

SATHYABAMA

Institute of Science and Technology

Jeppiaar Nagar, Rajiv Gandhi Salai,

Chennai - 600 119.

Tamilnadu, INDIA.

Choice based Course

Sponsored by Scheme for Promotion of Academic and Research Collaboration (SPARC)

Ministry of Human Resource and Development (MHRD)

Government of India, New Delhi

Collaborating Countries : India - Australia

Name of course: Biofouling and Coating for Engineering Applications

Course level: UG, III Year, (Sixth Semester) Elective course

Discipline: Chemical Engineering, Mechanical Engineering and Biotechnology

Lecture hours: 60 hours (Theory: 45 hours Practical: 15 hours)

Course Description:

The course proposed will provide the learning graduates an insight of the various reasons of biofouling in pipelines that transport crude and refined petroleum, gas, biofuels, other fluids including sewage, slurry, water for drinking or irrigation. The mechanism of biofouling will be dealt in detail. A comparison of various protective techniques will be highlighted for choice of methods for specific applications. The course will help in developing the interdisciplinary skill for Chemical Engineering, Mechanical Engineering and Biotechnology undergraduate students.

Course Contents(# of lecture hours)

Topic	Contents	# of hours
Unit 1 (a) Introduction to Biofouling Mechanisms and Substrates	(a) Biofilms: Introduction of biofilms, Types of biofilms, Benefits and risks of biofilms, Mechanism of formation of biofilms and applications of biofilms. Degradation of Substrates exposed to harsh environment including oil/gas/biofuels and aquatic environment	4.5h (PI India)
(b) Introduction to membrane processes and biofouling mechanism	(b) Membrane processes (Reverse Osmosis, Nanofiltration and Ultrafiltration) for water and wastewater treatment and desalination, emphasising different forms of membrane fouling (inorganic and organic fouling, biofouling and biofilm formation)	4.5h (PI Australia)
Unit 2 Biofouling and biocorrosion – Mechanisms and failure analysis	Types of degradation; characteristics of materials degradation-causes and effects; physical, chemical and biological deterioration; Roughness, Fatigue, corrosion and leaching studies.	9 (PI India)
Unit 3 (a) Biofilm Controlling Coating techniques	Introduction to Nanomaterials synthesis for coating applications. Techniques and importance of physical coatings - sputtering, evaporation, Pulsed Laser Deposition; chemical deposition – sol-gel method, dip/spin coating, electrochemical method, electroless coating etc., Properties and application of metallic coatings, criteria for	7h (PI India)

(b) Measurement of Biofouling	choosing a coating for biofilm control on metallic substrates for various industrial applications Pore blocking index and Assimilable Organic Carbon	2h (PI Australia)
<u>Unit-4</u> (a) Substrate Characterization	(a) Introduction, Principle and Techniques of Fourier-transform Infrared Spectroscopy (FTIR), Optical Microscopy, Transmission Electron Microscopy (TEM), Energy Dispersive X-ray Microanalysis (EDS), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and Scanning Probe Microscopy (SPM); Thermogravimetric analysis (TGA), Raman Spectroscopy, UV-VIS spectroscopy, X-ray Photoelectron Spectroscopy (XPS)	4.5h (PI India)
(b) Membrane fouling characterization	(b) Use of analytical instruments such as Fourier-transform infrared spectroscopy (FTIR), energy dispersive X-ray microanalysis (EDS), scanning electron microscopy (SEM), x-ray diffraction (XRD); UV-VIS spectroscopy, membrane surface zeta potential; contact angle analysis	4.5h (PI Australia)
<u>Unit-5</u> (a) Antifouling Studies	(a) quantification of biofouling, Prevention of biofouling, Leaching, biocorrosion and antifouling treatment, biofouling of membranes, numerical modeling of biofilm growth	6h (PI India)
(b) Biofouling control through pretreatment	(b) Biofilter, membrane hybrid system, membrane cleaning.	3h (PI Australia)

Lab component

Experiment	Brief Description	# of hours
Microscopic Studies for Investigation of Biofilm on contaminated Substrates	To determine the microbial count and identify the genus using Epifluorescence microscope	3
Total Viable Count (TVC) of different microbes on substrates	To investigate the diversity of microorganism by TVC on substrate exposed in environment	2
Metallic Coatings on Substrates	To prepare the substrate and synthesise the metallic coating for electroless deposition	3
(a) Substrate Characterization	(a) To study the surface morphology of metal coated substrate by FESEM	2
(b) Membrane characterization	(b) To study the surface and element characterization of new and used/fouled membranes	3 (PI Australia)
Antifouling Studies	To perform exposure studies of the coated substrate in microbial culture for determining antifouling efficiency of coating	2

Reference:

Books

1. Biofouling Methods Sergey Dobretsov, Jeremy C. Thomason, David N. Williams, 2014, ISBN:9781118336144, DOI:10.1002/9781118336144.
2. Pipeline Coatings (e-book), Y. Frank Cheng & Richard Norsworthy, 2017, ISBN: 978-1-57590-335-4
3. Jeong, S., **Naidu, G.**, Leiknes, T., **Vigneswaran, S.** (2017) '4.3 Membrane Biofouling: Biofouling Assessment and Reduction Strategies in Seawater Reverse Osmosis Desalination', *Comprehensive Membrane Science and Engineering*, Elsevier, pp. 48–71, doi:10.1016/b978-0-12-409547-2.12261-9

Article/Chapter

1. **Vinita Vishwakarma** (2018), Impact of Engineered Nanomaterials for Environmental Industries, Handbook of Nanomaterials for Industrial Applications, eBook ISBN: 9780128133521, Chapter-52, PART-VIII Engineered Nanomaterials in Environmental Industry, pp 952-958.
2. Sudha Uthaman, **Vinita Vishwakarma***, R. P. George, D. Ramachandran, Kalpana Kumari, R.Preetha, M. Premila, R. Rajaraman and U. Kamachi Mudali (2018), Enhancement of Strength and Durability of Fly Ash Concrete in Seawater Environments: Synergistic Effect of Nanoparticles, *Construction and Building Materials*, 187, 448–459.
3. Synergistic Effect of Peak Current Density and Nature of Surfactant on Microstructure, Mechanical and Electrochemical Properties of Pulsed Electrodeposited Ni-Co-SiC Nanocomposites by R D. P., Patra A. , Sengupta S. , Das S. , Das K. *Journal of Alloys and Compounds* 729 1093-1107 (2017)
4. Shon, H, Phuntsho, S, **Vigneswaran, S**, Kandasamy, JK, Aryal, R & Jegatheesan, V 2012, 'Physical, Chemical, and Biological Characterization of Membrane Fouling' in Zhang, TC, Surampalli, RY, Vigneswaran, S, Tyagi, RD, Ong, SL & Kao, CM (eds), *Membrane Technology and Environmental Applications*, American Society of Civil Engineers, USA, pp. 457-497.
5. Guo, W, Ngo, H & **Vigneswaran, S** 2012, 'Fouling Control of Membranes with Pretreatment' in Zhang, TC, Surampalli, RY, Vigneswaran, S, Tyagi, RD, Ong, SL & Kao, CM (eds), *Membrane Technology and Environmental Applications*, American Society of Civil Engineers, USA, pp. 533-580.
6. **Naidu, G.**, Jeong, S., **Vigneswaran, S.**, Rice, S. A. (2013). "Microbial activity in biofilter used as a pretreatment for seawater desalination". *Desalination*, 309, 254-260.
7. Jeong, S., **Naidu, G.**, Vollprecht, R., Leiknes, T., **Vigneswaran, S.** (2016), "In-depth analyses of organic matters in a full-scale seawater desalination plant and an autopsy of reverse osmosis membrane", *Separation and Purification Technology* 162 (2016) 171-179.
9. Jeong, S., Bae, H., **Naidu, G.**, Jeong, D., Lee, S., **Vigneswaran, S.** (2013). "Bacterial community structure in a biofilter used as a pretreatment for seawater desalination". *Ecological Engineering*, 60, 370-381.
10. Jeong, S., **Naidu, G.**, **Vigneswaran, S.** (2013). "Submerged membrane adsorption bioreactor as a pretreatment in seawater desalination for biofouling control". *Bioresource Technology*, 141, 57-64.
11. Jeong, S., **Naidu, G.**, **Vigneswaran, S.**, Ma, C. H., Rice, S. A. (2013). "A rapid bioluminescence-based test of assimilable organic carbon for seawater". *Desalination*, 317, 160-165
12. **Naidu, G.**, Jeong, S., Kim, S.-J., Kim, I.S., & **Vigneswaran, S.** (2014). "Organic fouling behavior in direct contact membrane distillation". *Desalination*, 347, pp. 230-239
13. Jeong, S., Cho, K., Jeong, D., Lee, S., Leiknes, T., **Vigneswaran, S.** Bae H. (2017) "Effect of engineered environment on microbial community structure in biofilter and biofilm on reverse osmosis membrane". *Water Research* 124(1) (2017) 227-237.

14. Jeong, S., Vollprecht, R., Cho, K., Leiknes, T., **Vigneswaran, S.** Bae, H., Lee, S. (2016) "Advanced organic and biological analysis of dual media filtration used as a pretreatment in a full-scale seawater desalination plant" *Desalination* 385 (2016) 83-92.
15. Jeong, S., **Vigneswaran, S.** (2015). "Practical use of standard pore blocking index as an indicator of biofouling potential in seawater desalination". *Desalination*, 365, (2015) 8-14
16. Jeong, S., Kim, S. -, Hee Kim, L., Seop Shin, M., **Vigneswaran, S.**, Vinh Nguyen, T., Kim, I. S. (2013). "Foulant analysis of a reverse osmosis membrane used pretreated seawater". *Journal of Membrane Science*, 428, 434-444.

**SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY
CENTRE FOR NANOSCIENCE AND NANOTECHNOLOGY
CENTRE FOR WASTE MANAGEMENT**

Name of course: Biofouling and Coating for Engineering Applications

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Discipline: Mechanical Engineering

INSTRUCTORS	
<p>INDIA Sathyabama Institute of Science and Technology, Chennai, India</p>	<p>AUSTRALIA University of Technology Sydney (UTS) ,Australia</p>
<p>Principal Investigator Dr.Vinita Vishwakarma, Professor/Scientist-F, Centre for Nanoscience and Nanotechnology Topics Covered: Introduction of biofilms, Types of biofilms, Benefits and risks of biofilms, Mechanism of formation of biofilms and applications of biofilms, quantification of biofouling, Prevention of biofouling, Leaching, biocorrosion and antifouling treatment</p>	<p>Principal Investigator Dr.Saravanamuthu Vigneswaran ,Distinguished Professor of Centre for Technologies in Water and Wastewater Environmental Engineering Topics Covered: Membrane processes ,Different forms of membrane fouling (inorganic and organic fouling, biofouling and biofilm formation),Pore blocking index and Assimilable Organic Carbon, Fourier-transform infrared spectroscopy (FTIR), energy dispersive X-ray microanalysis (EDS), scanning electron microscopy (SEM), x-ray diffraction (XRD); UV-VIS spectroscopy, membrane surface zeta potential; contact angle analysis; Biofilter, membrane hybrid system, membrane cleaning.</p>
<p>Co-Principal Investigator Dr.Dawn S S, Professor/Scientist-E ,Centre for Waste Management Centre of Excellence for Energy Research Topics Covered:Degradation of Substrates exposed to harsh environment including oil/gas/biofuels and aquatic environment, numerical modeling of biofilm growth</p>	<p>Research Personnel (India) Mr.Arun Govind M Scientific Assistant, Centre of Excellence for Energy Research Types of degradation; characteristics of materials degradation- causes and effects; physical, chemical and biological deterioration; transmission electron microscopy (TEM), Thermogravimetric analysis (TGA)</p>
<p>Research Personnel (India) Dr.Gobi Saravanan Scientist-C ,Centre for Nanoscience and Nanotechnology Roughness, Fatigue, corrosion and leaching studies. Nanomaterials synthesis for coating applications; sputtering, evaporation, Pulsed Laser Deposition; chemical deposition – sol-gel method, dip/spin coating, electrochemical method, electroless coating etc., Properties and application of metallic coatings, criteria for choosing a coating for biofilm control on metallic substrates for various industrial applications</p>	<p>Research Personnel (India) Dr.Kamalan Kirubaharan, Scientist-C, Centre for Nanoscience and Nanotechnology Centre for Nanoscience and Nanotechnology Raman Spectroscopy, X-ray photoelectron spectroscopy (XPS)</p>
<p>Dr.Kamalan Kirubaharan, Scientist-C, Centre for Nanoscience and Nanotechnology Optical microscopy, Atomic Force microscopy (AFM)</p>	<p>Dr.Kamalan Kirubaharan, Scientist-C, Centre for Nanoscience and Nanotechnology Centre for Nanoscience and Nanotechnology Raman Spectroscopy, X-ray photoelectron spectroscopy (XPS)</p>

Course Coordinators: Department of Mechanical Engineering: Dr.Prakash S, Dean ; Dr.Durairaj, Assistant Professor and Mr. Maheswaran, Assistant Professor

Lab Coordinators: Dr.T.S.Shyju,Dr.Kamalan Kirubaharan A M, Dr. D Dinesh Kumar, Mr.Vengatesh Paneerselvam , Mr.Suresh U

Ms.Nirmala N; Mr. Santhosh A; Mr.Karthik Alagarsamy; Ms.Aswini Priya; Ms.Priyadharshini P