# ES Environmental Science and Engineering

## Section 1: Mathematics Foundation

Linear Algebra: Determinants and matrices, Systems of linear equations, Eigenvalues and eigenvectors.

Calculus: Functions, Limit, Continuity, Differentiability, Local maxima and minima, Taylor series, Tests for convergence, Definite and indefinite integrals, Application of definite integral to obtain area and volume, Partial and total derivatives, Linear and non-linear first order ordinary differential equations (ODE).

Numerical Methods: Approximation, errors, accuracy and precision in numerical methods; Numerical solutions (roots) of linear and non-linear algebraic equations; Interpolation and curve fitting - Least square approximation, Newton's and Lagrange polynomials; Numerical differentiation and integration - trapezoidal and Simpson's rule; Numerical solution of ordinary differential equations - single and multi-step methods.

Probability and Statistics: Descriptive statistics, Measurement of central tendency, Dispersion, Skewness and kurtosis, Probability concepts, Conditional probability, Bayes theorem, Risk and reliability, Probability distributions, Correlation, Single and multiple regression models, Hypothesis testing (t-test, F-test, chi-square test).

## Section 2: Environmental Chemistry

Fundamentals of Environmental Chemistry: Covalent and ionic bonding; Chemical equations, concentration and activity; Structure and chemistry of organic molecules; Chemical equilibria; Thermodynamics and kinetics of chemical reactions.

Principles of Water Chemistry: Water quality parameters and their measurement; Acid-base equilibria; Buffer solution; Carbonate equilibrium; Solubility of gases in water; Complexation, precipitation, and redox reactions; Inorganic and organic contaminants.

Soil Chemistry: Organic matter, nitrogen, phosphorous, potassium, cation exchange capacity, base saturation, and sodium absorption ratio.

Atmospheric Chemistry: Composition of the atmosphere; Reactivity of trace substances in the atmosphere; Chemistry of ozone formation.

## Section 3: Environmental Microbiology

Prokaryotic and Eukaryotic Microorganisms: Characteristics of diverse groups of microorganisms; Classification of microorganisms; Microbial diversity; Role of microorganisms in wastewater treatment, bioremediation and biogeochemical cycling.

Cell Chemistry and Cell Biology: Structure of proteins, nucleic acid (DNA & RNA), lipids and polysaccharides; Structure of cell; Structure and function of cytoplasmic membrane, cell wall, outer membrane, glycocalyx; antimicrobial resistance, quorum sensing.

Microbial Metabolism: Anabolism and catabolism; Phosphorylation; Glycolysis; TCA cycle; Electron transport chain; Fermentation; Anaerobic respiration; Energy balances; Enzymes and Enzyme kinetics.

Growth and Control of Microorganisms: Bacterial nutrition and growth; Specific growth rate and doubling time; Monod's model; Types of culture media; Batch and continuous culture; Effects of environmental factors on growth; Control of microbes using physical and chemical methods.

Microbiology and Health: Pathogens and modes of transmission; Indicator organisms; Quantification of coliforms using MPN and membrane filtration techniques.

## Section 4: Water Resources and Environmental Hydraulics

Global Water Resources: Structure, properties and distribution of water; Threats to water resources; Water conservation.

Surface Water Resources: Hydrological cycle and water balance - precipitation, infiltration, evapotranspiration, runoff; Flow hydrographs; Unit hydrographs; Stage-discharge relationship; Reservoir capacity; Surface water management; Rain water harvesting and storage.

Groundwater Resources: Geologic formations as aquifers; Vadose and saturated zones; Confined and unconfined aquifers and their parameters - porosity, permeability, transmissivity and storage coefficient; Darcy's law and applications; Steady state well hydraulics.

Environmental Hydraulics: Concepts of mechanics; Properties of fluids; Pressure measurement; Hydrostatic force on surfaces; Buoyancy and flotation; Laminar and turbulent flow; Flow through pipes; Pipe networks; Forces on immersed bodies; Flow measurement in channels and pipes; Kinematics of flow; Continuity, momentum and energy equations; Channel hydraulics - specific energy, critical flow, hydraulic jump, rapid and gradually varied flow; Design of lined channels.

## Section 5: Water & Wastewater Treatment and Management

Water and wastewater quality parameters; Eutrophication and thermal stratification in lakes; River pollution - Oxygen sag curve.

Water treatment methods — screening, sedimentation with and without coagulation, filtration, desalination, disinfection; Water distribution and storage.

Point and non-point sources of wastewater; Population forecasting methods; Design of sewer and storm water sewers; Sewer appurtenances; Preliminary, primary, secondary and tertiary sewage treatment; Sludge generation, processing and disposal methods; Sewage farming.

Sources and characteristics of industrial effluents; Concept of Common Effluent Treatment Plants (CETP); Wastewater recycling and zero liquid discharge.

Kinetics and reactor design: Mass and energy balance, Order and rate of reactions, Batch reactors, Completely mixed flow reactors, Plug flow reactors.

## Section 6: Air and Noise Pollution

Structure and composition of the atmosphere; sources (natural and anthropogenic); Atmospheric processes (emission, transformation, transport, removal); Indoor air pollution; Effects on health and environment; Air pollution: gases and particulate matter; Air quality standards; Primary and secondary pollutants; Criteria pollutants; primary and secondary pollutants; ambient and emission standards; air quality indices; visibility and radiative effects.

Particulate Pollutants: Measurement and control methods; Control of particulate air pollutants using gravitational settling chambers, cyclone separators, wet scrubbers, fabric filters (Baghouse filter), electrostatic precipitators (ESP).

Gaseous Pollutants: Measurement and control methods; Control of gaseous contaminants: absorption, adsorption, condensation and combustion; Control of sulphur oxides, nitrogen oxides, carbon monoxide, and hydrocarbons; Diffusion, Fick's law and interfacial mass transfer. Vehicular emission control systems, including diesel particulate filters (DPFs), catalytic converters, and fuel standards.

Air Quality Management: Point, line and area sources; Inventory; Meteorology and dispersion; atmospheric stability and inversion, mixing height, wind rose diagrams, Gaussian plume dispersion modelling, and topographic influences.

Noise Pollution: Sources; Health effects; Standards; Measurement parameters (sound pressure level, equivalent continuous sound level *Leq*, day-night level *Ldn*); frequency analysis; and control and mitigation methods.

| **Section 7:** | **Solid and Hazardous Waste Management** |
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Integrated solid waste management; Waste hierarchy; Rules and regulations for solid waste management in India.

Municipal solid waste management: Sources, generation, characteristics, collection, segregation, and transportation, waste processing and disposal (including reuse options, biological methods, energy recovery processes and landfilling), waste-to-energy technologies, circular economy principles, life-cycle energy analysis, decentralized renewable systems, and urban metabolism.

Hazardous waste management: Characteristics, generation, fate of materials in the environment, treatment and disposal. Soil contamination and leaching of contaminants into groundwater.

Management of biomedical waste, plastic waste, waste from energy sector (solar/wind/batteries etc), C&D waste and E-waste: Sources, generation and characteristics; Waste management practices including storage, collection and transfer.

| **Section 8:** | **Global and Regional Environmental Issues** |
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Global effects of air pollution: Greenhouse gases, radiative forcing and global warming potential (GWP), climate change, urban heat islands, acid rain, ozone hole.
Ecology and various ecosystems; Biodiversity; Factors influencing increase in population, energy consumption, and environmental degradation.

| **Section 9:** | **Environmental Management and Sustainable Development** |
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Environmental Management Systems; ISO14000 series; Environmental Auditing: Environmental Impact Assessment; Life cycle assessment; Human health risk assessment; Occupational Health and Hygiene, Physical & Chemical Hazards.

Environmental Law and Policy: Objectives; Polluter pays principle, Precautionary principle; The Water and Air Acts with amendments; The Environment (Protection) Act (EPA) 1986; National Green Tribunal Act, 2010; National Environment Policy; Principles of International Law and International treaties.

Energy and Environment: Energy Sources: Overview of resources and reserves; Renewable and non-renewable energy sources; Energy-Environment nexus.

Sustainable Development: Definition and concepts of sustainable development; Sustainable development goals; Hurdles to sustainability; Environment and economics; carbon pricing, emission trading, Environmental, Social, and Governance (ESG) frameworks.