Environmental Engineering

Short notes for B.Tech Civil · GATE CE

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1. Water Demand and Population Forecasting

- Types of demand: domestic, industrial, institutional / commercial, public use, fire demand, losses and wastage.
- **Per capita demand** = total yearly water / (365 × population), in litres per capita per day (lpcd).
- CPHEEO guide value: about 135 lpcd for cities with piped water and sewerage.

➤ Variations in demand

- Maximum daily demand = 1.8 × average daily demand.
- Maximum hourly demand = 1.5 × maximum daily = 2.7 × average.
- Water treatment units are designed for max daily demand; distribution pipes for max hourly (or max daily + fire).

➤ Fire demand

FORMULA Kuichling: $Q = 3182\sqrt{P}$, Q in litres/min, P = population in thousands. Freeman: $Q = 1136 (P/5 + 10)$.

➤ Population forecasting

Method	Formula	Suitable for
Arithmetic increase	$Pn = P0 + n\,\bar{x}$	Old, large, settled cities
Geometric increase	$Pn = P0 (1 + r/100)^n$	Young, fast-growing cities
Incremental increase	$Pn = P0 + n\,\bar{x} + n(n + 1)\,\bar{y} / 2$	Average cities (most used)
Logistic curve	S-shaped saturation curve	Long-term, limited land

- n = number of decades, $\bar{x}$ = average increase per decade, $\bar{y}$ = average incremental increase.

EXAMPLE Census: 1991 = 40,000; 2001 = 50,000; 2011 = 62,000; 2021 = 75,000. Increases: 10,000, 12,000, 13,000, so $\bar{x}$ = 11,667. Incremental: 2,000, 1,000, so $\bar{y}$ = 1,500. Arithmetic 2031 = 75,000 + 11,667 = 86,667. Incremental 2031 = 75,000 + 11,667 + 1,500 = 88,167.

2. Water Quality

➤ Characteristics

- **Physical**: turbidity (NTU), colour, taste, odour, temperature.
- **Chemical**: pH, hardness, alkalinity, TDS, chlorides, fluorides, nitrates, iron, manganese, dissolved gases.
- **Biological**: coliform bacteria (indicator of faecal pollution), MPN test, membrane filter test.

➤ Drinking water limits (IS 10500, acceptable values)

Parameter	Acceptable limit
pH	6.5 to 8.5
TDS	500 mg/L
Total hardness (as CaCO3)	200 mg/L
Chloride	250 mg/L
Fluoride	1.0 mg/L (permissible 1.5)
Nitrate	45 mg/L
Total coliform	Not detectable in 100 mL

- Excess fluoride → fluorosis; too little → dental caries. Excess nitrate → blue baby syndrome (methaemoglobinaemia).
- **Hardness**: temporary (carbonate, removed by boiling) and permanent (non-carbonate: sulphates, chlorides of Ca and Mg).
- Hardness as CaCO3 = Ca^{2+} (mg/L) × 50/20 + Mg^{2+} (mg/L) × 50/12.

3. Water Treatment

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intake -> screening -> aeration -> coagulation + flocculation
  -> sedimentation -> filtration -> disinfection -> storage
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Sedimentation

FORMULA Stokes' law: $v_s = g (G_s - 1) d^2 / (18 \nu)$. Valid for laminar settling ($Re < 1$).

FORMULA Surface overflow rate (SOR) = Q / A (plan area). Detention time $t = V / Q$. Weir loading = Q / weir length.

- A particle is fully removed if its settling velocity ≥ SOR. Removal depends on SOR, not on depth (ideal tank theory).

EXAMPLE Particle $d = 0.02$ mm, $G_s = 2.65$, $\nu = 1.01 \times 10^{-6}$ m²/s. $v_s = 9.81 \times 1.65 \times (2 \times 10^{-5})^2 / (18 \times 1.01 \times 10^{-6}) = 6.475 \times 10^{-9} / 1.818 \times 10^{-5} = 3.56 \times 10^{-4}$ m/s (0.356 mm/s).

Coagulation and flocculation

- Coagulants: alum (most common), ferric chloride, ferrous sulphate, polyelectrolytes. Optimum dose found by the **jar test**.
- Alum works best at pH about 6.5 to 8.5. Alum consumes alkalinity.
- **Velocity gradient** $G = \sqrt{P / (\mu V)}$. Flocculation is controlled by $G \times t$ (Camp number).

Filtration

Slow sand filter	Rapid sand filter
Very low rate of filtration	About 30 to 40 times faster
Fine sand (effective size small)	Coarser sand
Cleaned by scraping top layer	Cleaned by back-washing
Biological layer (schmutzdecke) does the work	Needs coagulation before it
Large area, low cost to run	Small area, skilled operation

- **Pressure filters**: closed rapid filters for small plants and swimming pools.

Disinfection

- Chlorine is most common: forms HOCl (strong, at low pH) and OCl^- (weak, at high pH).

- **Breakpoint chlorination**: chlorine added beyond the point where combined chlorine is destroyed; after this, free residual rises linearly.
- A free residual (about 0.2 mg/L at the consumer end, as per CPHEEO practice) protects against recontamination.
- Others: UV, ozone (no residual), chloramines, bleaching powder.

➤ Softening and other processes

- **Lime-soda process**: lime removes carbonate hardness, soda ash removes non-carbonate hardness.
- **Zeolite (ion exchange)**: gives zero hardness; regenerated with brine (NaCl).
- Iron and manganese removal by aeration and filtration. Defluoridation by Nalgonda technique (alum + lime).

4. Water Distribution

- Systems: gravity, pumping, combined (pumping with storage).
- Layouts: dead-end (tree), grid iron, ring (circular), radial.
- Grid iron has no dead ends, water circulates; repairs affect small areas.
- Pipe network analysis: **Hardy Cross method** (loop corrections), equivalent pipe method.
- Storage reservoirs: balancing, emergency and fire storage. Capacity found by **mass curve** or tabular method.

5. Sewage and Sewerage

- **Sewage** = wastewater from homes and industries. **Sewerage** = the system of sewers.
- Systems: separate (sewage and storm water in different pipes), combined, partially separate.
- Dry weather flow (DWF) = about 75 to 80% of water supply.

> **FORMULA** Rational method: $Q = C\ I\ A\ /\ 360$ (Q in m^3/s, I in mm/h, A in hectares). Time of concentration = inlet time + time of flow.

- **Self-cleansing velocity**: minimum velocity that prevents deposition. **Non-scouring velocity**: maximum velocity that does not erode the sewer.

- Sewer appurtenances: manholes, drop manholes, catch basins, inverted siphons, flushing tanks.
- Sewer gases: H2S (crown corrosion of concrete sewers), CH4, CO2.

➤ Sewage characteristics

- **BOD** = oxygen used by microbes to oxidise organic matter (5 days at 20°C is standard).

FORMULA BOD5 = (DOi - DOf) / P, P = sample volume / diluted volume. BODt = L0 (1 - e^(-k t)) (base e) or L0 (1 - 10^(-K t)) (base 10, K = k / 2.303).

EXAMPLE 5 mL sample diluted to 300 mL. DOi = 8.0, DOf = 3.5 mg/L. P = 1/60. BOD5 = 4.5 x 60 = 270 mg/L. With k = 0.23 per day (base e): L0 = 270 / (1 - e^(-1.15)) = 270 / 0.6834 = 395 mg/L.

- **COD** ≥ BOD (chemical oxidation includes non-biodegradable matter). BOD/COD high → easily biodegradable.
- Solids: total, suspended, dissolved, volatile (organic), fixed.
- **Population equivalent** = total BOD from industry / BOD per person per day.

6. Sewage Treatment

Stage	Units	Removes
Preliminary	Screens, grit chamber, skimming tank	Floating matter, grit, oil
Primary	Primary sedimentation tank	Settleable solids, part of BOD
Secondary (biological)	Activated sludge, trickling filter, oxidation pond, UASB	Dissolved and colloidal organics (BOD)
Tertiary	Filtration, nutrient removal, disinfection	N, P, pathogens

➤ Activated sludge process (ASP)

FORMULA F/M ratio = Q S0 / (V X). Hydraulic retention time HRT = V / Q. Mean cell residence time θc = V X / (Qw Xw + Qe Xe).

FORMULA Sludge volume index SVI = settled sludge volume (mL/L, 30 min) x 1000 / MLSS (mg/L). Good settling: SVI about 50 to 150 mL/g.

- **Sludge bulking**: sludge does not settle (filamentous growth); SVI becomes high.
- Trickling filter: attached growth on media; problems are ponding, fly nuisance and odour.
- **Oxidation pond**: algae give oxygen, bacteria break organics (symbiosis). Septic tank + soak pit for small communities.
- **Sludge digestion** (anaerobic): acid formation then methane formation; gas mostly CH_4 and CO_2.

➤ Self-purification of streams

- **Streeter–Phelps oxygen sag curve**: DO first drops (deoxygenation) and then recovers (reaeration).
- Critical point = lowest DO. Self-purification constant $f = K_2 / K_1$ (reaeration / deoxygenation).
- Zones: degradation, active decomposition, recovery, clear water.

7. Solid Waste, Air and Noise Pollution

➤ Solid waste

- Functional elements: generation, storage, collection, transfer, processing, disposal.
- Disposal: sanitary landfill (with liner and leachate collection), composting (aerobic / vermi), incineration (reduces volume, energy recovery).
- Municipal solid waste in India is managed under the Solid Waste Management Rules, 2016 (source segregation is required).

➤ Air pollution

- **Primary pollutants**: emitted directly (SO_2, NO_x, CO, particulates). **Secondary**: formed in air (ozone, PAN, smog).
- Control devices for particulates: settling chamber, cyclone, fabric filter (bag house), wet scrubber, electrostatic precipitator (ESP, above 99% efficiency).
- Gaseous pollutants: absorption, adsorption, combustion.

Plume type	Atmosphere
Looping	Super-adiabatic (very unstable)
Coning	Near neutral
Fanning	Inversion (stable)
Lofting	Inversion below, unstable above (best)
Fumigation	Unstable below, inversion above (worst)

FORMULA Noise levels add on log scale: $L = 10 \log10(\Sigma\ 10^{(Li/10)})$. Two equal sources add 3 dB.

8. Most Asked Questions (practice)

1. Forecast population by arithmetic, geometric and incremental methods.
2. Explain variations in demand and their effect on design of units.
3. Explain IS 10500 limits and health effects of fluoride and nitrate.
4. Derive Stokes' law; show that removal depends on SOR, not depth.
5. Compare slow sand and rapid sand filters.
6. Explain breakpoint chlorination with a sketch.
7. Find BOD5 and ultimate BOD from dilution test data.
8. Design an ASP: find F/M, HRT, θc and SVI.
9. Explain the oxygen sag curve and zones of self-purification.
10. Explain plume behaviour and working of an ESP.

TIP GATE CE numericals come from BOD, Stokes' law, SOR, ASP parameters, hardness, population forecasting and rational formula. Learn BOD base-e and base-10 conversions well.