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| | large data sets and generate programs. Plot global ocean /atmosphere data for specific spatial and temporal ranges. | |

**Programme:** M.Sc. (Marine Sciences)
**Course Code:MSC 263** **Title of the Course: Law of the Sea and Coastal Regulation Zone**
**Number of Credits:** 02
**Effective from AY:**June2018-19

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| **Prerequisites for the course** | Students who have undergone courses of semester I of Marine Sciences. | |
| **Objective** | This course introduces the law of the Sea and the concept of coastal regulation zone. | |
| **Content** | Law of the Sea – Territorial Sea – Contiguous zone – Straits used for international navigation – Archipelagic states – Exclusive economic zone – Continental shelf – High seas – Regime of islands – enclosed or semi-enclosed seas – Right of access of land-locked states – Protection and preservation of marine environment – Scientific and technical assistant – international rules and national legislation to prevent, reduce and control pollution of the marine environment.<br><br>Coastal Regulation Zone – Demarcation – Prohibited activities – Regulation of permissible activities – Procedure for monitoring and enforcement – Classification of Coastal Regulation Zone – Category I (CRZ-I) – Category II (CRZ-II) – Category III (CRZ-III) – Category IV (CRZ-IV) – Norms for regulation of activities – CRZ-I – CRZ-II – CRZ-III – CRZ-IV – Guidelines for development in the designated areas of CRZ-III – Permitted petroleum products for storage in CRZ. | 12 hours<br><br>12 hours |
| **Pedagogy** | Lectures / Assignments / Seminars / Discussion | |
| **References / Readings** | 1. United Nations Convention on the Law of the Sea 1982 A Commentary, 2011 volume 7, Nordquist M. N., Martinus Nijhoff Publishers.<br>2. United Nations Convention on the Law of the Sea, 2009, United Nations, Nova Science Publishers, Inc., New York.<br>3. Coastal Regulation Zone 2011 and Island Protection Zone 2011 notifications issued 6.1.2011, Ministry of Environment and Forests.<br>4. Coastal Regulation Zone notification 1991 under E(P)A, 1986 – 19.2.91<br>5. Coastal Regulation Zone and Island Protection Zone notifications 2011, ICZM project, Ministry of Environment, Forests and Climate change, July 11, 2016. | |
| **Learning Outcomes** | 1. Understanding of the laws applicable for navigation in sea.<br>2. Knowledge of international and national legislation to control marine pollution.<br>3. Understanding coastal regulation zone to prevent the deterioration of coast. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 264Title of the Course: Remote sensing and its applications**
**Number of Credits:** 04
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Students undergoing course in any branch of Marine Sciences. |
| **Objective:** | All the coastal process is transient in nature. They are of either diurnal/weekly time scale. To deal with such variability the requirement is a method that would provide a synoptic coverage of the coastal and offshore regions. This is possible only by means of Remote sensing. Hence this emerging technology has been introduced as a course. |

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| **Content:** | Principles of Electromagnetic radiation– Energy matter interactions –- Rayleigh scattering – Mie scattering – Non selective scattering - Radiative transfer in the atmosphere – Stfan's and Wien's displacement laws –Zenith and azimuth angles.<br><br>Optical remote sensing – bio-optical properties of sea water - Inherent and apparent optical properties - scattering - absorption-attenuation - diffuse attenuation – Remote sensing reflectance - Case I and Case II waters - radiative transfer in the water column.<br><br>Sun photometry - Beer-lambert's law - spectral variation of aerosol optical thickness - atmospheric correction - interpretation of ocean colour - spectral response of water as a function of organic and inorganic constituents - Analysis of suspended minerals, chlorophyll *a* and dissolved organic matter through OCM/MODIS data.<br><br>Thermal infrared remote sensing- Thermal infrared properties - Atmospheric windows - Thermal radiation laws - Emissivity - sea surface temperature retrieval through IR sensors - Active and passive microwave remote sensing - Satellite altimetry of sea surface topography. Sensor characteristics – MSS, GOES, AVHRR, CZCS, SeaWiFS, IKONOS, MODIS, OCM I and OCM - II, LISS -1, LISS-II, WIFS and PAN – Fundamentals of digital image processing – Image rectification – Image enhancement – linear stretching – supervised and unsupervised classification - Introduction to Geographic Information system. | 12 hours<br><br>12 hours<br><br>12 hours<br><br>12 hours |
| **Pedagogy:** | Being a new and an emerging field, it is necessary to have class room contact hours. Hence, it is a class room taught course. In addition, to get acquaint with the course,seminar topics on the applications of remote sensing are given to the students at the beginning. | |
| **References/ Readings** | 1. Physical principles of remote sensing, 1990 – Rees, W.G., Cambridge Univ. Press, U.K.<br>2. Remote sensing optics and optical systems, 1980 – Slater, P.N., Addision Wesley Publ. Co.<br>3. Remote sensing and image interpretation ($2^{nd}$edn), 1987 – Lillesand, T.M. and Kiefer, R.W., John Wiley and sons.<br>4. Remote sensing: Principles and interpretations ($2^{nd}$edn), 1987 – Floyd and F. Sabnis Jr. W.H. Freeman and Co., New York.<br>5. Theory and application of optical remote sensing, 1989 – Asrar G., John Wiley & Sons.<br>6. Introduction to satellite oceanography, 1985 – Maul, G.A., Martinus Nijhoff Publ.<br>7. Advanced remote sensing from theory to applications (vol.1, 2 & 3), 1981 – Chlamys, F.T., Addision wisley Publ. Co. Inc., Canada.<br>8. Oceanography from space, 1987- Gover, J.A.R., Plenum Press, New York.<br>9. Remote sensing of atmospheres and oceans, 1980 - Deepak A., Academic press.<br>10. Satellite oceanography, 1985 - Robinson, I.S., John Wiley & Sons | |
| **Learning Outcomes** | Since the country is in advanced stage in the field of space Technology, the students opting for this course will be trained Manpower to carry forward Nation's need for human resources in the field of Remote sensing. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 265** **Title of the Course: Remote Sensing and its applications Practical**
**Number of Credits:** 02
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Students undergoing course in any branch of Marine Sciences. |
| **Objective:** | This course is the practical component of the theory students learn. This involves satellite data processing for various applications of Ocean/earth/ atmosphere. In this course, students will be exposed to different satellite data, various corrections to be applied and finally image processing for a finished geophysical product. |

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| **Content:** | **Module - I**<br>1. Field survey and laboratory analysis to generate apparent optical properties from case II waters using in-water radiometer, and profiles of salinity and temperature using conductivity, temperature and Depth (CTD) sensor, (16 hrs; Ref 1)<br>2. Generation of Inherent Optical properties (IOP) of optically active substances (OAS), namely absorption of chlorophyll-*a* (Chl-*a*), Chromophoric Dissolved Organic Matter (CDOM) and Total Suspended Inorganic Matter (TSM) from water samples collected during the field survey of case II waters (10 hrs; Ref 1)<br>3. Simulation of remote sensing reflectance and water leaving radiance from case II waters (4 hrs; Ref 2)<br><br>**Module – II**<br>1. Simulation of remote sensing reflectance for each optically active substance and delineation of range of wavelengths susceptible to each OAS and development of empirical algorithms (10 hrs; Ref 3)<br>2. Generation of aerosol optical depth using sun-photometer and analysis of aerosol optical depth to estimate atmospheric turbidity parameter and Angstrom exponent (8 hrs; Ref 4,5,8)<br>3. Satellite data processing to map chlorophyll *a*, using ERDAS IMAGINE SeaDAS (12 hrs; Ref 6, 7 and 8) | 24 hours<br><br>24 hours |
| **Pedagogy:** | This course is done through various programming to estimate Parameters followed by usage of different image processing packages. One such package student's use is SeaDAS software. | |
| **References/ Readings** | 1. Regional validation of MERIS CHLOROPHYLL products in North coastal waters (REVAMP) Protocol, based on NASA and colors protocols, 2002 - Tilstone, G.H, Moore, G.F, Sorensen. K, Doerffer. R, Rottgers, K.G, Ruddick. R, Psterkamp, P.V and Jorgensen, ENVISAT – 1<br>2. Physical principles of remote sensing, 1990 – Rees, W.G., Cambridge Univ. press, U.K. 25<br>3. Remote sensing: Principles and interpretations ($2^{nd}$ edn), 1987 – Floyd and F. Sabnis Jr, W.H. Freeman & Co., New York.<br>4. Theory and applications of optical remote sensing, 1989 – Asrar, G., John Wiley & Sons.<br>5. Introduction to satellite oceanography, 1985 – Maul, G.A., Martinus Nijhoff Publ.<br>6. Advanced remote sensing from theory to applications (Vol.1, 2 & 3), 1981, Chlamys, F.T., Addison – Wesley Publ. Co. Inc., Canada.<br>7. Oceanography from space, 1987 – Grover, J.A.R., Plenum Press, New York.<br>8. Remote sensing of atmospheres and oceans, 1980 – Deepak, A., Academic Press.<br>9. SBE plus CTD, User's manual www.seabird.com/pdf_documents/manuals/9_plus_017.pdf<br>10. Regional Oceanography, an Introduction, 2nd edition, 2003 - Tomczak, Mattias and Stuart Godfrey J, , Daya Publishing house, Delhi. | |
| **Learning Outcomes** | Students will be thoroughly trained in different process of satellite Data so as to generate various geophysical products. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 266Title of the Course: Analytical Chemistry of Sea water and**
**Number of Credits:** 04 **Instrumental Techniques**
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. |
| **Objective:** | 1. The course is aimed at understanding the collection sea water, sediment and biological samples by using different field equipments.<br>2. To adopt suitable techniques for preservation water, sediment and biological samples for their chemical analyses.<br>3. The course work is so designed to understand the errors generally occur in the analyses of samples by different techniques.<br>4. To study different techniques used for extraction of various inorganic chemicals ( fresh water, salt, bromine, calcium, magnesium and potassium) and organic chemicals (Agar, Carrageenan and Alginic acid) and<br>5. To study instruments used (Spectrophotometer, spectrofluorimeter, and flame photometer, AAS, ICP, GC and HPLC) for analyses of different chemical constituents in sea water. |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 267** **Title of the Course: Analytical Chemistry of Sea water and Instrumental Techniques Practical**
**Number of Credits:** 02
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. | |
| **Objective:** | 1. The chemical analysis of water provides considerable insight into the health of oceans.<br>2. The analyses of trace metals in sea water helps in understanding of water's interactions with Earth's geologic materials, and given insight into the impact of human activities on water bodies.<br>3. The bulk analyses of metals in sediment gives information about the total metal content in a particular environment and it does not give information about the speciation.<br>4. The sequential extraction procedure described in this course provides an insight into the speciation of a particular element in an environment and their predominant form in the marine environment. | |
| **Content:** | **Module – I**<br>1. Pre concentration of sea water for estimation of dissolved trace metals by AAS technique. (8 hrs; Ref 1, 2, 3, 4)<br>2. Digestion of particulate matter for estimation of trace metals (6 hrs; Ref 5)<br>3. Estimation of dissolved and particulate Mn in seawater by Flame AAS method. (6 hrs; Ref 2, 3)<br>4. Estimation of dissolved and Particulate Co in seawater by Flame AAS method (5 hrs; Ref 2, 3)<br>5. Estimation of dissolved and particulate Fe in seawater by Flame AAS method (5 hrs; Ref 2, 3)<br><br>**Module II**<br>1. Sediment digestion. (10 hrs; Ref 5)<br>2. Estimation of Mn in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5)<br>3. Estimation of Co in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5)<br>4. Estimation of Fe in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5)<br>5. Speciation of metals in sediments (Exchangeable and carbonate bound metals) (5 hrs; Ref 5) | 24 hours<br><br>24 hours |
| **Pedagogy:** | Lectures/ Demonstations/ Lab experiments. | |
| **References/ Readings** | 1. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public health association, Washington DC.<br>2. Analytical chemistry of seawater, 1975 – Riley J. P. In Chemical Oceanography, J.P. Riley and G. Skirrow (eds.), Vol. 3, Academic Press, London.<br>3. Methods of Seawater analysis, 1983 – Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419.<br>4. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1977 – Loring, D. H. and Rantala, R. T. T., Fish. Mar. Serv. Dev. Technical Report 700. | |
| **Learning Outcomes** | 1. The results of metal analyses of seawater samples are used to estimate the current levels of different trace metals in sea water. This would help in assessing the quality of water for sea life.<br>2. The results of speciation of metals in sediments give an insight into a particular metal and its association with different fractions of sediment components and this would help in un understanding the major form in which a particular metal is associated with a particular fraction of sediment. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 268** **Title of the Course: Aquaculture**
**Number of Credits:** 04
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. |
| **Objective:** | This course focuses on provision of basic concepts of farming of aquatic organisms. This also educates students to learn different methods of culture, involving preparation of pond to harvesting. Further, it also provides an insight on the national and international status. |

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| **Content:** | Principles of aquaculture, global scenario, status and prospects of coastal aquaculture in India, traditional aquaculture practices.<br><br>Basic considerations, site selection, water quality management, species selection, feasibility and technique applied for mussel, pearl oyster, fish, lobster and seaweed culture practices.<br><br>Shrimp aquaculture, types of culture practices, traditional, modified traditional, extensive, modified extensive, semi intensive and intensive, critical requirements, site selection and pond preparation, selection of candidate species, brood stock procurement, hatchery production and management, nutrition, live feed culture and formulated feed preparation, water quality management in hatchery.<br><br>Reproduction, induced maturation by eye stalk ablation, role of X organ, sinus gland system, status and prospects of brood stock, domestication and genetic improvement, shrimp diseases, pathology and parasitological, prophylactic and therapeutic measures, Coastal aquaculture Act, 2005. | 12 hours<br><br>12 hours<br><br>12 hours<br><br>12 hours |
| **Pedagogy:** | lectures/ tutorials/assignments/self-study | |
| **References/ Readings** | 1. Stickney, R. R. 2009. Aquaculture: An Introductory Text. 2nd edition. CABI. 304 pages<br>2. Parker, R. 2011. Aquaculture Science. 3rd Edition. Cengage Learning. 672 pages<br>3. Aquaculture, 1989 – Pillai, T.V.R.<br>4. Fish and fisheries of India, 1982 – Jhingran, V.G., Hindustan Publ. Corp. India Ltd. New Delhi<br>5. Diseases of Marine animals – Marine Ecology (Vol 4), 1983 – Kinne, O., Wiley<br>6. Crustacean aquaculture, 1983 Mckey, J.P. CRC series.<br>7. Aquaculture, 1972 – Bardach,J. E, Wiley-Inter-science<br>8. Prawn and prawn fisheries of India, 1976 – Kurian, C.V. & Sebastian, V.O. Hindustan Pub. Corp.<br>9. Environmental management for aquaculture, 1998 – Midlen, A., Springer, Netherlands<br>10. Nutrition and feeding of fish, 1999 – Lovell, T. Springer Science & Business Media | |
| **Learning Outcomes** | Provision of knowhow to take up culture of aquatic organisms, harvesting, diseases identification, prophylactic measures, harvesting and marketing. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 269 Title of the Course: Aquaculture Practical**
**Number of Credits:** 02
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. | |
| **Objective:** | This course aims to identify the cultivable species, their reproductive biology and methods of estimation of water quality parameters for cultivation. It also provides an exposure to the students for the demonstration of commercial practices of culture and hatchery practices. | |
| **Content:** | **Module – I**<br>1. Methods of estimation of dissolved oxygen, BOD, suspended solids, dissolved and particulate organic carbon and ammonia (14 hrs; Ref 1& 2)<br>2. Identification of cultivable fishes of shrimps, mussels, oysters, fish, crabs and sea weeds (4 hrs, Ref 3)<br>3. Reproductive system of shrimp (2 hrs; Ref 4),<br>4. Identification of larval stages of shrimp of commercial importance (4 hrs; Ref 3).<br><br>**Module – II**<br>1. Visit to shrimp hatchery and grow out farms for demonstrations (12 hrs, Ref 3 & 4)<br>2. Fabrication of biological filter in aquarium tank (6 hrs, Ref 5)<br>3. Fabrication of raft, transplantation of spat for mussel culture (6 hrs). | 24 hours<br><br>24 hours |
| **Pedagogy:** | Field visits, laboratory analysis and identification | |

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| **References/ Readings** | 1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.;Verlag Chemie, Weinheim.<br>2. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford.<br>3. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, *1988b* - Carpenter K.E. & Niem V.H. *Volume 2.Cephalopods, crustaceans, holothurians and sharks*. (Food and Agricultural Organization, Rome), pp. 687-1396.<br>4. Crustacean aquaculture, 1983 Mckey, J.P. CRC series.<br>5. Design and Selection of Biological Filters for Freshwater and Marine Applications, 8-11 November 2004, Honolulu, Hawaii, Edited by C. S. Lee<br>Volume 34, Issue 3, Pages 141-420 | |
| **Learning Outcomes** | Provides scope to understand various biological aspects of cultivable species and on sight experience of the operation of hatchery and culture systems. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 270** **Title of the Course: Physical Oceanography II**
**Number of Credits:** 01
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. | |
| **Objective:** | Students with any branch in science at their graduation level are eligible to get admission to PG in Marine Science. Ocean, being a dynamic ecosystem, to know the biology, geology and chemistry of the Ocean, it is imperative to know different physical process responsible to drive the system. | |
| **Content:** | Equipment used for physical oceanographic studies: Mechanical bathythermograph, Expendable bathythermograph, Reversing thermometers, CTD, Current meter, Acoustic Doplar Current Profiler (ADCP), Autosal. Equipment used for atmospheric studies: Psycho meter, anemometer, radio sonde, sun-photometer, Radiation meter, Automatic Weather Station - Research vessels: O.R.V. Sagar Kanya, R.V. Sagar Sampada. | 12 hours |
| **Pedagogy:** | The course is being taught using the conventional method of class room teaching using chalk and board. However, after each module an integral picture is drawn to them through power point presentation. In addition students are given seminar topic related to the course. | |
| **References/ Readings** | 1. The Ocean: Their Physics, Chemistry and Biology, 1962 - Sverdrup, H.U., Johnson, M.W. and Flemming, R.H., Asia Publ. House, New Delhi.<br>2. Descriptive Physical Oceanography: An Introduction, 1989 - Pickard, G.B. and Emery, W.J., Pergamon press, U.K.<br>3. Principles of physical oceanography, 1966 - Pierson, W.J. and Newmann, G.S., Prentice Hall, Inc., New Jersey, U.S.A. | |
| **Learning Outcomes** | Getting a larger picture of different equipments necessary for Physical Oceanographic and atmospheric studies | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 271** **Title of the Course: Physical Oceanography Practical II**
**Number of Credits:** 01
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent. |
| **Objective:** | Delineate and identify regions of a) watermasses, b) Most efficient sound channel in sea c) estimate ocean currents and measure atmospheric parameters. |

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| **References/ Readings** | 1. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, *1988b* - Carpenter K.E. & Niem V.H. *Volume 2.Cephalopods, crustaceans, holothurians and sharks*. (Food and Agricultural Organization, Rome), pp. 687-1396.<br>2. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. *1999a* - Carpenter K.E. & Niem V.H., *Volume 3. Batoid fishes, Chimaeras and bony Fishes Part 1 (Elopidae to Linophrynidae)*. (Food and Agricultural Organization, Rome), pp. 1397-2068.<br>3. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific., *1999b* - Carpenter K.E. & Niem V. H., *Volume 4. Bony Fishes Part 2 (Mugilidae to Carangidae)*. (Food and Agricultural Organization, Rome), pp. 2069-2790.<br>4. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific., *2001a* - Carpenter K.E. & Niem V.H. *Volume 5. Bony Fishes Part 3 (Menidae to Pomacentridae)*. (Food and Agricultural Organization, Rome), pp. 2791-3380.<br>5. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific., *2001b* - Carpenter K.E. & Niem V.H., *Volume 6.Bony Fishes Part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals*. (Food and Agricultural Organization, Rome), pp. 3381-4218. | |
| **Learning Outcomes** | Provides basic information towards the identification of few marine groups. | |

**Programme:** M.Sc. (Marine Sciences)
**Course Code:MSO 276** **Title of the Course: Environmental Impact Assessment**
**Number of Credits:** 01
**Effective from AY:**June2018-19

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| **Prerequisites for the course** | Students who have undergone courses of semester I of Marine Sciences. | |
| **Objective** | This course introduces concept of environmental impact assessment. | |
| **Content** | Environmental impact assessment (EIA) - Nexus between development and environment – Socio–economic impacts - purposes of EIA - aid to decision-making - formulation of development actions - sustainable development - EIA in project planning and implementation - EIA process - evaluation of proposed actions - scoping EIA methodologies - impact prediction- mitigation measures - monitoring - Environment Management Plan - planning - selection of appropriate procedures. | 12 hours |
| **Pedagogy** | Lectures / Seminars involving presentation of environmental impact assessment studies carried out at national and international levels. | |
| **References / Readings** | 1. Introduction to environmental impact assessment 2005, Glasson J., Therivel R., Chadwick A, Routledge, Taylor & Francis Group, London and New York.<br>2. Methods of Environmental Impact Assessment 2009, Morris P., Therivel R., 3rd edition, Routledge, Taylor & Francis Group, London and New York.<br>3. Methods of Environmental Impact Assessment 2001, Morris P., Therivel R., 2nd edition, Spon Press, Taylor & Francis Group, London and New York.<br>4. Environmental Impact Assessment 2011, Eccleston C. H., CRC Press, Taylor & Francis Group. | |
| **Learning Outcomes** | 1. Ability to carry out environmental impact assessment study.<br>2. A potential candidate for recruitment in the EIA consultancy firms. | |

**Programme:** M.Sc. (Marine Sciences)
**Course Code:MSO 277** **Title of the Course: Environmental Impact Assessment Practical**
**Number of Credits:** 01
**Effective from AY:**June2018-19

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| **Prerequisites for the course** | Students who have undergone courses of semester I of Marine Sciences. |
| **Objective** | This course introduces field survey, sampling and experiments to assess impact on the environment. |

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| **Content** | 1. Introduction to national and international standard values for ambient air, noise, water, sediments and industrial effluents (4 hrs; Ref 1,2)<br>2. On board trawler field trip to an estuary to get familiar with field study methods for collection of water, sediment and biological samples (10 hrs; Ref 3)<br>3. Determination of total dissolved solids in water (5 hrs; Ref 4, 5)<br>4. Determination of total suspended matter in water (4 hrs; Ref 6)<br>5. Determination of biogenic silica from sediments (6 hrs; Ref 7, 8)<br>6. Comparison of determined data with the national standard value (4 hrs; Ref 1, 2)<br>7. Analysis of environmental impact assessment reports available (4 hrs; Ref 1, 2) | 24 hours |
| **Pedagogy** | Field survey and sampling / Laboratory experiments / Interpretations | |
| **References / Readings** | 1. Environmental standards for ambient air, automobiles, fuels, industries and noise. Central pollution control board, Ministry of environment and forests, India, July 2000.<br>2. Standards and Thresholds for impact assessment, volume 3, Environmental protection in the European Union, 2008, Schmidt M., Glasson J., Emmelin L., Helbron H., Springer-Verlag Berlin Heidelberg.<br>3. Methods of seawater analysis, 1983 - Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419.<br>4. Sokoloff V.P. (1933) Water of crystallization in total solids of water analysis. Industrial and Engineering Chemistry, 5:336.<br>5. Howard C.S. (1933) Determination of total dissolved solids in water analysis. Industrial and Engineering Chemistry, 5:4.<br>6. Liu D., Fu D., Xu B., Shen C. (2012) Estimation of total suspended matter in the Zhujiang (Pearl) River estuary from Hyperion imagery. Chinese Journal of Oceanology and Limnology 30:16-21.<br>7. Mortlock R.A., Froelich P.N. (1989) A simple method for the rapid determination of biogenic opal in pelagic marine sediments. Deep-Sea Research, Part A, 36:1415-1426.<br>8. DeMaster D.J. (1979) The marine budgets of silica and $^{32}$Si. Ph.D. Dissertation, Yale University, 308pp. | |
| **Learning Outcomes** | 1. Ability to conduct field survey and sampling for environmental impact assessment study.<br>2. Conducting laboratory experiments and interpretation of data. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 278** **Title of the Course: GIS Applications in Marine Science Practical - I**
**Number of Credits:** 01
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Students who have undergone semester I of Marine Sciences. | |
| **Objective:** | To use GIS techniques in the field of oceanography / meteorology | |
| **Content:** | 1. GIS, GIS software familiarization and image properties (8 hrs; Ref 1&2)<br>2. Data acquisition and integration in GIS software (6 hrs; Ref 1&3)<br>3. Image edge detection, Transects, spectra and time series images (6 hrs; Ref 3)<br>4. Contrast stretching, Colour palettes, smoothing satellite images(4 hrs; Ref 3 & 4)<br>5. Digitizing Vector maps (6 hrs; Ref 6) | 24 hours |
| **Pedagogy:** | Tutorials/ assignments/practicals/field study | |
| **References/ Readings** | 1. Practical Handbook of Digital Mapping: Terms and Concepts Arlinghaus, 1994 Sandra L., - CRC Press.0-8493-0131-9<br>2. Coastal and marine geospatial technologies. 2010. Ed. David R Green, Springer, ISBN 978-1-4020-9719-5<br>3. *Remote Sensing Handbook for Tropical Coastal Management*. Coastal Management Source books 3.2004.Edmund P. Green, Peter J. Mumby, Alasdair J. Edwards and Christopher D. Clark, UNESCO, Paris.<br>4. Principals of Geographic information systems- An introductory text book, 2009 - Eds :ottoHuisman and Roff A. de By (ed.) International Institute for Geo-Information and Earth Observation, Netherlands.<br>5. Essentials of Geographic Information Systems, 2011 - Jonathan Campbell, Michael Shin | |

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| | Ref 1, 2, 3,4)<br>5. Estimation of Net heat flux from above extracted data sets and analysis of its distribution (6hrs; Ref 1, 2, 3,4)<br>6. Analysis of fluxes over Central Pacific during Normal, El-Nino and La Nina events (6hrs; Ref5)<br><br>**Module – II**<br>1. Arabian Sea SST and Indian Summer rainfall correlation (6hrs; Ref6)<br>2. Central Pacific SST and Indian Summer rainfall correlation (6hrs; Ref6)<br>3. Cyclone intensity estimation using Dvorak technique for satellite images (8hrs; Ref 6,7)<br>4. Determination and analysis of cyclone tracks in Arabian Sea and Bay of Bengal (6hrs; Ref6)<br>5. Analysis of annual variations of N and S hemispheric air temperature (4hrs; Ref3) | 24 hours |
| **Pedagogy:** | Tutorials/ assignments/practicals | |
| **References/ Readings** | 1. The Physics of marine atmosphere, 1965 –Roll, H.U., Academic Press, London.<br>2. Oceanography for meteorologists, 1945 –Sverdrup, H.U., George Allen & Unwin, London, U.K.<br>3. Climate change, 1995 –Houghton, J.T., Cambridge Univ. Press, U.K.<br>4. Atlas of Surface Marine Data 1994, Volume 1: Algorithms and Procedures, 1994 - A. da Silva, A. C. Young, S. Levitus, No. 6.Department of Commerce, NOAA, NESDIS.<br>5. Air -sea fluxes from ICOADS: the construction of a new gridded dataset with uncertainty estimate, 2011 - Berry, D. I., and E. C. Kent, International Journal of Climatology, 31, 987 -1001: DOI: 10.1002/joc.2059.<br>6. Tropical Meteorology, 2005 - Asnani G C.<br>7. The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years, 2006 - . Velden, Christopher, and Co-authors, *Bull. Amer. Meteor. Soc.*, 87,1195–1210. | |
| **Learning Outcomes** | Examine statistical relationship between El Nino and southwest Indian Monsoon, Explain spatiotemporal variability of fluxes and the possible governing factors. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 365** **Title of the Course: Marine Pollution**
**Number of Credits:** 04
**Effective from AY:**June, 2018-19

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| **Prerequisites for the course:** | Marine Biology and Marine Chemistry | |
| **Objective:** | 1. To understand the type of pollutants discharged into sea as a result of human activities, their sources and impact on marine life.<br>2. To study the addition of conservative (radioactive pollutants, trace metals and pesticides), non conservative pollutants (Oil and other organic wastes) and nutrient salts, their implications on human health and food resources and commercial interest.<br>3. Quantification of pollutant studies through suitable indicator organisms.<br>4. To study monitoring strategies of marine pollution through different approaches and assessment of pollution damage in order to understand | |
| **Content:** | Marine Pollution: Definition, categories of additions, Pollutant and its classification. Organic wastes: BOD, COD, dilution factor, Fluctuations in DO, Consequences of organic discharges to estuaries with examples; Thames and Mersey estuary; Consequences of sludge dumping at sea with reference to Thames and Firth of Clyde. Sewage treatment: Primary, Secondary and Tertiary treatment processes. Solid waste pollution: Classification and disposal of solid wastes.<br><br>Industrial pollution: sources, nature and their treatment processes with reference to wastes from paper and pulp and soap manufacturing industries. Marine corrosion: Definition, corrosion reactions, classification of corrosion, factors affecting corrosion of metals in sea water and prevention of marine corrosion. The state of some seas in the world (pollution aspect); The North sea, The Mediterranean sea and the Baltic sea.<br><br>Oil spills and cleanup: sources, major accidental spills, fate of spilled oil on the sea, consequences | 12 hours<br><br>12 hours |

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| | of oil spills and treatment of oil spills. Pesticide pollution: inputs, fate in the sea, factors affecting the bioaccumulation of pesticides, DDT-the most wide spread molecule, Impact of pesticides on the Environment, Mode of poisoning of pesticides, Methods to minimize pesticide pollution. Conservative pollutants: Measures of contamination, toxicity, measurement of toxicity, acute and chronic exposure, Detoxification. Metal pollution in coastal waters (Hg, Pb, Cd, Cu, Zn **a**nd Fe).The present status of coastal pollution in India and future strategies. Radioactive Pollution: Sources, Classification and effects of radiation; Protection and control from radiation: Maximum permissible dose concept, dose limits, Disposal of radioactive wastes; Beneficial aspects of radiation and food safety.<br><br>Indicator organisms: Criteria for selection of indicator organism: Quantification of pollution load, basic pre-requisites, response to different pollution load and time integration capacity, Macro algae, crustaceans and mollusks as indicator organisms for monitoring of trace metal pollution; Red tides : distribution, types of poisoning, effects and methods to minimize red tides in the sea. Monitoring strategies of marine pollution: Critical pathway approach and Mass balance approach. Standards in water quality: Assessment of pollution damage: The need, seriousness of damage, assessment of damage and problems of measuring impact. | 12 hours<br><br>12 hours |
| **Pedagogy:** | lectures/ tutorials/assignments/self-study | |
| **References/ Readings** | 1. Chemical Oceanography (Vol: 3), 1975 - Riley J.P and Skirrow, G. (eds.), Academic press, New York.<br>2. The health of the oceans, 1976 - Goldberg, E.D. UNESCO Press.<br>3. Marine Pollution, 1986 - Clark, R.B. Oxford science Publications.<br>4. Quantitative aquatic biological indicators, 1980 - Phillips J.D.H. Applied Science Publishers.<br>5. Thermal and radioactive pollution, 1994 - Sharma, B.K and Kaur, H. Krishna Prakasham Mandir, Meerut.<br>6. Water Pollution, 1994 - Sharma, B. K and Kaur, H. Krishna Prakasham Mandir, Meerut.<br>7. Marine and offshore corrosion, 1985 - Chandler, K.A. Butter Worths, London. | |
| **Learning Outcomes** | 1. The course helps in understanding the impact of various pollutants on marine ecosystem; it analyses the factors responsible for degradation and suggests suitable corrective measures around the world.<br>2. To create awareness among student, by information by educating them to safeguard the marine environment<br>3. The course further identify the factors responsible for causing marine pollution , to suggest policy measures to prevent marine pollution, to create sustainable marine environment and<br>4. To provide advisory and technical service to government and industry for pollution abatement. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 366** **Title of the Course: Marine Pollution Practical**
**Number of Credits:** 02
**Effective from AY:**June2018-19

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| **Prerequisites for the course:** | Marine Chemistry and Marine Biology | |
| **Objective:** | 1. The objective of this course understands the concentration of various pollutants in the seawater and their effect on marine life.<br>2. The analyses of BOD and COD are used to understand the impact organic pollution on water bodies.<br>3. Different pollutants like Fluoride and Hydrogen sulphide in sea water it greatly influence the quality of water for marine life including man. | |
| **Content:** | **Module – I**<br>1. Determination of dissolved oxygen in polluted waters. (6 hrs; Ref1)<br>2. Determination of biochemical oxygen demand in polluted waters. (6 hrs; Ref1)<br>3. Determination of chemical oxygen demand in polluted waters. (6 hrs; Ref2)<br>4. Determination of fluoride. (6 hrs; Ref3)<br>5. Determination of hydrogen sulphide. (6 hrs; Ref3)<br><br>**Module – II**<br>1. Pre-concentration of water by solvent extraction method (6 hrs; Ref 5,6,7)<br>2. Digestion of biological samples for estimation of toxic metals. (6 hrs; Ref8)<br>3. Estimation of Cd in polluted waters and biological sample. (6 hrs; Ref 5,6,7) | 24 hours<br><br>24hour |

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| | 4. Estimation of Cu in polluted waters and biological samples. (6 hrs; Ref 5,6,7)<br>5. Estimation of Pb in polluted waters and biological samples. (6 hrs; Ref 5,6,7) | s |
| **Pedagogy:** | Demonstations/ Lab experiments. | |
| **References/ Readings** | 1. Marine chemistry Vol. 1, 1972 - Martin, D.F, . Academic Press, London.<br>2. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public health association, Washington DC.<br>3. Methods of Seawater analysis, 1983 - Grasskhoff, K, M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim.<br>4. A practical hand book of seawater analysis, 1972 - Strickland, J.D.H, and Parsons, T.R., Fisheries Board of Canada bulletin. (2nd edition).<br>5. Analytical chemistry of seawater, In Chemical Oceanography, 1975 - Riley, J.P. and Skirrow, G. (eds.), Vol. 3. Academic Press, London.<br>6. Chemical Analysis. In: Methods in plant Ecology, 1976 - Allen, S. E., Grimshaw, H. M., Parkinson, J. A., Quarmby, C. and Roberts, J.D. 1976. S. B. Chapman (eds.), Blackwell Scientific Publications, Oxford, Chapter 8. | |
| **Learning Outcomes** | 1. The results of analyses of different pollutants in sea water and marine organisms can be used to assess the effectiveness of existing regulatory activities.<br>2. These concentrations will be compared with the daily intake of, or exposure to a pollutant by organism/man and it can lead to acceptable concentration of pollutant in organism.<br>3. These studies would help to regulate the release of a particular pollutant in the marine environment. | |

**Programme:** M.Sc. (Marine Sciences)
**Course Code:MSO 367** **Title of the Course: Bioaccumulation and Phytoremediation**
**Number of Credits:** 03
**Effective from AY:**June2018-19

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| **Prerequisites for the course** | Students undergoing course in any branch of Marine Sciences. | |
| **Objective** | This course introduces concept of bioaccumulation of metals and remediation of metal pollution by mangroves. | |
| **Content** | Metal sources to marine environment - natural - anthropogenic - metal retention in sediments -role of grain size - organic matter - Fe-Mn oxides - sulphides - Definition and significance of metal speciation - forms of metals - bioavailable - residual - bioavailability of metals -definition - driving factors for desorption of metals from the bioavailable fraction of the sediments - ionic composition – pH – Eh - organic matter degradation – metal toxicity assessment – SQUIRT - RAC. | 12 hours |
| | Bioaccumulation of metals – definition - metal accumulation in benthic biota - Arsenic bioaccumulation in biota of the Sundarban Mangrove Wetland – a case study - Bioaccumulation factor (BAF) - concept of Bioconcentration – Bioconcentration factor (BCA) - harmful effects of bioaccumulation of metals on biota - Biomagnification in trophic levels – risk to human health. | 12 hours |
| | Metal accumulation in mangroves – pneumatophores – leaves - stem - remediation of metal contamination – phytoremediation – application of mangrove species - Translocation factor (TF) - techniques of phytoremediation – Phytoextraction – Rizofiltration – phytovolatilization - phytostabilization, phytodegradation - Rhizodegradation/Phytostimulation - Advantages and disadvantages of Phytoremediation. | 12 hours |
| **Pedagogy** | Lectures / Assignments / Seminars / Discussion | |
| **References / Readings** | 1. Trace metals in a tropical mangrove wetland, 2018 Sarkar, S. K., Springer Nature Singapore Pte Ltd.<br>2. Trace elements in terrestrial environments, 2001 Adriano, D.C., Springer Science+Business Media, LLC.<br>3. Bioaccumulation in marine organisms, 2002 Neff, J. M., Elsevier Ltd.<br>4. The biology of mangroves and seagrasses, 2015 Hogarth P. J., Oxford University press.<br>5. Sequential extraction procedure for the speciation of particulate trace metals, 1979 Tessier, A., Campbell, P. G. C. and Bisson, M., Analytical Chemistry, American Chemical Society. | |
| **Learning Outcomes** | 1. Understanding of accumulation of metals by biota and mangroves.<br>2. Knowledge of application of mangroves in remediation of metal pollution. | |

**Programme:** M.Sc. (Marine Sciences)
**Course Code:MSO 368** **Title of the Course: Bioaccumulation and Phytoremediation Practical**
**Number of Credits:** 01
**Effective from AY:**June2018-19

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| **Prerequisites for the course** | Students undergoing course in any branch of Marine Sciences. | |
| **Objective** | This course introduces experiments to determine metal concentration in sediments, biota and mangroves to understand metal accumulation process and metal remediation potential of mangroves. | |
| **Content** | 1. Digestion and chemical speciation of metals in sediments (Exchangeable, carbonate, Fe-Mn oxide, organic/sulphide and residual bound metals) (13 hrs; Ref 3, 4, 5)<br>2. Estimation of Mn, Co, Ni in sediments by flame AAS method (6 hrs; Ref 1, 2, 3, 4, 5)<br>3. Digestion of tissues of biota (5 hrs; Ref 5, 6, 7)<br>4. Estimation of Mn, Co, Ni in biota by flame AAS method (6 hrs; Ref 5, 6, 7)<br>5. Digestion of mangrove tissues (5 hrs; Ref 5, 8, 9)<br>6. Estimation of Mn, Co, Ni in mangrove tissue samples (6 hrs; Ref 5, 8, 9) | 24 hours |
| **Pedagogy** | Field studies / Laboratory experiments / Interpretations | |
| **References / Readings** | 1. Analytical chemistry of seawater, 1975 – Riley J. P. In Chemical Oceanography, J.P. Riley and G. Skirrow (eds.), Vol. 3, Academic Press London.<br>2. Methods of seawater analysis, 1983 – Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419.<br>3. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1977 Loring , D. H. and Rantala, R. T. T., Fish. Mar. Serv. Dev. Technical Report 700.<br>4. Sequential extraction procedure for the speciation of particulate trace metals, 1979 Tessier, A., Campbell, P. G. C. and Bisson, M., Analytical Chemistry, 51(7):844-851, American Chemical Society.<br>5. Trace metals in a tropical mangrove wetland, 2018 Sarkar, S. K., Springer Nature Singapore Pte Ltd.<br>6. Temporal and spatial variation on heavy metal concentrations in the bivalve Perna perna (Linnaeus, 1758) on the northern coast of Rio de Janeiro state, Brazil, 2004 Ferreira, G.A., Machado, A.L.S., Zalmin, I.R., Brazilian Archives of Biology and Technology 47:319-327.<br>7. Heavy metals in Patella caerulea (mollusca, gastropoda) in polluted and non-polluted areas from the Iskenderun Gulf (Mediterranean Turkey), 2010 Yuzereroglu, T. A., Gok, G., Cogun, H. Y., Firat, O., Aslanyavrusu, S., Maruldali, O. and Kargin, F. Environmental Monitoring and Assessment 167(1-4):257-264.<br>8. Assessment of sediment quality in Avicennia marina-dominated embayments of Sydney Estuary: The potential use of pneumatophore (aerial roots) as a bio-indicator of trace metal contamination, 2014, Nath, B., Birch, G. and Chaudhuri, P., Science of the Total Environment 472:1010-1022.<br>9. Toxicity, growth and accumulation relationships of copper lead and zinc in the grey mangrove Avicennia marina (Forsk.) Vierh, 2002, MacFarlane, G. R. and Burchett, M. D., Marine Environmental Research 54:65-84. | |
| **Learning Outcomes** | 1. To understand field survey and sampling.<br>2. Ability to interpret data and link bioavailability with bioaccumulation.<br>3. To understand phytoremediation process. | |

**Programme:** M. Sc. (Marine Sciences)
**Course Code: MSO 369** **Title of the Course: Aerosol and Climate**
**Number of Credits:** 03
**Effective from AY:**June2018-19

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| **Prerequisites for the course:** | Students undergoing course in any branch of Marine Sciences. |
| **Objective:** | This course is introduced as an attempt to make students understand the significant role of aerosol on regional climate in particular and Global climate in general. |