

**ADVANCED OXIDATION PROCESSES, BIOREMEDIATION AND
GLOBAL WATER SHORTAGE – A VISION FOR THE FUTURE****SUKANCHAN PALIT**

Assistant Professor (Senior Scale), Department of Chemical Engineering, University of Petroleum and Energy Studies, Post-Office-Bidholi via Premnagar, Dehradun-248007, Uttarakhand, India.

ABSTRACT

The world of environmental engineering science and the future of advanced oxidation processes are moving steadily from one paradigm over another. Advanced oxidation processes are revolutionizing the future of industrial wastewater treatment. The vision of science, the brisk forays of technology and the future of mankind is moved from one visionary direction over another. Environmental challenges are gearing up for new dimensions of technological innovations. In such a critical juncture, AOP or advanced oxidation processes are ushering in a new future in the area of industrial wastewater treatment and global drinking water shortage. The author brings into the forefront of scientific scenario the immense potential of advanced oxidation processes, novel separation processes and the future perspectives of the application of non-conventional industrial wastewater treatment techniques. Environmental engineering is briskly surpassing one visionary frontier over another. The question of environmental sustainability and the wide concern of environmental restrictions have created an immense surge and instinctive striving towards newer tools such as advanced oxidation processes and bubble column reactors. Application of bubble column reactors has a newer definition in this present decade. A terminology title bio-ozonation evolved over the scientific horizon of human endeavour. Advanced oxidation processes are in today's scientific endeavour surpassing visionary frontiers. Ozonation is no more a scientific illusion. Bioremediation along with ozonation will open up newer vision and a newer generation of scientific thought and scientific steadfastness. In the present treatise, the author delves deep into the present understanding and future dimensions of the science and engineering of advanced oxidation processes and particularly bio-ozonation. Bio-ozonation and bio-remediation have tremendous scientific potential and improved wastewater degradation efficiency. Wastewater reclamation and degradation of recalcitrant chemicals in industrial wastewater are the major targets of environmental engineering tools. In the present treatise, the author delineates with immense and cogent insight the effectivity and importance of environmental engineering techniques in details. The author skillfully touches upon the combination of ozonation and bioremediation with deep comprehension. History of science and technology has its own visionary path. Bioremediation will open up new windows of innovation in years and decades to come.

KEYWORDS: bioremediation, biodegradation, ozonation, wastewater, pollution control

**SUKANCHAN PALIT**

Assistant Professor (Senior Scale), Department of Chemical Engineering,
University of Petroleum and Energy Studies,
Post-Office-Bidholi via Premnagar, Dehradun-248007, Uttarakhand, India.

1.0 INTRODUCTION

Environmental engineering paradigm in today's human civilization is moving steadfastly and briskly surpassing one visionary frontier over another. Environmental disaster, environmental catastrophes and man's indomitable scientific and engineering endeavour has urged civil society and human mankind to implement environmental restrictions. Visionary tools for the degradation of wastewater are devised and the challenges of novel techniques such as advanced oxidation processes and bioremediation are addressed. History of mankind is witnessing a new chapter and a newer vision of civilisation's well being. Man's as well as a scientist's vision is emboldened with the turn of each decade in the present century. The author deals with incisive mind the non-conventional wastewater degradation techniques in its visionary pursuit for the future. Novel separation processes are in a new generation of environmental science revival. The innovative areas of advanced oxidation processes, bioremediation and novel separation processes are ushering in new challenges. The author with deep comprehension and innovative lucidity brings forward to the forefront the immense challenges and future perspectives in the field of advanced oxidation processes and bioremediation²⁶. The world of AOP and its challenges are gearing up towards newer dimension and newer future perspectives.^{25,26} Vision of science, advancement of engineering and great scientific understanding will one day open up new vistas in the domain of non-conventional oxidation techniques and the wide world of environmental engineering science²⁶.

1.1 Vision behind the present treatise

Environmental engineering science today stands in the midst of immense introspection and visionary hope. Water treatment, desalination and wastewater treatment today are progressing steadily in its research endeavour to a newer vision and new and pragmatic challenges^{1,2,3,25}. Environmental pollution control is at a disastrous state in today's world. In a similar vein, environmental sustainability is moving through disastrous consequences. The present treatise reflects the doctrine, importance and purposeful vision behind advanced oxidation processes, bioremediation and the newer world of bio-ozonation.²⁵ Ozonation combined with biodegradation truly is the verge of newer scientific challenge and newer scientific understanding. Challenges are vast, wide and extremely visionary. The vision needs to be surpassed at every turn of a decade in the present century. In such a widely critical juncture of history, time and vision, the challenges and difficulties needs restructuring and re-envisioning.^{4,5,6,26} The present treatise unfolds the intricacies of advanced oxidation processes and bioremediation with emphasis on bio-ozonation in particular. Bio-ozonation is a new and innovative field and a visionary scientific endeavour. History of environmental engineering science will witness a new dawn of innovation if the process of laboratory

scale research is applied to the greater cause of industrial wastewater treatment.

1.2 The Scope of the study

Advanced oxidation processes and non-traditional environmental engineering processes are ushering in a new dawn of human civilization and a new era of scientific research pursuit. The scope of the study is vast, wide and versatile. Advanced oxidation techniques are geared towards a world of challenge. The vision of scientific research is awesome and ever-inspiring. Man's vision, civilisation's progress and the wide road of visionary future will lead a long way in the true realization and true imagination of the world of scientific research pursuit of advanced oxidation process.²⁶ The author skillfully deals with incisive precision the tremendous potential of advanced oxidation processes, the vision for the future and the deep comprehension behind integrated advanced oxidation processes.²⁶ The aim and the scope of the study delves deep into the scientific doctrine behind Advanced Oxidation Processes, the scientific vision and truth and the immense scientific challenges which lie ahead^{14,15,16,25,26,27}.

2.0 Advanced oxidation processes-its vision and its future

Advanced oxidation processes, chemical oxidation and integrated non-conventional processes are in the road to a new beginning. Integration of advanced oxidation processes at this critical juncture is opening up new windows of successful scientific innovation. The vision of the application of AOPs is creating newer scientific waves. The efficiency and effectivity needs to be readdressed at the utmost. Challenges and vision of science in today's world have a truly scientific umbilical cord. In such an era of scientific validation along with scientific vision, a man's vision as well as a scientist's thrust will lead a long way in the true emancipation of science and technology. The vivid and true emancipation of non-conventional and novel separation processes lies in its application. Scientific cognizance, scientific truth and holistic scientific vision are paving the way of new avenues of scientific exploration and scientific fortitude.²⁶ Environmental engineering and advanced oxidation processes are today revolutionizing the scientific and engineering scenario.^{14,15,16,25,26,27}

2.1 The scientific doctrine and scientific challenges

Scientific doctrine, scientific challenges and scientific fortitude are the coinwords of future. History of mankind, environmental and energy sustainability and scientific vision are gearing up for new challenges of scientific validation.^{25,26} The world of mankind's research pursuit are standing in the pillars of vision and validation. The true scientific doctrine of AOP is in a new scientific generation. The scientific doctrine lies in the validation of scientific truth and the pursual of scientific imagination and immense validation.²⁶ Mankind is moving towards a newer dawn of civilization.²⁶ Success, progress of engineering and scientific challenges are the coinwords of a newer scientific pursuit in integrated advanced

oxidation processes.²⁶ The author successfully delves into the vision of tomorrow and brings to the forefront of scientific pillar a true scientific understanding and scientific justification.^{25,26}

2.2 Industrial wastewater treatment, chemical oxidation techniques and the vision for the future

The deep scientific understanding and purposeful scientific vision are the pillars of scientific urge and immense scientific instinct of tomorrow. History of human civilization is at deep crossroads. Lower economic growth, unsuccessful environmental sustainability and unmitigated environmental disaster are gearing up for new challenges and a new future. The pillars of innovative science and the towers of scientific validation are the national growth parameters of tomorrow. Chemical oxidation techniques, advanced oxidation principles and environmental pollution control will chart a new vision of environmental science.^{25,26,27}

3.0 Deep introspection and inherent concept of advanced oxidation processes

Advanced oxidation processes today is in the age of a newer vision and newer challenges.²⁵ Vision of science, the advancement of technology and the path towards progress will go a long way on realizing scientific vision. In today's scientific world, scientific validation will pave a long way in the clear and thoughtful emancipation of technology. Future thoughts in the field of advanced oxidation processes should be linked with scientific forbearance and scientific truth. Global water shortage has urged the scientific community to gear towards newer innovations and newer future dimensions. Conceptual advancements, problems and difficulties in industrial wastewater treatment has vehemently urged human endeavour to yearn for newer future directions.^{14,15,16,25,26,27}

4.0 Scientific cognizance and scientific doctrine behind advanced oxidation processes

A wide range of organic compounds is detected in industrial and municipal wastewater. Some of these compounds (both synthetic organic chemicals and naturally occurring substances) pose severe problems in biological treatment systems due to their resistance to biodegradation or/and toxic effects on microbial processes. As a result, the use of alternative treatment technologies, aiming to mineralize or transform refractory molecules into others which could be further degraded, is a matter of great concern. Among them, advanced oxidation processes(AOPs)have already been used for the treatment of wastewater containing recalcitrant organic compounds such as pesticides, surfactants , colouring matters, pharmaceuticals and endocrine disrupting chemicals.²⁵ Moreover ,they have been successfully used as pretreatment methods in order to reduce the concentrations of toxic organic compounds that inhibit biological wastewater treatment processes. The main mechanism of AOPs function is the generation of highly reactive free radicals. Hydroxyl radicals (HO[•]) are effective in destroying organic chemicals because

they are reactive electrophiles (electron preferring) that react rapidly and nonselectively with nearly all electron-rich organic compounds. They have an oxidation potential of 2.33 V and exhibit faster rates of oxidation reactions comparing to conventional oxidants such as H₂O₂ or KMnO₄. Once generated, the hydroxyl radicals can attack organic chemicals by radical addition, hydrogen abstraction and electron transfer. A great number of methods are classified under the broad definition of AOPs. Most of them use a combination of strong oxidizing agents (eg: H₂O₂, O₃) with catalysts (eg transition metal ions) and irradiation (eg: ultraviolet, visible). Among different available AOPs producing hydroxyl radicals, titanium dioxide/UV light process, hydrogen peroxide /UV light process and Fenton's reactions seem to be some of the most popular technologies for wastewater treatment.

5.0 Global water shortage and heavy metal groundwater remediation

Global water shortage is in a state of immense distress and deep introspection. Arsenic groundwater and heavy metal groundwater contamination are causing havoc in the environmental engineering scenario worldwide. In such a crucial juncture, history of advanced oxidation processes and its application are witnessing a new vision and definitive future. Heavy metal groundwater remediation is the vision for the future.²⁶ Global challenges needs to be re-envisioned at each step of scientific endeavour. India, Bangladesh and South Asia are in the face of tremendous and unending challenges. Global water shortage in South Asia is in its deepest crisis.^{14,15,16,25,26,27}

5.1 Vision of science and technology and the scientific research pursuit

Scientific endeavour is in a state of immense distress. Scientific validation and scientific vision is the order of today. Human challenge is in the midst of an immense catastrophe. In such a crucial juxtaposition, the world needs to be re-envisioned with the march of history. Scientific research pursuit is at its best in today's world.²⁶ The plausible question of environmental sustainability needs to be rejustified and revisited at every step of human endeavour.²⁶ Vision of science and technology are gearing up towards new challenges and a purposeful vision. Mankind's surge towards knowledge is befitting towards new technological innovation.²⁶ The question of industrial wastewater treatment should be in the forefront of policy of civil society. Scientific research pursuit should reach the common mass. Scientific research pursuit in today's global scientific scenario needs overall revamping and re-envisioning. The AOP technique needs to be revitalized. The vision, purpose and the unsurpassed barriers ahead needs to be reshaped and re-envisioned.^{25,26,27}

5.2 Scientific endeavour and scientific vision in the field of advanced oxidation processes and bio-remediation

Advanced oxidation processes and subsequent bio-remediation will open up new chapters of science and engineering. Bioremediation is the new generation technology. History of science, advancement of technology and the wide and versatile road towards progress are marching towards a newer future direction²⁶. Scientific vision is at its zenith. The vision of the challenges and the vision of future are the ultimate parameters of industrial wastewater treatment and worldwide global water challenge. Vision of science is in the path of new regeneration. Nuclear age along with superiority of internet age are the forerunners of a new generation and is ushering in a challenging phase.²⁶

5.3 Doctrine behind advanced oxidation processes, bio-ozonation and bio-remediation

Environmental sustainability and environmental catastrophe today stands as a visionary scientific thought and they are connected by an umbilical cord which can never be severed. Advanced oxidation process and bio-ozonation is the next generation technology. Bio-remediation and bio-ozonation are pollution free and are effective waste degradation techniques of this century.^{7,8,9,25} In today's world of environmental engineering science, challenges needs to be surmounted and visionary frontiers needs to be surpassed. Today history of engineering science is witnessing a new dawn and a newer vision. Advanced oxidation process and wastewater treatment have an umbilical cord which will go a long way in realizing the vision of zero-discharge norms and towards validation of environmental engineering tools. Advanced oxidation process is one of the major non-conventional methods of industrial wastewater treatment. Among the various advanced oxidation processes, bio-ozonation stands to have immense scientific potential and a visionary future. The world of optimism stands with glory and forbearance in the distant scientific horizon. The goal of any AOPs design is to generate and use hydroxyl free radical (HO) as strong oxidant to destroy compounds that cannot be oxidized by conventional oxidant. Advanced oxidation processes are characterized by the production of OH radicals and selectivity of attack which are a useful attribute for an oxidant. The versatility of AOP is also enhanced by the fact that they offer different possible ways for OH radicals.^{10,11,12}

6.0 Bio-ozonation and bioremediation - the future environmental engineering tool

Bio-ozonation is a futuristic environmental engineering tool and a visionary methodology to improve upon the success of our present generation science and engineering endeavour. Success, difficulties and barriers of human growth depends on human scientific endeavour. In such a crucial juncture, application of bio-ozonation will certainly open up new ventures and new vistas of human vision and immense scientific fortitude. Scientific truth, scientific vision and scientific attitude are

the torchbearers of the future of environmental engineering techniques. The world of difficulties needs to be redrafted and redrawn. History of environmental engineering is witnessing a new beginning and a new dawn of scientific vision. The scientific progress needs to be targeted towards scientific validation which will surely open up a new era of immense innovation and intuition. Bio-ozonation today stands in the midst of immense scientific truth and scientific vision. The path and progress of science and technology need to be re-addressed and re-envisioned with the urgent caution towards global water shortage. Mankind's history, global water crisis and environmental sustainability will go a long way in evolving new dimensions of scientific understanding and scientific truth. Environmental sustainability is the present and next generation concern and immediate scientific truth. Sustainable development with respect to environment and sound ecology will surely open up new directions of hope and optimism. Bioremediation is surpassing visionary frontiers. The application of bioremediation and ozone-oxidation are creating a new vision and new avenues of challenges.

7.0 Advanced oxidation process, application and visionary challenges

History of environmental engineering science is witnessing a new dawn of scientific prowess. Chemical oxidation has brought the scientific community to an era of enormous scientific potential in the field of environmental engineering. The world of challenges needs to be reshaped and restructured. Application, challenges and path towards progress are interlinked and will go a long way in achieving the vision of environmental zero discharge norms. Zero discharge norms are the primordial issue of the present generation and the present day human civilization. Ecological balance stands in the midst of tremendous disaster and immense optimism. At this juncture of history, vision and time, the world of challenges needs to be addressed in its extreme introspection. Advanced oxidation processes, its application and immense visionary challenges stands in the distant scientific horizon with great optimism. Zero-discharge norms will one day usher in a new dimension of future thoughts. The world of immense challenges in the field of environmental engineering needs to be surmounted at this crucial hour of ecological imbalance. Ecology and environment needs to be protected and that needs to be protected vehemently and effectively. Man's vision should be reshaped and rejudged.

7.1 Bioremediation and effective application to industrial wastewater treatment

Bioremediation and application to industrial wastewater treatment are the forerunners to the vast and versatile domain of effective and non-traditional environmental engineering tools. History of human mankind needs to be redrafted and reshaped in view of the immense trust in scientific research pursuits in the field of environmental engineering. Industrial wastewater treatment is of immense importance to the future of environmental engineering science. The vision, the goal and the

objective of the application of advanced oxidation process and bioremediation will go a long way in unfolding the immense potential and scope of the future of environmental remediation tools.^{13,14,15} Bioremediation techniques and bio-ozonation in today's world stands in the midst of immense hope, optimism and scientific vision. The concept of environmental sustainability is at a disastrous stake in the present day human civilization. The history of mankind is at the throes of an impending environmental disaster.

7.2 Bio-ozonation and the next generation environmental engineering tool

Bio ozonation is a relatively new terminology. This is an industrial wastewater treatment technique. The immense vision of science, progress in bioremediation and ozonation are opening up new wonders and new scientific truths of environmental engineering scenario. The effects of bioremediation are proved with improved wonders. The next generation tool is evoking new emancipation of science and technology of novel separations also such as membrane science. Bio-ozonation is the next generation visionary environmental engineering technique^{1,2,3}. Man's vision as well as mankind's vision is inspiring, steadfast and ground-breaking. In view of the issue of environmental sustainability, history of environmental engineering science needs to be revamped with the turn of a decade and the ushering of a new century. Bio-ozonation is the next-generation tool which combines biodegradation and ozonation. This integrated venture will open up new vistas in wastewater degradation technology. Bio-ozonation field needs to be re-envisioned and revamped with the passage of time. This integrated will result in greater and enhanced degradation efficiency. The need of the hour is greater efficiency of biodegradation and that goal needs to be fulfilled.

7.3 Ozonation technique and other integrated advanced oxidation processes

Ozonation technique and integrated advanced oxidation processes are the next generation environmental engineering tool. History of mankind needs to scientifically restructure with the view of environmental sustainability. The targeted approach towards zero discharge norms is visionary and extremely inspiring.^{16,17,18} Chemical oxidation and advanced oxidation today stands in the verge of new discoveries, new challenges and newer innovations. New and visionary innovations with scientific intuition will open up new challenges and newer dimensions.

8.0 Recent scientific endeavour in the field of advanced oxidation processes and ozonation

Scientific research pursuit in the field of advanced oxidation processes and other integrated advanced oxidation processes is vast, versatile and widely visionary. History of science and engineering is moving from one visionary phase to another. The challenges are surmounting but the barriers to scientific validation are reshaped and restructured. Scientific endeavour is far-

reaching and crossing visionary frontiers. Man's vision needs to be enhanced and envisioned. History of civilization is moving from one difficult frontier over another.^{16,17,18} Advanced oxidation processes is in the process of a new generation and a newer vision.

Stasinakis(2008)⁹ elucidated on the use of advanced oxidation processes(AOPs)for wastewater treatment in a mini review. The aim of the study was to review the use of titanium dioxide/UV light process, hydrogen peroxide / UV light process and Fenton's reactions in wastewater treatment. In this research, the main reactions and the operating parameters (initial concentration of the target compounds, amount of oxidation agents and catalysts, nature of wastewater etc) affecting these processes are reported with lucid details while several recent applications to wastewater are presented. Al-Kdasi et al(2004)³also dealt in a review the treatment of textile wastewater by advanced oxidation processes. The use of conventional textile wastewater treatment processes becomes drastically challenged and metamorphosed to the environmental engineers with increasing more and more restrictive effluent quality by water authorities. Conventional treatment such as biological treatment discharges will no longer be tolerated as 53% of 87 colours are identified as non-biodegradable. A critical overview of basis and treatment efficiency for different AOPs are considered and presented according to their specific and critical features. Gogate et al(2004)⁵ dealt lucidly in a comprehensive review of imperative technologies for wastewater treatment with the aim towards oxidation technologies at ambient conditions. The present work deals lucidly on five different oxidation processes operating at ambient conditions such as cavitation, photocatalytic oxidation , Fenton's chemistry (belonging to the class of advanced oxidation processes) and ozonation, the use of hydrogen peroxide (belonging to the class of chemical oxidation technologies).

8.1 Recent and purposeful scientific thrust and scientific pursuit in the field of bioremediation

Bioremediation is a technology which is surpassing many visionary frontiers. Man's vision needs to be restructured and the vision of science needs revamping in such a critical juxtaposition of history and time. Integrated bioremediation and bio-ozonation techniques are the future generation technologies. Bhatnagar et al(2013)¹⁹ in an instinctive review dealt lucidly on bioremediation as an effective sustainable environmental management tool. Bioremediation is considered as one of the safer, cleaner, cost-effective and environment friendly technology for decontaminating sites which are contaminated with a wide range of pollutants. Bioremediation effectively envisions the future of environmental pollution control. Harekrushna et al(2012)²⁰ dealt lucidly on bioremediation in an instinctive review. A brief outline of the development of bioremediation technologies is presented with instinctive comprehension. The major features and limitations are presented and an overview of the current state of the art in the field of applications is sketched. The term bioremediation has been introduced to describe the

process of using biological agent to remove toxic waste from the environment. Bioremediation is the most effective tool to manage the polluted environment and recover contaminated soil. Ubalua (2011)²¹ delineated lucidly in a review article bioremediation strategies for oil polluted marine eco-systems. The marine environment is subject to contamination by organic pollutants from a variety of sources. Significant degradation of these compounds may take many years and it is frequently necessary to consider methods to accelerate this process. Kumar et al(2011)²² delineated lucidly in a review paper on bioremediation as a management tool. The term bioremediation is used to describe the process of using biological agents to remove toxic agents from environment. Bioremediation, both in situ and ex situ have enjoyed strong scientific growth, in part due to the increased use of natural attenuation, since most natural attenuation is due to biodegradation. Ruggaber et al (2006)²³ described with cogent insight in a review paper enhanced bio-remediation with enzymatic processes. The use of extracellular enzymes has been a standard in many industries for many years, only recently they have been studied for bioremediation. Extracellular enzymes are either secreted from organisms such as white rot fungi or are produced during a fermentation process and possess the ability to break down bonds within organic compounds and catalyze transformation into less toxic biodegradable forms. The vision of this treatise is to explore current state of use of extracellular enzymes in enhancing the bioremediation of recalcitrant substances and wastewater, as well as the benefits and disadvantages associated with the use of enzymes. Naik et al(2012)²⁴ dealt lucidly in a review paper on parameters affecting bioremediation. Bioremediation has provided problem solving opportunities in the field of solid waste by detoxifying effluents/wastes. This treatise reviews the parameters affecting bioremediation and the possible changes that might affect the process.

9.0 Future directions, future dimensions and the road ahead in research

Future directions in the domain of scientific pursuit should be targeted towards scientific vision and immense scientific understanding. The visionary implications of global water shortage need to be redrafted and reshaped with the critical view of global water shortage and global environmental sustainability. History of environmental engineering is witnessing a new dimension and a newer vision of tomorrow. Advanced oxidation processes, bio-ozonation and other tools of human scientific research pursuit are surpassing one visionary frontier over another. Bioremediation on the other side of the environmental engineering coin has evolved a new course of history with its greater and improved scientific understanding. Environmental regulations and environmental restrictions are creating a greater awareness and a greater scientific and engineering vision.

10.0 The path of scientific steadfastness and scientific resilience

History of science and technology is moving steadily and briskly with immense scientific steadfastness and scientific resilience. Man's vision needs to be redrafted and re-emphasized in view of the grave situation of environmental pollution control. Environmental catastrophes, disasters and in the similar manner the vision to excel in scientific pursuit has urged scientists and environmental engineers to apply new environmental engineering tools. Scientific resilience and scientific steadfastness are the order of the day. Man's vision needs to be reshaped and reorganized with the question of environmental sustainability. Today's generation is a world of immense targets and indomitable barriers. So the main thrust area should be to improve upon environmental sustainability with the help of novel separation tools.

11.0 Environmental sustainability, environmental engineering tools and the road to progress

Environmental sustainability and environmental engineering techniques are in the path towards progress in human civilization. The world of challenges, barriers and difficulties are the ultimate vision for future in road to human progress. Non-conventional and non-traditional tools of degradation of wastewater degradation are the ultimate solutions. It needs to be readdressed and reenvisioned. Environmental sustainability in today's world is in a state of unimaginable distress. The road to progress is arduous. The tools of sustainability arise from the concerted effort of common mass and civil society. Steadfastness and vision are the torchbearers of tomorrow. The world of challenges, the concerted surge of the civil society and the road towards the future are the forerunners of a greater challenge towards progress,

12.0 Science and engineering behind environmental catastrophes

Science and engineering is moving fast and steadfastly towards a newer generation of immense scientific vision. Environmental catastrophes have shaped mankind's scientific research endeavour. Traditional tools as well as non-traditional concepts are veritably gaining ground towards a newer visionary future. Civil society and human mankind have conceptually addressed the issue of environmental sustainability and environmental pollution control. Novel separation tools and non-traditional oxidation techniques will enhance human knowledge and human vision for industrial pollution control.

12.1 Water shortage, industrial wastewater treatment and environmental engineering techniques

Water shortage is an immense hurdle to the progress of human mankind. Global water shortage, industrial wastewater treatment and the holistic hurdles to economic growth are the negative issues to the progress of human civilization. History of environmental engineering strategies needs to be revamped and re-envisioned. In such a critical juncture of history and time,

man needs to gear up towards an effective vision and a purposeful scientific future. The frontiers of challenges are wide and visionary. Effort, direction and future strategies will go a long way in evolving a new generation of scientific hope and immense optimism.

12.3 Global water shortage and new generation technologies

Global water shortage and application of new generation environmental engineering tools are ushering in a new vision in the domain of technological validation. The target of our present scientific generation is to delve deep into the unknown and unravel the hidden truths of environmental engineering techniques. Global water shortage is in a deep and unfathomable crisis. The human civilization is moving towards one crisis over another. Human mankind is in deep trouble. The history needs to be revisited and re-envisioned. The crisis is of impending environmental disasters and ecological imbalance. New generation technologies are opening new dimensions of scientific research thrust areas and new scientific vision in years to come.

13.0 Success and potential of environmental engineering tools

Future dimensions and future potential in the field of advanced oxidation processes, bioremediation and bio-ozonation is wide, versatile and far-reaching. The scientific challenges need to be overcome and history of science and engineering needs to be revisited. Man's vision needs to be re-challenged and re-envisioned with the progress of science. Success and potential of the application of engineering tools depends on vision and the definitive targeted scientific approach. The vision of science and engineering needs to move towards the goal steadfastly and with immense firmness. Environmental pollution control is at a disastrous stake in today's generation. So the visionary path needs to be reshaped.

13.1 Bioremediation and advanced oxidation processes- its immense potential and the success ahead

Bioremediation and advanced oxidation processes has the immense scientific potential and the success ahead needs to be restructured with the progress of human civilization and the march of science. Bioremediation and bio-ozonation are the next generation technological innovations and the innovative path to progress. Its immense potential and the successful path ahead will surely open up new dimensions of future scientific endeavour.

14.0 Vision of advanced oxidation processes and its impact on global water shortage

Global water shortage and the vision of application of advanced oxidation processes will go a long way in opening doors of innovation and establishing a new scientific generation. History of science and engineering needs to be revamped and restructured in view of the tremendous thrust of technology on human society. In such a juncture, scientist's vision needs to be revalidated

and rejudged. The immense visionary future of advanced oxidation process stands in the midst of scientific vision and scientific forbearance. History of environmental engineering science is witnessing a new scientific revolution and scientific justification. The world of challenges needs to be revamped and reorganized in the applicability of advanced oxidation process or bio-ozonation.

14.1 Man's vision, mankind's vision and the progress of engineering

Progress of engineering and mankind's vision are the fore-runners of civilisation's newer vision. Innovation, history and progress are ushering in a new dawn of mankind. The world of challenges in the domain of advanced oxidation processes and bioremediation needs to be surmounted and frontiers surpassed. Environmental restrictions and environmental regulations are urging the scientific domain to reach visionary heights. Rekindling of human thoughts and re-envisioning of human innovation is the order of the day in the present century. Bio-ozonation is the next generation science and the next generation innovative technology. Redefinition of environmental engineering science will surely open up new vistas of research along with the tremendous potential of bio-ozonation.

14.2 Environmental sustainability and global water shortage

Environmental sustainability and global water shortage are linked by an umbilical cord which can never be severed. History of mankind, the march of knowledge and the vision of tomorrow are surging forward with a view of its urgency towards a new environmental engineering generation. Groundwater contamination and the far-reaching consequence of presence of harmful metals in groundwater are urging scientists and engineers to explore new avenues.

15.0 Future dimensions of bio-ozonation and other integrated advanced oxidation processes

Future dimensions and future potential in the field of bio-ozonation and other advanced oxidation processes stands in the midst of immense scientific optimism and hope. Environmental restrictions and stringent regulations are the backbones of scientific environmental engineering progress. The targets of zero-discharge norms will surely go a long way in evolving a new future dimension of environmental engineering techniques mainly bio-ozonation which is today in a latent stage. Innovations, discoveries and progress of science are the primordial issues of the future generations.

15.1 Future directions in the field of bio-remediation

A future direction in the domain of bio-remediation is vast, versatile, inspiring and ground-breaking. History of environmental engineering science is witnessing a new dawn and newer scientific steadfastness. Bio-remediation is a well established branch of environmental engineering science but bio-ozonation is latent and immature. Bio-remediation needs to charter a new course of history and

time with the evolution of new innovations and newer discoveries.

15.2 Future of bio-ozonation, new scientific endeavour and the progress of worldwide environmental pollution control

Future of bio-ozonation is extremely bright and far-reaching.^{12,13,14,15} History of environmental engineering science is moving towards a newer vision and a newer purpose. The mission will be incomplete if scientific validation is not addressed. Man's vision as well as mankind's progress will open up new vistas of research frontiers if the success of novel environmental engineering techniques and new tertiary treatments such as bio-ozonation is vehemently addressed.

15.3 Future endeavour and scientific thrust areas

Scientific thrust areas in today's world face immense challenges. Future pursuit in science of environmental engineering needs to witness a new revolution and a new envisioning. Scientific thrust areas in the field of advanced oxidation processes and bioremediation needs to be re-envisioned and re-emphasized. Man's vision and mankind's truth are in the process of immense reorganization in the present decade of this present century. History of science and engineering is in the midst of immense optimism and scientific endurance. Human civilization today is marked by one potential environmental disaster over another. Catastrophe, barriers and difficulties will go a long way in uncovering the wide gamut of hidden truth of the history of environmental engineering science.

16.0 The world of challenges and the future of worldwide industrial wastewater treatment

Global water shortage, drinking water crisis and industrial pollution have urged human civilization to endeavour into newer vision and newer strategies. Membrane science and advanced oxidation techniques are the visionary future of environmental engineering domain. Industrial wastewater treatment and application of non-traditional techniques are in a critical phase as regards application and effectiveness. The challenges need to be vehemently addressed with vision and scientific adjudication.

17.0 Global environmental sustainability, the vision for the future and the world of barriers

Today's global environmental scenarios are in a state of immense distress. The vision for the future is stunted and the unsurpassed barriers challenged. The issue of environmental sustainability has a purposeful vision which needs to be rebuilt and reshaped. The target, the vision and the imminent barriers will lead a long way in uncovering the world of unsurpassed frontiers of successful sustainable development. Infrastructural development needs to be reshaped with the step of realization of environmental sustainability and ecological balance. Man's vision, a scientist's prowess and the immense urge to excel will one day lead to a newer visionary future dimension.

18.0 Advanced oxidation processes integrated with bio-remediation –the next generation tool

Advanced oxidation processes are in a process of new generation. Bio-remediation along with advanced oxidation processes are the next generation scientific and engineering tools. Global sustainability is in a state of visionary rejuvenation. The barriers, the utmost challenges and the global water crisis are the forerunners of a new world order. AOP and bioremediation is in the midst of immense crisis as well as unmitigated challenges. AOP is the next generation technology. Future of global water crisis is bleak and devastating. In such a critical juxtaposition, bio-remediation needs to be re-envisioned. Science will move towards a newer direction at each step of human progress with each visionary direction of environmental sustainability.

19.0 Future of global environmental sustainability

Future of global environmental engineering scenario and successful environmental sustainable development are the primordial issues to drive our human civilization forward. The challenges need to be readjudicated and reassessed. Global environmental sustainability is moving towards drastic changes. Environmental engineering paradigm has ensured scientists to devise newer methods which though non-traditional will be effective. In such a juncture, bio-ozonation and integrated advanced oxidation processes will open up new future dimensions in scientific research pursuit.

19.1 Man's prowess, a scientist's grit and mankind's futuristic vision

Man's scientific prowess and mankind's futuristic vision are the inevitable torchbearers to a newer visionary tomorrow. Germane process technology, relevant future strategy and immense scientific vision. Global environmental disasters are creating one serious thought over another. The visionary scientific challenges of today are the scientific efforts of tomorrow. History of human civilization needs to gear up effectively and vehemently towards a newer vision of industrial pollution control.

20.0 Future strategies, future direction and future potential of non-traditional environmental engineering tools

Strategies and potential in the progress of environmental engineering science need newer reassessment and effective and purposeful vision. Non-traditional environmental engineering tools are futuristic techniques of tomorrow. Bio-remediation, bio-ozonation and application of advanced oxidation processes needs to be conceptually detailed through scientific pursuit. Ozonation and integrated advanced oxidation processes are the next generation visionary environmental engineering techniques.

20.1 Future innovation, future introspection and the scientific progress ahead

Future innovation, a deep introspection and a purposeful scientific vision needs to be widely addressed. Strategies

for the future are the torchbearers to a new age of industrial pollution control and industrial wastewater treatment. The world of challenges and scientific progress are moving from one newer vision towards another. The visionary progress of science and engineering will go a long way and a visionary path towards a remarkable path of challenge in future.^{16,17}

20.2 Future flow of thoughts and the future of global environment

Advanced oxidation processes, bioremediation and bio-ozonation are the critical avenues of research in view of the immense environmental awareness and massive environmental regulations.^{16,17} Intense future potential of these environmental engineering tools will open up a new era of scientific vision. Scientific innovations, scientific thrust areas and scientific intuitions are the major challenges which need to be overcome along with compliance to the need of the human society. History needs to be redrafted and re-envisioned with the march of science. Future of global environment is at stake and needs to be reshaped and restructured. Global environment, global ecology and scientific innovations are the parameters of growth of a nation and a parameter of human progress. In such a critical juxtaposition, environmental engineering science and its tools will surely create a new worldly vision for the future of human civilization.

23.0 REFERENCES

1. Kupa.U.,Stanczyk-Mazanek.E.,Stepniak.L.. The use of advanced oxidation process in the ozone+ hydrogen peroxide system for the removal of cyanide from water.,Desalination, 223,187-193,(2008)
2. Zhou.H.,Smith.D.W. Advanced technologies in water and wastewater treatment,Journal of Environmental Engineering Science,1:247-264,(2002).
3. Al-Kdasi,Ildris.A.,Saed.K.,Guan.C.T. Treatment of textile wastewater by advanced oxidation processes:a review, Global Nest, The International journal, 6,(3): 222-230,(2004)
4. Palit.S. 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,(2012)
5. Gogate.P.R.,Pandit.A.B. A review of imperative technologies for wastewater treatment I:oxidation technologies at ambient conditions, Advances in Environmental Research ,8:501-551,(2004)
6. Chiron.S.,Fernandez-Alba.A.,Rodriguez.A.,Garcia-Calvo.E. Pesticide Chemical Oxidation: State of the Art., Water Research, 34,(2):366-377,(2000).
7. Kos.L.,Perkowski.J. Decolouration of real textile wastewater with advanced oxidation processes,Fibres and textiles in Eastern Europe.,11(4):81-85,(2003).

21.0 CONCLUSION

Environmental awareness and scientific vision will go a long way in paving a new path of innovation in the field of novel wastewater degradation techniques. History of science and engineering are repeating itself towards a new dawn of environmental engineering science and of immense scientific vision. Sustainable development and the scientific frontiers needs to be addressed in the progress of human society. The world environmental engineering vision will surely usher in a new dawn of innovation and discovery. Environmental engineering paradigm and environmental and ecological awareness is the order of the day and the ultimate vision for the future. The dawn of human civilization needs to be re-envisioned with each step of environmental progress. The vision of science and engineering will in the near future will open up new doors of innovation and new windows of vision in years to come.

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8. Suty.H.,D.e Traversay.C.,Cost.M. Applications of advanced oxidation processes: present and future, Water Science and Technology, 49(4):227-233,(2004).
9. Stasinakis.A.S. Use of selected advanced oxidation processes(AOPs) for wastewater treatment-a mini-review, Global NEST Journal, 10 (3): 376-385,(2008).
10. Joseph.C.G.,Puma.G.L.,Bono.A.,Krishnaiah.D. Sonophotocatalysis in advanced oxidation process: A short review, Ultrasonics Sonochemistry, 16:583-589(2009)
11. Huber.M.M.,Canonica.S.,Park.G.Y.,Gunten.U.V. Oxidation of pharmaceuticals during ozonation and advanced oxidation processes ,Environmental Science and Technology, 37: 1016-1024,(2003).
12. Esplugas.S.,Bila.D.M.,Krause.L.G.T.,Dezotti.M. Ozonation and advanced oxidation technologies to remove endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs)in water effluents, Journal of Hazardous Materials ,149:631-642,(2007)
13. Palit Sukanchan. Progress in membrane separation processes, ozonation and other advanced oxidation processes- A review, International Journal of Chemical and Analytical Science , 3(1) : 1290-1292,(2012).
14. Palit Sukanchan. 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(2012).
15. Palit Sukanchan. Ozonation of Direct Red – 23 dye in a fixed bed batch bubble column reactor, Indian Journal of Science and Technology, 2 (10):14-16,(2009).
 16. Palit Sukanchan. Ozonation associated with nanofiltration as an effective procedure in treating dye effluents from textile industries with the help of a bubble column:A review, International Journal of Chemistry and Chemical Engineering, 1 (1): 53-60,(2011)
 17. Kantarci.N.,Borak.F.,Ulgen.K.O. Bubble Column Reactors,Process Biochemistry, 40:2263-2283,(2005).
 18. Cheryan.M. Ultrafiltration and Microfiltration Handbook,1st Edition,Technomic Publishing Company Inc, Lancaster, Pennsylvania, USA, 1998.
 19. Bhatnagar.S.,Kumari.R. Bioremediation- a sustainable tool for environmental management- a review, Annual Review and Research in Biology, 3(4): 974-993(2013)
 20. Harekrushna.S., Das. C.K. A review-on bioremediation, International Journal of Research in Chemistry and Environment, 2(1): 13-21,(2012).
 21. Ubalua.A.O. Bioremediation strategies for oil polluted marine ecosystems, Australian Journal of Agricultural Engineering, 2(6):160-168(2011).
 22. Kumar.A.,Bisht.B.S.,Joshi.V.D.,Dhewa.T. Review on bioremediation of polluted environment-a management tool, International Journal of Environmental Sciences, 1(6):1079-1093,(2011).
 23. Ruggaber.T.P., Talley.J.W. Enhancing bioremediation with enzymatic processes- a review, Practice periodical of Hazardous, Toxic and Radioactive Waste Management, 10(2):73-86, (2006).
 24. Naik.M.G.,Duraphe.M.D. Review paper on – parameters affecting bioremediation, International Journal of Life Science and Pharma Research, 2(3): 77-80,(2012).
 25. Palit.S. Advanced Oxidation Processes, Nanofiltration and Application of Bubble Column Reactor,In Kharisov.B.I.,Kharissova,O.V.,Dias.H.V.R.(Eds), Nanomaterials for environmental protection, John Wiley and Sons,USA, (2014),pp 207-215.
 26. Palit.S. Man's vision, mankind's vision and progress of science and technology- the inspirations and visions to target for the future, International Journal of Advancements in Research and Technology, Editorial),8th August,(2013).
 27. Palit.S. Membrane separation processes and advanced oxidation processes of dyes in bubble column reactor-a keen and far-reaching review, International Journal of Chem Tech Research, 4(3): 862-866,(2012).