its relation to membrane surface charge (electrokinetic)characteristics were investigated. Membrane electrokinetic properties are the backbone and a veritable pillar to the future of separation phenomenon. Childress et al(2000)[4] lucidly observes and informs the scientific fraternity the challenge of electrokinetic characteristics in membrane separation processes.

Li et al(2004)[5] elucidated upon organic fouling and chemical cleaning of nanofiltration membranes and its measurements and mechanisms. Fouling and subsequent chemical cleaning of nanofiltration (NF) membranes used in water quality control applications are often inevitable. To unravel the mechanisms of organic fouling and chemical cleaning , it is critical to understand the foulant-membrane, foulant-foulant and the foulant-cleaning agent interactions at the molecular level. In this visionary study, the adhesion forces between the foulant and the membrane surface and between the bulk foulant and the fouling layer were determined by atomic force microscopy(AFM). The authors elucidated on the phenomenon of membrane fouling which is a barrier to the separation mechanism. Fouling results in deterioration of membrane performance (i.e., permeate water flux and quality) and ultimately shortens membrane life. Among the potential foulants that are ubiquitous in natural and waste waters, dissolved organic matter is the most recalcitrant. Fouling stands as a major impediment to membrane separation phenomenon. Challenge of science and engineering , the wide and versatile area of membrane science and the progress of technology will go a long way in the true emancipation and successful realization of separation phenomenon.

Vandezande et al(2007)[6] critically reviewed solvent-resistant nanofiltration. They lucidly dealt with separation at molecular level. Over the past decade, solvent resistant nanofiltration (SRNF) has gained a lot of scientific attention as it is a promising and visionary energy and waste efficient unit process to separate mixtures down to a molecular level. This incisive and critical review focuses on all aspects related to this burgeoning and ever-growing technology. Science and engineering of nanofiltration is slowly opening a new chapter in the domain of novel separation processes. Even though pressure driven solvent separations had been prevalent since 1965, SRNF is a comparatively new technology that broke through around the beginning of this century. It has tremendous research and industrial potential since it allows separations of organic mixtures down to a molecular level by simply applying a pressure gradient over a membrane. Science and engineering of membrane separation processes is ever-increasing with successful research and development pursuit. Vandenzade et al(2007)[6] discusses with great details and scientific vision the science of solvent resistant nanofiltration. A scientist's vision, civilisation's progress and the solutions to global water crisis are equally emboldened at each step of human history and human life.

Van der Bruggen et al(2008)[7] dealt with cogent insight and deeper comprehension the drawbacks of applying nanofiltration and how to avoid them. This review discusses six challenges for nanofiltration where solutions are still scarce: 1)avoiding membrane fouling and ways to remediate, 2)improving the separation between solutes that can be achieved, 3) further treatment of concentrates, 4) chemical resistance and limited lifetime of membranes, 5)insufficient rejection of pollutants in water treatment procedures, 6)the need for modeling and simulation tools. Van der Bruggen et al(2008)[7] observes and informs the nitty-gritty of the fouling effect of the science of nanofiltration and brings into the scientific forefront the vision of the difficulties and barriers of fouling.

Cho et al(1999)[8] delineated lucidly with sound visionary effort membrane filtration of natural organic matter. The authors discussed in details initial comparison of rejection and flux decline characteristics with ultrafiltration and nanofiltration membranes. Membrane filtration is a progressive area of membrane science. It is surpassing vast and versatile visionary frontiers. Natural organic matter stands as a major research thrust area of membrane science. The author with deep and effective comprehension brings to the scientific forefront the vision, objective and scientific candour of the vast and versatile world of membrane filtration. Thus membrane science is ushering in a new era in chemical process engineering.

Schafer et al(1998)[9] in their instinctive research delineated nanofiltration of natural organic matter and subsequent removal, fouling and influence of multivalent ions. They discussed in details the fouling phenomenon of nanofiltration membranes due to the presence of calcium and humic substances or natural organic matter in surface waters. Fouling of nanofiltration membranes in today's scientific world and scientific

civilization stands in the midst of immense difficulties and barriers. The authors elucidates in details the nanofiltration of humic acids in minute details and with scientific precision.

Wang et al(2005)[10][10] dealt with deep and cogent insight separation performance of a nanofiltration membrane influenced by species and concentration of ions. Nanofiltration , which has been largely developed over the past decade , is a promising technology for the treatment of organic and inorganic pollutants in surface and groundwater. The authors explored membrane performance with the membranes manufactured by Nitto Denko Corporation of Japan.

Radjenovic et al(2008)[11] studied rejection of pharmaceuticals in nanofiltration and reverse osmosis membrane drinking water treatment. Science and engineering of membrane science is veritably ushering in a new era of deep scientific emancipation with years to come. Application of nanofiltration in the world of pharmaceutical science is not new yet visionary. Scientific vision, scientific candour and scientific adjudication is at its utmost best as pharmaceutical science enters a new era.

Tang et al(2007)[12] researched on the topic of fouling of reverse osmosis and nanofiltration membranes by humic acid . They progressed through scientific research pursuit on effects of solution composition and hydrodynamic conditions. The researchers dealt with fouling of reverse osmosis and nanofiltration membranes by humic acid , a recalcitrant natural organic matter(NOM). Reverse osmosis and nanofiltration membranes are ushering in a new era in the pursuit of science and technology. The authors with deep insight and surgical precision deals with the burning topic of fouling in details.

Manttarri et al(2002)[13] elucidated upon the effect of temperature and membrane pre-treatment by pressure on the filtration properties of nanofiltration membranes. The effect of temperature on the retention in nanofiltration of model substances (glucose)and substances in industrial streams had been studied in the temperature interval of 25 deg C to 65 deg C. Science, technology and engineering are ushering in a new eon of human civilization. The vision of science, validation of engineering science and progress of membrane separation processes will all lead to a new emancipation of scientific understanding in years to come.

Akbari et al(2002)[14] analysed and delineated with deep comprehension the treatment of textile dye effluents using a new photografted nanofiltration membrane. The performance of a nanofiltration membrane is done which is fabricated by UV-photografting. Sodium p-styrene sulfonate was used for the modification of a polysulfone ultrafiltration membrane. The grafted membranes have been evaluated for the removal of five different dyes with an aim to reuse water in process house.

Boussahel et al(2000) [15]investigated the removal of pesticide residues in water using the nanofiltration process. Science of membrane separation process is augmented at its utmost with each step of revolutionary and far-reaching scientific pursuit. Teixeira et al (2005) [16] delineated the role of membrane charge on nanofiltration performance. The zeta potential along the surface and through the pores of a commercial nanofiltration membrane was studied with several electrolyte solutions(including monovalent and divalent hardness ions, KCl, $CaCl_2$ and $MgSO_4$) to investigate the influence of salt type and pH on the charge of the membrane surface and in the membrane pores. Removal of pesticides is of utmost importance in the domain of environmental engineering. Scientific temper and scientific fortitude are in today's human civilization opening up a new chapter in membrane separation processes.

7. Fouling of Membrane and Scientific Perspective

Fouling of membranes stands as an impediment to successful membrane separation processes. Scientific perspectives and vision of science are targeted towards alleviation and minimization of fouling phenomenon. Novel separation processes and membrane separation processes in today's world have a distinct and purposeful vision. The vicious challenges to drinking water treatment and the wide world of industrial wastewater treatment are veritably opening up new vistas of science.[1],[2]

Fouling is one of the main problems in any membrane separation, but for nanofiltration it might be even somewhat more complex because of the interactions leading to fouling take place at nanoscale, and therefore difficult to comprehend. Its negative consequences are obvious and include the need for pretreatment , membrane cleaning , limited recoveries and feed water loss, and short lifetimes of membranes. In that direction, membrane fouling is closely related to other problems such as concentrate treatment and membrane stability

and lifetime; a total control of fouling would reduce the need for cleaning and would enhance the permeate yield.

Foulants playing a role for nanofiltration membranes can be organic solutes , inorganic solutes, colloids, or biological solids. Science and technology is opening up newer chapters and visionary frontiers in the field of membrane science. A scientist's vision as well as an environmental engineer's prowess is emboldened at each step of definite research pursuit.

Table 1- Visionary scientific endeavour in the field of nanofiltration and ultrafiltration

Authors:	**Visionary work done:**
Hilal et al(2004)[3]	A comprehensive review on nanofiltration membranes.
Childress et al(2000)[4]	Membrane charge performance.
Li et al(2004)[5]	Organic cleaning and chemical cleaning of nanofiltration membranes**.**
Vandenzande et al(2008)[6]	Solvent resistant nanofiltration**.**
Vanderbruggen.B.,et al(2008)[7]	Drawbacks of nanofiltration.
Cho et al(1999)[8]	Membrane filtration of natural organic matter**.**
Schafer et al(1998)[9]	Nanofiltration of natural organic matter.
Wang et al(2005)[10]	Separation performance of a nanofiltration membrane.
Radjenovic et al(2008)[11]	Rejection of pharmaceuticals by nanofiltration and reverse osmosis membranes.
Tang et al(2005)[12]	Fouling of reverse osmosis and nanofiltration membranes.
Manttari et al(2002)[13]	Effect of temperature and membrane pretreatment pressure.
Akbari et al(2002)[14]	Treatment of textile dye effluents by nanofiltration membranes.
Boussahel et al(2000)[15]	Removal of pesticides by nanofiltration.
Teixeira et al(2005)[16]	The role of membrane charge on membrane performance.

8. Future Insight and Future Vision of the Application of Membrane Science

Purposeful and ultimate vision of membrane science are far-reaching and ever-growing. Future insight into the application areas of membrane science reveals its tremendous potential. The forecasts of future science reveals the wide vision of nanofiltration and ultrafiltration in water technology. Future insight into the scientific endeavour and subsequent application of membrane science is vast and versatile. The challenges, the scientific sagacity and the vision of water technology and novel separation processes are in today's world opening up new doors of innovation and scientific intuition.

Membrane science is a vast and versatile domain of scientific research pursuit. Vision of mankind , progress of science and the civilisation's urge to excel are the pallbearers of a greater emancipation of scientific endeavour. Water science and technology are in the path of a new scientific rejuvenation and a newer scientific vision. Global water crisis has urged scientific and technological pursuit to revamp the avenues and vistas of the global challenge towards sustainability. Environmental sustainability is the order of the day. Membrane science and other novel separation processes are opening up wide windows of immense innovation in years to come.[1],[2]

9. Scientific Vision, Scientific Understanding and Environmental Sustainability

Environmental sustainability and tools of environmental engineering science will veritably change the scientific horizon of environment. The scientific challenges, the path of human progress and the vision behind progress will surely lead a long way in opening up new doors of innovation in membrane science. Scientific vision is in the midst of immense difficulties and massive challenges. Scientific vision in today's world is immense and challenging. Sustainable infrastructural development is the ultimate need of the hour. In such a vein, vision of science should be targeted towards environmental sustainability. Provision of clean drinking water and environmental sustainability are immensely related in today's human civilization. Environmental sustainability is the immediate need of the hour. Sustainable development of human environment and human civilization is of utmost importance. Scientific fortitude and scientific sagacity will lead a long way in the true

emancipation of today's environmental engineering science. Environmental sustainability is a challenge of today's human civilization. The only torchbearer to the successful realization of environmental sustainability is the application of environmental engineering techniques. Novel separation processes is in the midst of immense comprehension and deep challenges. Scientific vision needs to be revamped with the growing concern of ecological disbalance. [1],[2]

10. Environmental Sustainability, Environmental Engineering Techniques and Future of Environment

Sustainable development of environment is the issue of the hour. Vision of environmental engineering techniques needs to be restructured. The future of civilisation's environment is at a deep stake and a devastating state. Man's as well as a scientist's prowess and vision needs to be overhauled. Nanofiltration, ultrafiltration and other novel separation processes needs to be scientifically re-challenged. Scientific validation and scientific successes in today's world are in the path of immense glory and comprehension. Sustainability is a primordial issue in the path towards excellence for today's human civilization. Environmental as well as energy sustainability are revolutionizing human development. Purposeful vision, development of science and the vision to excel will realize environmental sustainability and human concerns about future of environment. In today's scientific world, environmental engineering science and environmental sustainability have an umbilical cord. Technological vision is at a state of great distress with the ever-growing environmental catastrophes. The target and the aim of environmental engineering science should be towards successful and long term sustainable development.[1],[2]

11. Global Water Crisis and Membrane Science

Global water crisis today stands in the midst of devil and the deep sea. Membrane science and other environmental engineering techniques are widening the vistas of science and technology. Environmental sustainability and global water crisis are today in the midst of vicious challenges. Science, technology and engineering are re-envisioning itself at every step of human life. Global water crisis is knocking the doors of human civilization. Membrane science in today's scientific world stands in the midst of global water crisis and scientific rejuvenation. Ecological disbalance, environmental regulations and the future progress of human civilization has urged the scientific community to venture into the world of novel separation processes. Science needs to be revisited and reenvisioned in this world of environmental crisis. In today's human civilization, provision of basic human needs stands in the midst of immense turmoil. Clean drinking water needs stands as a major parameter towards the advancement of environmental engineering science. Water crisis is a major impediment to the advancement of science and technology and the growth of a nation. A vicious crisis which is occurring in South Asia is the arsenic groundwater contamination. Human civilization stands in the midst of unimaginable and burgeoning crisis. Science and engineering has no answers at such a devastating situation in South Asia particularly Bangladesh and West Bengal state of India. In this treatise, the author gleans and delineates the present and future scientific perspectives of the world's greatest environmental crisis and the methods to tackle it. In such a crucial juncture of human civilization, environmental engineering science needs to be re-envisioned at every step of human scientific endeavour. Vision of engineering, advancement of membrane science and the immense scientific challenges will usher in a newer scientific understanding of the global water crisis.

12. Heavy Metal Groundwater Remediation and Future of Membrane Science

Another facet of application of water technology is the challenge of heavy metal groundwater remediation. Arsenic drinking water and groundwater contamination is a bane to human civilization and human progress. Environmental sustainability is at a state of veritable distress. Scientific vision has limited answers. Human scientific progress in such a critical juncture is the only decisive answer. The status of arsenic groundwater contamination is exceedingly disastrous. South Asia is replete with immense water crisis and also the inevitable crisis of ecological disbalance. Heavy metal contamination of groundwater and arsenic crisis today stands in the midst of unimaginable disaster and deep disaster. The scientific vision and understanding needs to be re-envisioned at every step of human life and endeavour. Membrane science and novel separation processes are the only decisive alternative.

13. Arsenic Groundwater Remediation and Future of Environmental Engineering

Environmental engineering science is in the midst of unimaginable catastrophe. Sustainability is the only definite answer. Arsenic groundwater remediation and the realization of environmental sustainability are the primordial issues facing human mankind today. A strong human conscience and a strong vision will be the winner of the day if arsenic and heavy metal remediation needs to be tackled at the utmost. Cancer and other health related issues are the result and the devastating end to the arsenic crisis. Scientific forbearance and immense fortitude is needed in charting out a plan to tackle arsenic groundwater remediation. Man's vision needs to be revamped at every step of life. Human progress in today's world depends veritably depends on advancements in science and technology. In a similar vein, march of science is linked with provision of drinking water and application of environmental engineering tools. The crisis needs to be re-envisioned at each step of human progress.[1],[2]

14. Vision of Science and Application of Nanofiltration and Ultrafiltration:

Nanofiltration and ultrafiltration are the environmental engineering tools which are surpassing visionary frontiers. The application areas are linked towards successful environmental sustainability. In today's human civilization, successful environmental engineering techniques ushers in successful environmental sustainability. The vision of science and the vision of application areas of nanofiltration and ultrafiltration are veritably inspiring and charting out a new chapter in human history and scientific progress. Scientific vision, the fortitude and the struggle and challenges are ushering in a newer future direction in the field of drinking water treatment and membrane science. Environmental engineering science and membrane science needs to be restructured and is the need of the hour.

15. Future of Environmental Engineering and Membrane Science and Scientific Perspectives

Future of environmental engineering and membrane separation processes is vast and versatile. Human scientific progress is in the path of a new rejuvenation. Water technology and water science is the primordial issue in the progress of human civilization. The alleviation of groundwater contamination stands today in the midst of immense introspection and deep comprehension. Man's scientific progress is in the midst of disaster with the ever growing concern of groundwater contamination in South Asia and different parts of the world. The participation of the civil society in solving the drinking water crisis needs to be effective at every step of human scientific endeavour. Scientific perspectives in today's scientific horizon need to be re-envisioned. The scientific challenge, the world of environmental engineering science and process engineering will go a visionary way in the true realization of sustainable development.[1],[2]

16. Future Recommendations of the Study

Future vision and future recommendations of the domain of application of environmental engineering science is vast and far-reaching. Nanofiltration and ultrafiltration are surpassing scientific frontiers. The intricacies of membrane science and the difficulties and barriers of fouling are opening up new realms of scientific research in years to come. Global water crisis, human scientific progress and the wide and visionary road ahead are today's forerunners to a greater emancipation of the science of membrane separation process. Novel separation process is the futuristic technology. Man's vision as well as a scientist's intuition are greatly enhanced and envisaged with every step of scientific research pursuit. Water technology and water crisis are opening up new doors of scientific innovation and new avenues of science and engineering. In today's world, human scientific progress should be linked with the progress of human civilization. In the similar vein, provision of basic human needs are of utmost importance. The vistas of future are wide, vast and versatile. Future recommendations of the study should be targeted towards intense scientific research endeavour and linked with provision of basic human needs.[1],[2]

17. Conclusion

In today's world and today's human civilization, environmental engineering techniques should be linked with environmental sustainability and successful sustainable development. Science and engineering paradigm are moving extremely fast surpassing one visionary frontier over another. Membrane science, nanofiltration and ultrafiltration are the forerunners of a newer future thought and a visionary future of science

and engineering. Today's world of environmental engineering science is faced with immense challenges and veritable disaster with the destruction of ecology. At such a crucial juncture, sound scientific research pursuit is the pallbearer towards newer innovation and a newer scientific realm. Membrane science and technology , vision of science and engineering and the wide world of scientific progress , in near future, will veritably open up a new chapter in realization of successful environmental sustainability.

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