

DEPARTMENT OF CIVIL ENGINEERING, MIT Manipal
M.Tech. ENVIRONMENTAL ENGINEERING

Program Structure (Applicable to 2019 admission onwards)

Year	FIRST SEMESTER							SECOND SEMESTER						
	Sub Code	Subject Name	L	T	P	C	Sub Code	Subject Name	L	T	P	C		
I	MAT 5160	Computational Methods and Optimization Techniques	3	1	0	4	CIE 5284	Ecology and Environmental Impact Assessment	3	1	0	4		
	HUM 5151	Research Methodology and Technical Communication	1	0	3	2	CIE 5285	Industrial Waste Water Treatment	3	1	0	4		
	CIE 5181	Advanced Water and Waste Water Treatment	3	1	0	4	CIE ****	Elective I	3	1	0	4		
	CIE 5182	Air and Noise Environment	3	1	0	4	CIE ****	Elective II	3	1	0	4		
	CIE 5183	Applied Environmental Chemistry and Microbiology	3	1	0	4	CIE ****	Elective III	3	1	0	4		
	CIE 5184	Solid and Hazardous Waste Management	3	1	0	4	****	Open Elective	3	0	0	3		
	CIE 5163	Advanced Environmental Engineering Lab	0	0	6	2	CIE 5266	Computer Applications in Environmental Engineering Lab	0	0	6	2		
						CIE 5267	Environmental Engineering Applications Lab	0	0	3	1			
			Total	16	5	9	24	Total	18	5	9	26		
THIRD AND FOURTH SEMESTER														
II	CIE 6098	Project Work												
									Total	0	0	25		

PROGRAM ELECTIVES			
CIE 5024	Disaster Management	CIE 5029	Membrane Process for Water and Waste Water Treatment
CIE 5025	Earth and Environment	CIE 5030	Occupational Safety and Health
CIE 5026	Environmental Management	CIE 5031	Remote Sensing and GIS in Environmental Engineering
CIE 5027	Environmental Quality and Pollution Monitoring Techniques	CIE 5032	Transport Processes and Modeling of Aquatic Systems
CIE 5028	Green Technology		

OPEN ELECTIVES			
CIE 5051	Advanced Strength of Materials	CIE 5053	Non - Destructive Testing of Materials
CIE 5052	Energy and Environment		

SEMESTER I

MAT 5160 COMPUTATIONAL METHODS AND OPTIMIZATION TECHNIQUES [3 1 0 4]

Statistics and Probability, frequency, characteristics, central tendency and dispersion, concepts of Probability, binomial, poisson and normal distribution, applications, analysis problems using Computer Programming, numerical methods and solutions of partial differential equations, finite difference method, Optimization significance, problems and multivariable optimization, Linear programming and solutions of standard, pivotal, simplex methods, numerical search methods for 1-D non – linear, quadratic and cubic interpolation methods.

Reference Books:

1. Antony Raiston Philip Rabinowitz - A First Course in Numerical Analysis. Dover Publications; Second edition (2001)
2. Brice, Luther N.A. and James O. Wilkes - Applied Numerical Methods. Krieger Pub Co (1990)
3. Rao. S.S. – Optimization, John Wiley & Sons, 2009
4. Sienkiowics O.C. - The Finite Element Method
5. Statistical Hydrology

HUM 5151 RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 2]

Basic concepts: Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, need for having a working hypothesis, Characteristics and Types of hypothesis, hypothesis testing, Sampling methods- Introduction to various sampling methods and their applications. Data Analysis: Sources of data, Collection of data, Measurement and scaling technique, and Different techniques of Data analysis. Thesis Writing and Publication: thesis writing, journal and conference papers writing, IEEE and Harvard styles of referencing, Effective Presentation, Copyrights, and avoiding plagiarism.

References:

1. Dr Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE, 2005.
2. Geoffrey R. Marczyk, David DeMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2004.
3. John W. Creswel , Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, SAGE, 2004
4. Suresh C. Sinha and Anil K. Dhiman, Research Methodology (2 Vols-Set), Vedam Books, 2006.
5. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publisher, 2008.

CIE 5181 ADVANCED WATER AND WASTEWATER TREATMENT [3 1 0 4]

Water Quality and treatment, Physical, chemical and biological parameters of water, standards, indices, water purification systems, Unit operations and unit processes both for water and wastewater treatment, Overview of biological wastewater treatment, objectives, biological

treatment processes, aerobic and anaerobic treatment processes for waste water.

References:

1. MetCalf and Eddy. Waste water Engineering, Treatment, Disposal and Reuse, Tata McGraw-Hill
2. Peavy,H.s, Rowe, D.R, Tchobanoglous, G. Environmental Engineering, Mc-Graw -Hill.
3. Weber, W.J. Physicochemical Processes for Water Quality COLLtrol, John Wiley.

CIE 5182 AIR AND NOISE ENVIRONMENT [3 1 0 4]

Air Pollution significance, sources, classification and characteristics of air pollutants, chemical and photochemical reactions, meteorological variables, lapse rate, inversions, stability conditions, general characteristics of stack plumes, stack height, Gaussian dispersion equation, ambient and stack sampling, analysis and control, global effects of air pollution, air quality, emission standards, air pollution act, legislations and index, noise pollution, significance, sources, effects, measurement, control measures and legislations.

References:

1. Rao H.V.N. and Rao M.N, (1989), "Air pollution", Tata Mc Graw Hill, New Delhi.
2. Rao C.S., (1995), "Environmental Pollution control", Wiley Eastern Ltd. Delhi.
3. Wark Kenneth and Wamer C.F, "Air Pollution its Origin and Control". Pearson; 3 edition (1997)
4. Sincero. A. P.and Sincero G.A; "Environmental Engineering". Prentice Hall.
5. Air Pollution - Sampling and Analysis - APHA.

CIE 5183 APPLIED ENVIRONMENTAL CHEMISTRY & MICROBIOLOGY [3 1 0 4]

Basic concepts from general chemistry, qualitative chemistry, quantities chemistry, physical chemistry, colloid chemistry, biochemistry, radio chemistry. Instrumental methods of analysis. Environmental biochemistry – proteins, carbohydrates, lipids, enzymes, nucleic acid, metabolic processes. Chemical toxicology, coagulation and water softening. Microbiology – scope and introduction, characterization, classification and identification of microorganisms, pure cultures and cultural characteristics, enzymes and their regulations, microbial metabolism, control of microorganisms.

References:

1. Sawyer, C.L. McCarty P.L. and Parkin, G.F., Chemistry for Environmental Engineering, McGraw-hill, (2003)
2. Pelezar, M.J., Chan E.C.S and Hrieg, N.R., Microbiology, Tata McGraw Hill, (1986)
3. Julia Levy, Campbell, J.J.R and Henry Blackburn, T, Introductory Microbiology, John Wiley & Sons, 1973
4. Benefield, L.D. and Randall C.W., Biological processes design for waste water, Prentice Hall, 1980
5. Metcalf and Eddy. Inc., Waste water Engg. Treatment, disposal reuse, Tata McGraw Hill Publishing Company Ltd., New Delhi, (2002).

CIE 5184 SOLID AND HAZARDOUS WASTE MANAGEMENT [3 1 0 4]

Introduction to Solid waste, Hazardous waste, legal frame work, Cradle to grave concept, Waste manifest system. Waste generation Collection and transportation: Solid waste generation, Methods to estimate waste quantities, Material recovery facility collection rate, collection routes optimization, transfer station, Method and means of transportation. Processing and recycling, energy recovery system. Hazardous waste treatment, physicochemical process, Disposal Methods, control and treatment of landfill gases and leachates, Land fill operations. Siting of wastes management facilities: Site Remediation, the hazardous system and the national priority list. Remedial Action, Radio Active Wastes treatment

References:

1. Integrated Solid Waste Management – George Tchobanaglou, Hilary Theisen and Samuel A. Vigil, (1993),
2. Environmental Engineering – A Design Approach Sincero, A.P., and Sincero, G.A., (1999), Prentice Hall of India Pvt. Ltd., New Delhi.
3. Solid Waste Engineering – Vesiland, A, Thompson Books.
4. Solid Waste Management – CPHEEO Manual
5. Hazardous Waste Management- Wentz C.A., McGraw Hill, 1989.

CIE 5163 ADVANCED ENVIRONMENTAL ENGINEERING LABORATORY [0 0 6 2]

Determination of physical, chemical and bacteriological characteristics, coagulation, chlorination, heavy metal, colour, adsorption studies, pilot scale studies, demonstration and study of various instruments used for analysis of water and waste water analysis.

References:

1. American Public Health Association et al. 'Standard Methods for the Examinations of Water and Waste Water' APHA.
2. Aneja, K.R. 'Experiments in Microbiology, Plant Pathology and Tissue Culture'. WishwaPrakashan, New Delhi.
3. Manual of methods of General Bacteriology, ASM Publication.

SEMESTER II

CIE 5281 ECOLOGY AND ENVIRONMENTAL IMPACT ASSESSMENT [3 1 0 4]

Ecology classification, terminology, sub-divisions, structure and functions of ecosystems, energy flow, primary production, ecological succession, population and habitat ecology, biochemical cycles, aquatic and terrestrial ecosystems, eutrophication, Environmental Impact Assessment significance and need, EIS, FONSI, procedure for conducting EIA, conceptual framework, Impact assessment methodologies of EIA, assessment and prediction of impacts on environmental attributes, public participation, IAA, REIA, EIA for development projects.

References:

1. Odum - Fundamentals of Ecology - Saunders, 1967.
2. Kormondy- Concepts of Ecology- Printcehall publication, 1965.
3. Anantkrishna, T.N - Bio-resources Ecology- Oxford and IBH Publishing Co., 1989.
4. Krebs J. - Ecology - The experimental analysis of distribution and abundance-II Edition Harper international, 1972.

5. Canter L - Environmental Impact Assessment McGraw Hill 1977.
6. Mall C.A.S. and Day J.W - Ecosystem modeling in theory and practice: An introduction with case NI stories - John Wiley.

CIE 5282 INDUSTRIAL WASTEWATER TREATMENT [3 1 0 4]

Effects of Industrial Wastes on sewerage system and sewage treatment plants and receiving water bodies. Effluent standards and receiving water quality standards. Different aspects and choices of various alternatives. Industrial Waste Survey-Process flow charts, condition of waste stream. Material balance. Pretreatment of Industrial Wastewater – Wastewater Treatment in specific industries: Distillery, Sugar, Pulp and paper, Cement, Textile, Dairy, Fertilizer, Pesticides, Pharmaceutical, Ultimate disposal of Industrial Wastewater, effects of waste additions on physical and chemical properties of soil, Bio-Remediation of Distillery, Sugar, Refinery and Dairy Industries. Design of complete treatment system disposal for industries

References:

1. Nelson N Nemerow – "Liquid Waste of industry theories, "Practices and Treatment. Addison Wiley New York.
2. Nardam S Azad – "Industrial Wastewater Management Hand Book" McGraw Hill book Co., Newyork.
3. Dickinson - Practical Waste Treatment and Disposal Applied Science publication, London.
4. Self N.J – Industrial pollution Control.
5. Gaynor W Dawson, et al – "Hazardous Waste Management"- A Wiley- Interscience Publication, New York.
6. James F parr et al – "Land Treatment of Hazardous Wastes"- Noyes Data Corporation, Parkridge, New Jersey, USA.

CIE 5266 COMPUTER APPLICATIONS IN ENVIRONMENTAL ENGINEERING LABORATORY [0 0 6 2]

C++ programming language, Input, output and logical statements; iterative loops, Programming of environmental management problems such as population forecasting, physical and chemical characteristics, Streeter Phelps equation, stack height, screens, aeration tank, sedimentation tank, sand filters, sewer.

Use of packages in Environmental Engineering.

References:

1. Balaguruswamy E., (2006) 'Object Oriented Programming with C++', Tata McGraw Hill, New Delhi.
2. Ang and Tang, (1984) "Probability concepts in engineering planning and design", Vol. I and II, Wiley International.
3. Kottegoda N.T., Rosso Renzo, (1998) "Statistics, Probability and Reliability for Civil and Environmental Engineers", Mc-Graw Hill International.
4. AICTE Continuing Education Programme, "Quantitative Methods in Construction Management"

CIE 5267 ENVIRONMENTAL ENGINEERING APPLICATIONS LABORATORY [0 0 3 1]

Sampling and analysis and treatment of water and waste water, ground water quality, ambient and stack sampling of air pollutants and analysis, use of remote sensing and GIS, mini projects related to the areas of water, waste water, ground water, ambient air and using packages related to surface water, ground water, air, remote sensing and GIS.

SEMESTER III and IV

CIE 6098 PROJECT WORK [0 0 0 25]

Students are required to undertake innovative and research oriented projects, which not only reflect their knowledge gained in the previous two semesters but also reflects additional knowledge gained from their own effort. The project work can be carried out in the institution/ industry/ research laboratory or any other competent institutions. The duration of project work should be a minimum of 36 weeks. There will be a mid-term evaluation of the project work done after about 18 weeks. An interim project report is to be submitted to the department during the mid-term evaluation. Each student has to submit to the department a project report in prescribed format after completing the work. The final evaluation and viva-voice will be after submission of the report. Each student has to make a presentation on the work carried out, before the departmental committee for project evaluation. The mid-term & end semester evaluation will be done by the departmental committee including the guides.

PROGRAM ELECTIVES

CIE 5025 EARTH AND ENVIRONMENT [3 1 0 4]

Planet Earth Evolution and constitution, Minerals and Rocks forms, relationship to crystals, rocks and their types, Surface features of the Earth, Landforms, weathering and erosion, Plate tectonics and sea-floor spreading, Economic Geology, Earth hazards, Importance of biodiversity to mankind and its preservation, Natural resources: Renewable and non-renewable resources - Alternatives to fossil fuels, Pollution of air, water and soil and its control- discussion of several case studies, Climate change, Reasons and effects of climate change on the environment, mitigation, geo-engineering techniques.

References:

1. A B Roy (2010) Fundamentals of Geology, Narosa Publishing House, New Delhi
2. Gerard Kiely (2007) Environmental Engineering, Tata McGraw Hill Education Private Ltd., New Delhi

CIE 5031 REMOTE SENSING AND GIS IN ENVIRONMENTAL ENGINEERING [3 1 0 4]

Definition, Basics of Remote sensing, Sensors, Multi spectral scanners, Platforms, Data Acquisition and Interpretation - Visual and digital interpretation, Application of remote sensing techniques. GIS - Concepts, functionality, Data acquisition, processing, storage and retrieval, Hardware and software requirements, GIS and Remote sensing data integration, GIS in Decision support system, Network analysis & applications in Environmental Management.

References:

1. George Joseph, Fundamentals of Remote Sensing Universities Press, Hyderabad 2005
2. Thomas M. Lillesand, Ralph W. Kiefer, Jonathan W. Chipman Remote sensing and image interpretation John Wiley & Sons, 2008 4.
3. Burrough P.A., Principles of Geographical Information System for Land Resources Assessment, Oxford Publications, 1980
4. Paul A. Longley, Micheal F. Goodchild, David J. Magaine David J. Magaine, David W Rhind. Geographical Information System. Vol. I & II, John Wiley & Sons. Inc., 1999
5. M. Anji Reddy, Textbook of Remote Sensing and Geographical Information systems, BS Publications, Hyderabad. 2011.

CIE 5032 TRANSPORT PROCESSES AND MODELING OF AQUATIC SYSTEMS [3 1 0 4]

Rivers, streams and lakes: Derivation of steady state stream equation. 1-D Oxygen balance models - Streeter- Phelps equation. Calibration and verification of 1-D Oxygen model. Mixing Zones in rivers - definition, steady state 2-D analysis. Dissolved Oxygen models for lakes under

completely mixed and stratified conditions. Estuaries; Physical aspects of estuaries. Distribution of water quality in estuaries. Estimation of tidal dispersion coefficient. Derivation of estuary equation. Ground water quality modeling concepts- simplified nutrient loading models for rivers and lakes.

References:

1. Rich L.G. Environmental Systems Engineering McGraw Hill-1972.
2. Biswas A.K. - Models for water quality management- McGraw Hill 1980.
3. Rinaldi S.D. and Soncini, R- Modelling and Control of river water quality McGraw Hill-1979.
4. Gower A.M. - Water quality in catchment ecosystems John Wiley- 1980.
5. Thomann and Mueller, 1986. Principles of water quality management and control- Harper and Row pubs.

CIE 5027 ENVIRONMENTAL QUALITY AND POLLUTION MONITORING TECHNIQUES [3 1 0 4]

General principles of sample collection and data analysis. Gravimetric methods for solids analysis in water and wastewater, analysis of common cations and anions in water/wastewater. Titrimetric methods; Electrochemical methods; Spectrophotometric methods; Biological methods and microbiology; Monitoring and analysis of air pollution. Monitoring soil and groundwater pollution

References:

1. Sawyer, C. L. McCarthy, P.L and Parkin, G. F. Chemistry for Environmental Engineering, McGraw-Hill.

CIE 5026 ENVIRONMENTAL MANAGEMENT [3 1 0 4]

Environment and Sustainable Development - carrying capacity, relationship with quality of life, carrying capacity and resource utilization. Environmental Laws and Policies - Water Act, Air Act, Environment Protection Acts, Solid Waste management Rules, Hazardous and Biomedical waste Rules, Related Policies - Importance in Management. Environmental Economics: Introduction, economic tools for evaluation, Cleaner development mechanisms (CDM) and their applications. Environmental Audit - methods, procedure, reporting and case studies. Environmental management system and Techniques - Environmental Safety and ISO 14000 series of standards, ISO 14001 Standards, Environmental Management systems. (EMS) and 18000 series of standards.

References:

1. Lohani B. N (1984), "Environmental Quality Management", South Asian Publishers, New Delhi
2. Chanlett, (1973) "Environmental Protection", McGraw Hill Publication, New York.
3. Danoy G.E., and Warner R.F., (1969), "Planning and Design of Engineering Systems", Unwin Hyman Publications.
4. T. V. Ramachandra & Kulakarni, Environmental management

CIE 5024 DISASTER MANAGEMENT [3 1 0 4]

Principles of Disaster Management, Assessment of Disaster Vulnerability, Preparedness and Mitigation measures for various Disasters, Issues in Environmental Health, Water & Sanitation. Post Disaster Relief & Logistics Management, Emergency Support Functions and their coordination mechanism, Resource & Material Management, Voluntary Agencies & Community Participation at various stages of disaster management, Integration of Rural Development Programmes with disaster reduction and mitigation activities, Role of Remote Sensing, Science & Technology.

References:

1. Savinder Singh Environmental Geography, Prayag Pustak Bhawan, 1997

2. R.B. Singh (Ed) Disaster Management, Rawat Publication, New Delhi, 2000
3. H.K. Gupta (Ed) Disaster Management, Universiters Press, India, 2003
4. R.B. Singh, Space Technology for Disaster Mitigation in India (INCED) University of Tokyo, 1994
5. Dr. Satender , Disaster Management in Hills, Concept Publishing Co., NewDelhi, 2003
6. M.C. Gupta Manuals on Natural Disaster management in India, National Centre for Disaster Management, IIPA, New Delhi, 2001

CIE 5028 GREEN TECHNOLOGY [3 1 0 4]

Green technology, overview to site design: site planning and analysis, market analysis vs. Site analysis, Water and site design: problems and issues with water and site practices, Waste as a resource economics, water and industrial effluent reuse, pisciculture, groundwater recharge of sewage effluents. Health aspects of water reuse - guidelines for evaluating recreational water reuse, resource conservation and recovery act, source reduction and waste minimization, waste to energy, metals recovery

References:

1. Springer, "Recycling and Resource Recovery Engineering" - Springer – Verlag Berlin Heidelberg (1996)
2. ICE: Reuse of Sewage Effluent, Proceedings of the International Symposium, Thomas Felford London (1985)
3. Dean R.B. and E., "Water Reuse Problems and Solutions" Academic Press (1981)
4. Green Building Rating System for New Construction and Major Renovations (LEED-NC), Version 2.2, October 2005, 81 pp.
5. Matthiessen, Lisa Fay, and Morris, Peter, "Costing Green: A Comprehensive Cost Database & Budgeting Methodology", 2003, 27 pp.
6. Roberts, Don V., "Sustainable Development-A Challenge for the Engineering Profession", FIDIC Annual Conference, Oslo, Norway, 18 June 1990, 23 pp.

CIE 5029 MEMBRANE PROCESS FOR WATER AND WASTE WATER TREATMENT [3 1 0 4]

Introduction to membrane separation processes, principles and application of Membrane filtration, Reverse osmosis, Nanofiltration, Ultrafiltration, Microfiltration, Membranes and modules, MF/UF experimental set up, Laws of MFIUF, Limiting Phenomena, Economic study, Applications, Case studies.

References:

1. Bailey and Ollis, Biochemical Engineering and Fundamentals, McGraw Hill International, 1986.
2. Smith, Principles of Biochemistry, 7th Edition, McGraw Hill international.
3. Agarwal's A Text book of Biochemistry, Goe\ Publishing House, Meerut.
4. P.K. Guptha, Elements of Biotechnology, Restogi Publishers, Meerut. S.
5. American Water Works Association Research Foundation, Water Treatment- membrane processes, Mc. GrawHill.

CIE 5030 OCCUPATIONAL SAFETY AND HEALTH [3 1 0 4]

Occupational safety and Healthact. Occupational Safety and Health Administration, right to know Laws, Accident Causation, Correcting Missing Skills, Investigator Tendencies and Characteristics, Human Error Model, Petersew's Model, Epidemiological Models, Ergonomics at work place, Occupational Hazard and Control - Hazard Analysis, Fault Tree Analysis, Human Error Analysisin Causation with Hazard Analysis, Emergency Response. Hazards and their Control in various industries,

Fire prevention and Protection, Technical Requirements of Product Safety Programme, Occupational Health and Safety Considerations, Personal Protective Equipments, Occupational Health and Safety case studies.

References:

1. David L. Goetsch. "Occupational Safety and Health" for Technologists, Engineers and Managers 3Mediton. Prentice hall.
2. David. A. Calling - Industrial Safety Management and Technology, Prentice Hall, New Delhi.
3. Della D. E. and Giustina, Safety and Environmental Management. Van Nostrand Reinhold International Thomson Publishing Inc, 1996.
4. Trevethick R. A. Environmental and Industrial Health Hazards, William Heinemann Medical Books Ltd., London (1973).

OPEN ELECTIVES

CIE 5051 ADVANCED STRENGTH OF MATERIALS [3 0 0 3]

Torsion: Torsion of non-circular and thin walled sections. Unsymmetrical bending of straight beams, thin walled beam cross sections - shear centre for thin walled sections. Bending of curved beams: crane hooks, closed rings - correction factor for flanged cross sections. Bending of beams curved in plan. Beams on Elastic foundation.

References:

1. Srinath L.S., Advanced Solid Mechanics TMH., New Delhi.
2. Boresi A.P., and Sidebottom O.M., Advanced Mechanics of Materials, John Wiley and sons in N.Y.
3. Den Hartog, Advanced Strength of Materials, McGraw Hill, N.Y.

CIE 5052 ENERGY AND ENVIRONMENT [3 0 0 3]

Introduction: Energy consumption, crisis, Policies, Laws and Principles. Renewable sources of energy and Environmental aspects: example: solar energy, Hydro power, etc Non-renewable sources of energy and Environmental aspects –, coal, oil, natural gas. Global and regional impacts of Climate change: Greenhouse effects, global warming and Acid rain

References:

1. G.D.Rai. "Non-Conventional energy sources" Khanna publishers.
2. D P Kothari, et.al., "Renewable energy sources & Emerging Technologies".
3. Wilber L.C. "Hand book of Energy Systems" Engg Wiley & Sons 1989.
4. Rao and Parulekar B.B. Energy Technology- Non-conventional Renewable & Conventional, Second Edition Khanna Publication 1977.

CIE 5053 NON- DESTRUCTIVE TESTING OF MATERIALS [3 0 0 3]

Introduction, Liquid Penetrant Tests, Magnetic particle testing, Acoustic Emission Test, Ultrasonic test, Electromagnetic Testing Method, Leak Testing Methods, Radiographic Testing Method.

References

1. Barry Hull & Vernon John, Non-destructive Testing, 1st edition, Macmillan, London, 1988.
2. R. Halmshaw, Non-destructive Testing, 2nd edition, Edward Arnold, London, 1991.
3. McGonnagle W. J., Non-destructive testing, Gordon & Beach Science, New York, 1983.