Environmental Sustainability Using Green Technologies

Edited by V. Sivasubramanian

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Preface

Sustainability is balancing environmental protection and social responsibility with a healthy economy over time. Green engineering and chemistry play an important role in creating the options that enable sustainability by developing chemicals, processes, value-added products, and systems that are environmentally preferable, more energy and resource-efficient, and often more cost-effective. Achieving sustainable economic growth will require changes in industrial processes, in the type and amount of resources used, and in the products that are manufactured. The world must move to a more energy-efficient society by using resources more responsibly and organizing industrial processes in ways that minimize and reuse wastes. Sustainable chemical processes are dealing with the problems of waste, inefficiencies in processes, and adopting the life-cycle approach to process and product development. Sustainability is an action-oriented variant of sustainable development. It is needed to develop the ability to make a choice that respects the relationship between the three E's: economy, ecology, and equality. If all the three E's were incorporated in the national goals of countries, then it would be possible to develop a sustainable society.

There are tremendous challenges when man moves toward sustainable development but fails to use the necessary tools to overcome the challenges. It is our duty to adapt the nature and not vice versa. The flora and fauna of ecosystems are being seriously threatened by the impact of human activities. Environmental sustainability is about making responsible decisions that will reduce our negative business impact on the environment. It is not simply about reducing the amount of waste produced or using less energy, but is concerned with developing processes that will lead to businesses becoming completely sustainable in the future. Hopefully, it would reduce the burden on the earth.

This book, *Environmental Sustainability Using Green Technologies*, aims to provide comprehensive coverage on emerging dimensions on environmental sustainability. It contains 16 articles by eminent experts on different aspects of the subject. Articles on wastewater treatment technologies, nanomaterials in environmental applications, green synthesis of ecofriendly nanoparticles, the role of phytoremediation in maintaining environmental sustainability, algal biosorption of heavy metals, mass production of microalgae for industrial applications, an integrated biological system for the treatment of sulfate rich wastewater, anaerobic digestion of pharmaceutical effluent, treatment of textile dye using bioaccumulation techniques, production of biosurfactants and their applications in bioremediation, biodegradable polymers, microbial fuel cell (MFC) technology, biodiesel from nonedible oil using a packed-bed membrane reactor, production of ecofriendly biodiesel from marine sources, pretreatment techniques for the enhancement of biogas production, and a review of source apportionment of air pollutants by receptor models. The book also covers information on newer biotechnological tools and techniques required for sustainable development. Various aspects covering efficient bioremediation methods have been included to project their importance in the 21st century.

This book can serve not only as an excellent reference material, but also as a practical guide for professors, research scholars, industrialists, biotechnologists, and workers in the applied field of environmental engineering.

Velmurugan Sivasubramanian

Editor

Velmurugan Sivasubramanian is an associate professor and former head of the Department of Chemical Engineering at National Institute of Technology Calicut (NITC), in Kozhikode, India. He worked at Tamil Nadu Industrial Explosives Ltd. as a senior plant engineer for five years after his graduation. Since 2001, he has been teaching fluidization engineering, environmental engineering, wastewater engineering, energy management, safety and hazards control, principles of chemical engineering, operations management, total quality management for master of technology degree in chemical engineering, petroleum refining and petrochemicals, pharmaceutical technology and environmental science and engineering; chemical reaction engineering, mechanical operations, mass transfer, chemical technology, environmental studies, safety in chemical process industries, energy management, process economics and industrial management, petrochemicals, downstream processing/bioseparations and operations research for a bachelor of technology in chemical engineering and biotechnology; and bioreactor engineering, fluidization engineering, biological wastewater treatment, environmental biotechnology, safety management in process industries, fire engineering and explosion control, and fire modeling and dynamics for the doctoral program.

He received the Dr. Radhakrishnan Gold Medal Award, Jawaharlal Nehru Gold Medal Award, and National Citizenship Gold Medal Award from Global Economic Progress and Research Association (Thiruvannamalai, Tamil Nadu) and the Universal Achievers Gold Medal Award from the Universal Achievers Foundation (Salem, Tamil Nadu) for his outstanding individual achievement in education and contribution to education and national development.

He is involved in the development and commercial exploitation of wastewater treatment using novel bioreactors such the inverse fluidized bed reactors (IFBRs), photobioreactors (PBRs) for the remediation of dyes, pharmaceuticals, and heavy metals. His team has installed a novel magnetic biocomposite for the treatment of dye effluent. Recently, his team successfully developed a 4 m^3 floating drum biodigester for the production of biogas, which is used as a fuel in the NITC hostel mess.

Sivasubramanian has published several research papers in international and national journals and conferences in the area of environmental and chemical engineering for the treatment of effluents from various industries. His team has earned five best paper awards at national and international conferences. He is editor for five peer-reviewed journals and he also serves as reviewer for more than 50 journals.

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List of Abbreviations and Symbols

CHAPTER 1

AOP	advanced oxidation processes
BOD	biochemical oxygen demand
COD	chemical oxygen demand
GAC	granular activated carbon
IPS	intermediate pumping station
MF	microfiltration
MFC	microbial fuel cell
MLD	million liters per day
MPS	main pumping station
NF	nanofiltration
ORR	oxygen reduction reaction
PVC	polyvinyl chloride
RBC	rotating biological contactor
RO	reverse osmosis
STP	sewage treatment plant
TOC	total organic carbon
TOD	total oxygen demand
TTC-DHA	triphenyl tetrazoliumchloride dehydrogenase activity
UF	ultrafiltration
US	ultrasound
UV	ultraviolet
VOC	volatile organic carbon
VUV	vacuum ultraviolet
WAO	wet air oxidation

CHAPTER 2

Abbreviations

A swept area
AC alternating current
Au gold
Bar barometric pressure
BPPOdp brominated poly(2,6-diphenyl-1,4-phenylene oxide)
BTX benzene, toluene, and xylene
CdSe cadmium selinide
CFM cubic feet per minute
CNT carbon nanotube
CO_2 carbon dioxide
Cp power coefficient of wind turbine
CVD chemical vapor deposition
DC direct current
DD dichlorodiphenyltrichloroethane
DP deposition-precipitation
E_k rate of kinetic energy change
HRSG heat recovery and steam generation
HRTEM high resolution transmission electron microscope
HTS high temperature super conducting
ICMS integrated cell-material sciences
IGCC integrated gasification combined cycle
IPCC Intergovernmental Panel on Climate Change
MTR membrane technology research
MWCNTs multiwalled carbon nanotubes
nm min^{-1} nanometer per minute
NMP N-methyl-2-pyrrolidone
NOM natural organic matter
OTM oxygen transport membrane
P wind power
p-n junction positive channel, negative channel junction
P3HT poly(3-hexyl)thiophenezinc oxide
PAI polyamide–imide
PCBs polychlorinated biphenyls
PDMS polydimethylsiloxane
PECVD plasma-enhanced CVD
PEG-DME polyethylene glycol-dimethylether

PEI–PAI	polyethylene imine–poly (amide–imide)
PIM-1	polymer with intrinsic microporosity
PM	permenant generators
PMSGs	permanent-magnet synchronous generators
POG	point of generation
Ppm	parts per million
Ppmv	parts per million by volume
PSiNWs	porous silicon nanowires
PU	poly(urethane)
PV	photovoltaic
PVAc	poly(vinyl acetate)
QDs	quantum dots
RO	reverse osmosis
SAED	selected area electron diffraction pattern
SAXS	small angle X-ray scattering
SBM	Santa Barbara Amorphous
SiNWs	silica nanowires
SM	steam generators
STP	standard temperature and pressure
SWNTs	single-wall carbon nanotubes
TCE	trichloroethylene
TEM	transmission electron microscopy
V	wind speed
V_1 and V_2	upwind and downwind
VALA	vacuum ultraviolet radiation-assisted laser ablation
VLS	vapor–liquid–solid
VOCs	volatile organic compounds
VUV	vacuum ultraviolet radiation
WEC	World Energy Council
WGSMR	water gas shift membrane reactor
WTGs	wind turbine generating systems
XANES	x-ray absorption near edge structure
XPS	x-ray photon spectroscopy
XRD	x-ray diffraction

Symbols

(Ω)	electrical resistance ohm
ρ	air density
Ωcm	ohm centimeter

%	percentage
°C	degree centigrade
°F	degree Fahrenheit
Al_2O_3	aluminum trioxide
Au	gold
BiMo	bismuth molybdenum
C_2H_3CN	vinyl cyanide
C_2H_4	ethene
C_2H_4O	acetaldehyde
C_3H_4O	cycloproponone
C_3H_6	propene
Ce	cerium
CeO_2	cerium oxide
$cm\ s^{-1}$	centimeter per second
Co	cobalt
Co_3O_4	cobalt oxide
Cu_2O	copper oxide
eV	electron volt
Fe_2O_3	ferric oxide
GW	gigawatt or one billion watts
H	hour
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
in.	inch
kW	kilowatt
LiCl	lithium chloride
m	mass
m	meter
m	momentum
mg/L	milligram per liter
MgO	magnesium oxide
MJ/kg	mega joule per kilogram
mL	milliliter
MW	milliwatt
N	niobium
N_2	nitrogen
NH_3	ammonia