PRINCIPLES
of
ENVIRONMENTAL CATALYSIS

OVERVIEW

There is a significant interest in developing practical and novel technologies that can minimize environmental pollutants produced from anthropogenic processes. Environmental catalysis is one such tool available to scientists and engineers not only to control and treat harmful environmental pollutants but also to prevent the formation of pollutants in the first place. In addition, environmental catalysis also involves alternate and greener routes to production of value-added products. Centi et al. estimated the demand for environmental catalysis to exceed US$3 billion and expected to grow significantly. Concurrent with research and development in the area of catalysis, it is equally important to train and equip the future workforce with relevant technological skills needed for application of environmental catalysis. However, currently, there is no practical course available to students and personnel of environment-related industries that specifically focus on principles, mechanisms, and the mathematics of environmental catalysis. The proposed course titled "Principles of environmental catalysis" is expected to fulfill this need by introducing the participants to the fundamentals of environmental catalysis and their applications. The course will review the basics of chemical kinetics, cover adsorption, heterogeneous catalysis, rate equations, external and internal transport processes in heterogeneous reactions. Relevant examples from gaseous and liquid waste treatment and bioprocessing and will be discussed.

You Should Attend If…	Engineers and researchers from manufacturing, service and government organizations including R&D laboratories. Students at MSc/MTech/PhD levels. Faculty from academic and technical institutions.
FEE Structure	The participation fees for taking the course is as follows: **Participants from abroad : US $200** **Industry Participants: INR 4000/-** **Faculty: INR 2000/-** **Students: INR 1000/-(OBC/UR); INR 500 (SC/ST);** **INR 0/- (PWD)** The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, 24 hr free internet facility. The paid hotel/ guest house accommodation may be provided on first come first serve basis with prior request.

COURSE DETAILS

Course Structure (6th - 17th August, 2018)	**DAY 1** **Lecture 01** (09:00AM-10:30AM): **Material Balances** Introductory principles, opportunities and challenges in environmental catalysis, concept of mass and energy balances in environmental engineering followed by simple example problems **Lecture 02** (11:00AM-12:30PM): **Reactor Design-I** Fundamentals of reactions and kinetics, concept of reactor design and fractional conversions. **Tutorial 01** (13:30PM-15:30PM): *Applying mass and energy balances to solve numerical problems commonly encountered in environmental engineering.* **DAY 2** **Lecture 03** (09:00AM-10:30AM): **Reactor Design-II** Types of reactors used for treatment of solid, liquid, and gaseous wastes, batch, and continuous reactors, and rate laws. **Lecture 04** (11:00AM-12:30PM): **Analysis of Experimental Data** Planning, collection, and analysis of laboratory data to determine time, concentration, and reaction kinetics. Differential and integral rate laws and estimation of reaction rate constants via mathematical analysis. **Tutorial 02** (13:30PM-15:30PM): *Use of design equations for analysis of data and reaction kinetics. Example problems on differential and integral rate laws and estimation of reaction rate constants via least-square regression analysis.* **DAY 3** **Lecture 05** (09:00AM-10:30AM): **Concept of Catalysis** Principles of catalysis, definition, characteristics, and mechanism, homogeneous and heterogeneous catalysts with examples. **Lecture 06** (11:00AM-12:30PM): **Characterization of Catalysts** Theories of heterogeneous catalysis, catalyst preparation and characterization techniques, use of nanotechnology in catalyst synthesis, and general steps in a catalytic reaction. **Tutorial 03** (13:30PM-15:30PM): *Interpretation of catalyst characterization data.* **DAY 4** **Lecture 07** (09:00AM-10:30AM): **Adsorption** Principles of adsorption, adsorptive treatment for mitigation of environmental pollutants, kinetics and mechanism. **Lecture 08** (11:00AM-12:30PM): **Design of Adsorption Systems** Use of Langmuir, Freundlich, and other kinetic models for design of single-stage and multi-stage adsorption systems. **Tutorial 04** (13:30PM-15:30PM): *Solutions to problems related to estimation of adsorption capacity using linear and non-linear models followed by design of adsorption systems.* **DAY 5** **Lecture 09** (09:00AM-10:30AM): **Biological Filtration** Bio-catalytic treatment of pollutants, concept of biological filtration, design considerations, operation and scale up. **Lecture 10** (11:00AM-12:30PM): **Modelling of Biological Filters** Kinetics of contaminant removal and modelling of biofiltration systems and practical aspects. **Tutorial 05** (13:30PM-15:30PM): *Biological filtration system: design problem.*

DAY 6

Lecture 11 (09:00AM-10:30AM): **Catalytic Waste Treatment**
Catalytic treatment of wastewater and air, developing rate equations, mechanism, rate-limiting steps, qualitative analysis of rate equations. Catalyst preparation and synthesis of novel eco-friendly catalysts.
Lecture 12 (11:00AM-12:30PM): **Principles of Catalytic Reactor Design**
Validation through experimental data, procedure for determining reaction mechanism and rate-limiting steps, design of heterogeneous reactors. Design of catalytic processes for sustainable chemistry and mitigating indoor pollutants.
Tutorial 06 (13:30PM-15:30PM): *Analysis of reaction rate equations for Langmuir-Hinshelwood, Eley-Rideal, and other mathematical models.*

DAY 7

Lecture 13 (09:00AM-10:30AM): **Advanced Oxidation Concepts**
Advanced oxidation of environmental pollutants, catalytic ozonation, use of oxygen, hydrogen peroxide, and permanganate as oxidants. Design of nanostructured catalytic materials.
Lecture 14 (11:00AM-12:30PM): **Selective and Partial Oxidation**
Selective oxidation of organic pollutants and rational design of catalysts. Selective oxidation catalysts for reduction of the vehicular pollutants.
Tutorial 07 (13:30PM-15:30PM): *Analysis of data for catalytic oxidation of volatile organics using mechanistic and empirical mathematical models.*

DAY 8

Lecture 15 (09:00AM-10:30AM): **External Diffusion in Catalysis-I**
External transport processes in heterogeneous reactions, diffusion and mass transfer coefficients, diffusion through a film to a catalyst particle.
Lecture 16 (11:00AM-12:30PM): **External Diffusion in Catalysis-II**
Diffusion and mass transfer in heterogeneous catalytic reactions.
Tutorial 08 (13:30PM-15:30PM): *Example problems pertaining to diffusional transport across films and packed bed reactor.*

DAY 9

Lecture 17 (09:00AM-10:30AM): **Diffusion Coupled with Catalytic** Reactions
Diffusion with chemical reaction on a single particle, mass transfer-limited and reaction limited regimes, mass transfer with reactions in packed bed and slurry reactors.
Lecture 18 (11:00AM-12:30PM): **Internal Diffusion in Catalysis-I**
Internal transport processes in heterogeneous reactions, concept of porous catalysts, effective diffusivity, diffusion and reaction in a porous catalysts pellet.
Tutorial 09 (13:30PM-15:30PM): *Group activity (design problem for reactor and media selection)*

DAY 10

Lecture 19 (09:00AM-10:30AM): **Internal Diffusion in Catalysis-II**
Concept of Thiele modulus, internal and overall effectiveness factor, reaction-limited or diffusion-limited prediction via Mears' and Weisz-Prater criteria. Handling of spent catalysts, catalyst deactivation and regeneration, catalyst disposal and environmental impact.
Lecture 20 (11:00AM-12:30PM): **Fluidization Principles**
Engineering principles of fluidization, Carman-Kozeny and Ergun's models.
Tutorial 10 (13:30PM-15:30PM): *Numerical examples to determine effectiveness factors and reactor/catalyst sizing minimum fluidization velocities.*

THE FACULTY

Dr. Praveen Kolar is currently an Associate Professor in Biological and Agricultural Engineering at the North Carolina State University, Raleigh, NC, USA. Kolar runs a research program in value-added agricultural waste management, where the research is primarily focused on converting agricultural wastes into catalysts and adsorbents that are applied to environmental and bioenergy processes. Kolar's research has resulted in 43 articles in refereed journals and over 50 presentations on various aspects of catalysis. He has directed/directing five dissertations and eight masters' theses and served/ serving on 15 masters and dissertation committees. Kolar is an active member of the American Society of Agricultural and Biological Engineering, wherein he serves as a chair of the P-128 ethics competition committee. He teaches undergraduate courses in Transport Phenomenon and Food Processing Engineering and a graduate course in Engineering Principles of Heterogeneous Catalysis.

Dr. Somvir Bajar is currently working as an Assistant Professor in Department of Environmental Sciences, Central University of Haryana, Mahendergarh, Haryana, India. He has started his research carrier focusing on exploration of energy recovery possibilities from waste sectors and sustainable solutions for abatement of pollutants through bioremediation. He has more than 6 years of teaching and research experience and has published 13 publications in peer reviewed national and international journals and 08 book chapters. He has served PGIMER, Chandigarh as Senior Demonstrator of Environmental Health for more than 02 years and worked on several projects focussed on extending evidence based association of environmental pollutants and human health to reduce burden of diseases and disabilities. He has been also involved in providing environmental consultancy to more than 600 industries including 03 thermal power plants. He also played a considerable role in development and implementation of self-sustaining business model with the consultancy activities in his carrier.

Course Coordinator

Dr. Somvir Bajar
Teacher-In-Charge & Assistant Professor
Department of Environmental Sciences
Central University of Haryana
Mahendergarh – 123031
Haryana, India
E-mail: sksomvir@gmail.com

Local Coordinator

Dr. Aditya Saxena
Department of Physics
Central University of Haryana
Mahendergarh – 123031
Haryana, India
E-mail: adityasaxena@cuh.ac.in