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Application of bubble column reactor in environmental engineering - future directions, future dimensions, visionary and deep comprehension

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ABSTRACT: History of environmental engineering science, visionary tools and their applications are moving towards a newer visionary scientific generation of science and technology. Zero discharge norms, environmental sustainability and the immense progress of engineering has brought human civilization from the brink of an immediate and imminent environmental disaster. These disasters are due to the tremendous industrialization of human civilization. Thus in such an encompassing disaster and a critical juncture of history and time , importance of environmental engineering science has predominant importance. The domain of environmental engineering is moving towards a new generation of scientific determination and scientific steadfastness. The challenges which lie before in the path of endeavour are crucial to scientific advancement. Environmental regulations and rigid restrictions stands today as an important issue in the path towards scientific progress and scientific pursuit. Here stands today the contribution of cutting edge technology and the vision to excel. Wastewater treatment and wastewater degradation stands today as a primordial issue in the history of mankind in the present day civilization. Cutting edge technologies such as application of bubble column reactor for wastewater treatment has an unquestioned hope and unquestioned vision. Bubble column reactors has become an effective tool in giving the environmental engineer and environmental scientist the standards and the basis of better wastewater degradation. Scientific advancement has immense answers and in such a crucial juncture of universal environmental sustainability, the world of unknown opens up new vistas and new doors of innovation in the path towards progress. This treatise emboldens the answers to immense questions of wastewater treatment, advanced oxidation processes and application of bubble column reactor.

KEYWORDS: environment, bubble, reactor, wastewater, reactor, engineering, wastewater, pollution.

1 INTRODUCTION

The domain of environmental engineering is witnessing drastic and far-reaching changes. Immense ecological damage and environmental disasters are destroying human habitat. In such a critical juncture of history of human mankind, industrial wastewater treatment needs to be reassessed and rejudged with the progress of civilization. Application of bubble column reactor stands as an important and primordial vision to the newly developed regime of industrial wastewater treatment. The world of challenges needs to be revamped and restructured in such a crucial juncture of history of human civilization. Mankind today stands in the midst of immense optimism , hope, scientific vision and scientific justification. Ecological imbalance is a boon to a greater environmental disaster of immense proportion in years to come. With this concept in mind, mankind should rejustify itself to a greater vision of application of novel separation processes, advanced oxidation processes and the improved application of tools of degradation such as bubble column reactor. Future directions, future dimensions and scientific understanding will enhance with improved implication in validating knowledge in the field of application of bubble column reactor.

2 BUBBLE COLUMN REACTOR, ITS DEFINITIVE VISION AND ITS IMPROVED APPLICATION SCENARIO

Bubble column reactor and novel separation processes in today's scientific paradigm should have an umbilical cord which need not be severed. Its vision and improved application are the primordial issues of environmental engineering science. Industrial water pollution and ecological imbalance are the major parameters in the progress of science of environmental engineering. Global water shortage and drinking water shortage crisis has become an inevitable parameter to the immense growth of a developing country as well as a developed country.[1],[2],[3],[4]

Bubble column reactors owe their wide and versatile application area to a number of advantages they provide both in design and operation as compared to other reactors. First and foremost, they have excellent heat and mass transfer characteristics, meaning high heat and mass transfer coefficients. Little maintenance and low operating costs are required due to lack of moving parts and compactness. The durability of the catalyst or other packing material is high.[15],[16]

Recent research endeavour with bubble columns frequently focuses on the following topics: gas holdup studies, bubble characteristics , flow regime investigations and computational fluid dynamics studies , local and average heat transfer measurements and mass transfer studies. The effects of column dimensions, column internals design, operating conditions, i.e., pressure and temperature, the effect of superficial gas velocity, solid type and concentration are commonly investigated in these studies. Many experimental studies have been directed towards the quantification of the effects that operating conditions, slurry physical properties and column dimensions have on performance on bubble columns.[15],[16]

2.1 BUBBLE COLUMN REACTORS: CONCEPTS, DOCTRINES AND PUBLISHED WORK

As far as published studies are concerned, the main interest is concentrated on design and scale-up, fluid dynamics and regime analysis and characteristics parameters, especially gas-holdup, bubble characteristics, mass transfer coefficient and heat transfer coefficient

The design and scale-up of bubble columns have gained considerable attention in recent years due to complex hydrodynamics and its influence on transport characteristics. Although the construction of bubble columns is simple, accurate and successful design and scale-up require an improved understanding of multiphase fluid dynamics and its influences. Industrial bubble columns usually operate with a length-to-diameter ratio, or aspect ratio of at least 5. In biochemical applications this value usually varies between 2 and 5. The effects brought about by the selection of column dimensions have found interest in bubble column reactor design. First and foremost , the use of large diameter reactors is desired because large gas throughputs are involved. Additionally large reactor heights are required to obtain large conversion levels. However , there are also disadvantages brought about by the use of large diameter and tall columns in terms of ease of operation. As a result it is necessary to talk about an optimization process for best output.[16]

3 ENVIRONMENTAL ENGINEERING SCIENCE, VISIONARY TOOLS AND FAR-REACHING APPLICATIONS

Visionary applications of bubble column reactor in enviromental engineering science are immense, wide and ground-breaking. Environmental engineering is moving briskly surpassing one visionary frontier over another. The greatness of human civilization needs to be reshaped and reassessed. In today's world and today's generation, heavy metal groundwater remediation remain a formidable challenge. Bioremediation , bioadsorption and bio-ozonation stands today as a primordial alternative to this vicious challenge. In view of an inevitable global water shortage and industrial water pollution, the importance of novel separation processes and application of bubble column reactors stands high in the midst of immense optimism and steadfastness.[5],[6],[7],[8]

4 BUBBLE COLUMN REACTOR, VISIONARY CHALLENGES AND THE EFFECTIVE THRUST AREAS OF TECHNOLOGY

The path to excel in the field of environmental engineering is wide, versatile and unsurpassed. Progress of technology is visionary at every turn of decade. Hindrance, hurdles and barriers are standing in the path to progress of human mankind but visionary implications are many. Environmental regulations and restrictions has brought the human civilization out of the brink of immense catastrophe. Zero discharge norms have plunged the scientific community to immense optimism, scientific hope and scientific vision. Progress of science and technology has cogent and insightful parameters-the urge to drive scientific optimism forward. In such a scenario, the application of bubble column reactor is a boon to the purposeful and definitive vision for the future.[9],[10],[11],[12]

5 BUBBLE COLUMN REACTOR, ITS APPLICATION , PURPOSEFUL AND IMPROVED VISION

Bubble column reactor and its purposeful and improved vision are widening the colossal scientific achievements and bringing in new optimism in effectivity of environmental engineering techniques. Environmental engineering today stands in the midst of absolute optimism and unhindered progress. Environmental engineering, application of bubble column reactor and membrane separation process are interrelated domains of scientific research pursuit. Newer optimism, immense hope and scientific vision are the order of today's scientific civilization.

6 SCIENTIFIC SAGACITY, SCIENTIFIC VISION AND THE IMMEDIATE FUTURE OF APPLICATION OF BUBBLE COLUMN

Scientific sagacity and visionary path of progress are opening up new dimensions in the application areas of bubble column reactor. Progeny of the application areas of bubble column reactor are wide, versatile and visionary. History of environmental engineering, its visionary implications and immense possibilities has helped civilization out of the brinks of disaster.

7 GLOBAL WATER SHORTAGE CRISIS, INDUSTRIAL WASTEWATER TREATMENT AND THE AVENUE TO PROGRESS

Global water shortage has today plunged human mankind to the depths of infinite disaster. Drinking water provision has emerged as a primordial thrust area in a nation's growth. Man's vision is hugely enhanced and the future scientific endeavour is reshaped and rejustified. Man's as well as a scientist's path to progress is surpassing many visionary boundaries. History of science and technology will be a definitive witness to the scientific ordeals of time. Global water shortage crisis and industrial pollution stands today in the midst of immense optimism and hope. Bubble column reactor is a visionary tool whose efficacy is unlimited. Textile wastewater treatment and industrial pollution control are the backbones of its immense application domain.

The scenario of global water availability is grave and is of utmost and immediate concern to human society. Growth and progress of human civilization have an umbilical cord with the global water shortage. The path to progress in solving intricacies of industrial pollution control and environmental engineering science needs to be reassessed. History of human civilization today is in the avenue of brisk and infinite vision. That vision should alter the course of scientific understanding and scientific thought.

8 ENVIRONMENTAL AND ENERGY SUSTAINABILITY – THE SCIENTIFIC VISION FOR THE IMMEDIATE FUTURE

Environmental sustainability is the formidable issue of the present day human society and present day human generation. Scientific vision, scientific justification and scientific hope today stands in the midst of devil and the deep sea. The immediate future stands bright and visionary at the distant scientific horizon. Environmental and ecological imbalance has brought the human civilization today in deep peril. Scientific advancements has to be reassessed and revamped with the march and progress of science and technology. Energy sustainability in the same vein today stands in the midst of immense optimism in today's human civilization. The scientific vision of energy as well as environmental sustainability has to be targeted towards the needs of human development and human scientific advancement. Human society and the march of science and technology regenerates itself each turn of a decade and century. Environmental and energy sustainability stands in the midst of unbridled hope and deep insight.[13],[14],[15],[16]

9 ADVANCED OXIDATION PROCESS AND ITS VISIONARY APPLICATION IN THE DOMAIN OF INDUSTRIAL WASTEWATER TREATMENT

Advanced oxidation processes and novel separation processes today stands as a primordial backbone and a visionary tool towards effective remediation of contaminated drinking water and contaminated groundwater. History of science and technology needs to be revamped at the immediate need of human society and the scientific advancements of present day civilization. The effectivity of advanced oxidation processes and ozonation in particular are versatile, visionary and proven. The holistic approach of the application of bubble column reactor needs to be readjudicated and revamped. The challenges will loom large over the distant scientific horizon but visionary ideals will eventually surpass these inimitable barriers.

10 NOVEL SEPARATION PROCESS, MEMBRANE SCIENCE AND THE SCIENCTIFIC URGE TO EXCEL:

Novel separation processes and membrane science has visionary implication to the future progress of environmental engineering science. The scientific urge to excel has surpassed human scientific boundaries. Excellence and brilliance in scientific pursuit in today's world needs a wholesome and holistic regeneration and scientific revamping. Novel separation processes and membrane science are the backbones of environmental engineering research pursuit in today's visionary path to progress, success and immense optimism. The scientific urge to excel has been proven over the four decades in the environmental engineering pursuits. History of membrane science and environmental engineering endeavours will surely open up new doors of immense innovation and scientific intuition in years to come.

11 HUMAN MANKIND'S PROGRESS IN THE DOMAIN OF ENVIRONMENTAL ENGINEERING

Mankind's progress and thrust in scientific understanding and scientific vision is inspiring as well as path enhancing. Ecological imbalance and environmental disasters has brought the present day civilization to the brink of inimitable disaster. Thus environmental engineering is the mainstay for future generations. The hurdles, barriers and frontiers of challenges are wide and immense. Environmental sustainability is the need of the hour. Scientific reassessment of environmental engineering has to be more definitive. Progress in this area of science has to parallely move with the virtues and fruits of engineering. Civil society, governmental regulations, environmental restrictions and visionary optimization are the primordial issues of present and future generations.

Human mankind and the progress of civilization today stands in the midst of immense optimism and hope. In such a respect, environmental regulations and ecological imbalance stands steadfast and firm. The tools of environmental engineering such as bubble column reactor, advanced oxidation processes or novel separation processes will surely open up doors of immense imagination and windows of innovation for the future perspective and the future paradigm.

12 VISION OF MANKIND AND VISION OF ENVIRONMENTAL ENGINEERING FOR THE IMMEDIATE FUTURE

Vision of mankind and human civilization is poised for immense growth and immense optimism. The immediate future for environmental engineering has opened up new vistas of human growth and newer scientific vision. The vision for the future in the domain of environmental engineering is progressive and definitive. The challenges to the application needs to be surpassed with extreme steadfastness and firmness. Mass and heat transfer effects needs to be addressed vehemently and briskly. History of environmental engineering science will witness a new dawn with the slow and brisk progress of time.

The immediate future in the progress towards zero-discharge norms is inspiring and of definitive vision. Civil society, governmental decisions and environmental restrictions will go a long way in unraveling the definite truth behind environmental engineering endeavours.

13 VISION OF APPLICATION OF BUBBLE COLUMN REACTOR AND ITS IMPROVED EFFICACY

Bubble column reactors are the tools of engineering for the future. Hydrodynamics, heat and mass transfer phenomenon are the primordial issues for the future of the application of bubble column reactors. Improved technologies and definitive vision will lead the scientific endeavour to a newer generation. Improved efficacy and visionary implications will open up new doors of innovation.

14 BUBBLE COLUMN REACTOR , ADVANCED OXIDATION PROCESSES AND ITS IMMEDIATE VISION

The immediate vision in the application of bubble column reactor needs to be surpassed. History of science and engineering, the vision for future and the immense scientific optimism are the flagbearers of the greater objective of the application of this domain. The effectiveness and efficiency of the application of bubble column reactor is the backbone of scientific truth and immense scientific understanding.

15 IMPROVED HYDRODYNAMICS, IMPROVED HEAT AND MASS TRANSFER CHARACTERISTICS AND THE DEFINITIVE VISION

Bubble column reactors are intensively used as multiphase contactors and reactors in chemical, biochemical and petrochemical industries. This progressive vision in its application needs to be reassessed. They provide several advantages during operation and maintenance such as high heat and mass transfer rates , compactness and low operating and

maintenance costs. Three phase bubble column reactors are widely employed in reaction engineering , i.e., in the presence of a catalyst and in biochemical applications where microorganisms are utilized as solid suspensions in order to manufacture industrially valuable bioproducts. The design and scale-up of bubble column reactors generally depend on the quantification of three main phenomena:i)heat and mass transfer characteristics ; ii) mixing characteristics and iii) chemical kinetics of the reacting system. Thus the reported studies emphasize the requirement of improved understanding of the multiphase fluid dynamics and its influence on phase hold ups, mixing and transport properties.

16 NANOFILTRATION, APPLICATION OF BUBBLE COLUMN REACTOR AND ITS PROGRESSIVE VISION

Nanofiltration and application of nanotechnology today stands as a major thrust area in the march of environmental engineering science. Mankind's boon of science, scientific vision and progressive thoughts and vision are all interrelated. Application of bubble column reactor is the focal point of the current ongoing research thrust and the primordial backbone of tomorrow's scientific application.

17 FUTURE OF DOCTRINE OF APPLICATION AREAS OF BUBBLE COLUMN REACTOR

Doctrine of application areas of bubble column reactor is wide, varied , ever inspiring and path-breaking. History of mankind is a visionary witness to the winds of immense changes and upheavals. Bubble column reactors has shown its efficacy and its wide importance.The doctrine of applications has improved the definitive and futuristic vision of bubble column reactor. Environmental engineering science and application of bubble column reactor have an umbilical cord which cannot be surpassed. Progress, application and improved performance stands today as a major thrust area of the definitive vision of bubble column reactor. History of science, progressive vision and improved effectivity will surely help to enhance the doctrine of the application domain of bubble column reactor.

18 PROGRESS OF SCIENCE AND TECHNOLOGY AND THRUST AREAS OF ENVIRONMENTAL ENGINEERING

Science, engineering and technology are the pallbearers of the next generation human endeavour. The thrust areas needs to be reassessed and rejudged. The frontiers of application areas of environmental engineering are vehemently surpassed and the jargons of application areas and techniques of environmental engineering are resolved with immense scientific acuity. Progress in science in today's scientific world should be targeted towards definitive vision and purposeful scientific attitude. [13],[14]

19 HISTORY OF SCIENCE AND ENGINEERING, SURGE TOWARDS A NEWER VISION AND THE IMMENSE CHALLENGES IN ENVIRONMENTAL ENGINEERING SCIENCE

History of technology and science, scientific truth and scientific vision are the focal points of future human generations. The challenges towards the application of scientific visionary tools needs to be redrafted and revamped. Water shortage crisis, zero discharge norms and the scientific conclusions of environmental engineering science are the immense boons to the future of human mankind. Environmental engineering paradigm in today's world needs to be reassessed and revamped with a view to zero-discharge norms. Optimism, hope and immense scientific steadfastness will go a long way in determining human mankind's development parameter.

20 FUTURE DIRECTION, FUTURE VISIONARY THOUGHT AND THE STRIVING TOWARDS A NEWER SCIENTIFIC HOPE AND SCIENTIFIC OPTIMISM

Future direction and future dimensions in the field of application of bubble column reactors are ground-breaking and vision-surpassing. History of mankind needs to be readjudged and reassessed with the turn of each decade and each century. Future visionary thoughts will surely be targeted towards a definitive mission and purposeful goal. New scientific sagacity and scientific vision will surely pull our fragmented civilization out of the impending water shortage crisis.

21 FUTURE DIMENSION OF APPLICATION OF VARIOUS ENVIRONMENTAL ENGINEERING TECHNIQUES

Man's as well as a scientist's vision are immensely path-breaking, far-reaching and imaginative. History will visibly repeat itself with deep insight. Environmental engineering techniques, visionary implications and the progress of science and

technology are the inevitable parameters of the development and growth of a nation. Future dimensions with regards to environmental engineering techniques needs a thorough assessment and a poignant and incisive insight. In view of the ecological imbalance , the question of application of tools of environmental engineering will surely bring in a new era of scientific hope and scientific justification.

22 FUTURE VISION, PROGRESS OF ENVIRONMENTAL ENGINEERING AND THE FUTURE PATH TO PROGRESS

Future vision in the field of environmental engineering needs to be restructured and revamped. The future path to progress is wide and exceedingly imaginative. Mankind's history needs to follow a new path of environmental engineering endeavour. Zero discharge norms, effective visionary techniques and the wider vision of industrial pollution control are the parameters of future progress. History of civilization today stands in the brink of immense disaster and unsurpassed catastrophe. The jargons of human science in today's world are obliterated and the vision of tomorrow in the field of scientific vision and scientific judgement has been inspiring. Challenges, difficulties and barriers of human endeavour are immense and unsurpassed till today but the visionary implications are opening new vistas of pursuit for enhancing the scientific vision of tomorrow.

23 CONCLUSION

Bubble column reactors are one of the major environmental engineering tools for the future. Future dimensions, future progress and future vision needs to be realigned with the view of immediate need of zero-discharge norms. Environmental regulations and environmental restrictions has brought human civilization out of immediate disaster. Newer techniques, novel separation processes and effective tools such as bubble column reactors are ushering in a new scientific generation of renewed hope , intuition and perfect vision. Bubble column reactors with its enhanced scientific understanding and scientific truth are the world of vision of tomorrow. Enhanced heat and mass transfer characteristics, improved hydrodynamic applications and progressive scientific vision will be leading human vision and scientific steadfastness to a newer future generation.

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