OPAL CVE512 Solution

1a. ~~what~~ Waste stabilization Pond (WSP) is a basin dug on the earth for removal of organic & pathogenic organisms.

Mention only six types of that can be used in Nigeria.

- Facultative ponds — Abuja wastewater treatment facilities
- maturation ponds — ~~Cross River & Delta~~ Kaduna & Ogun
- Anaerobic ponds — food processing industries in Kano
- High rate algal pond — University of Ibadan
- Microphyte ponds —
- Multicelled ponds

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Also state where they are typically used in Nigeria

Aerobic ponds — Cross river & Delta's state

Polishing ponds — Sokoto & Bauchi State

1b. Explain three Emperical model used in WSP

- McGarry & Pescod (1970) - Proposed the r/ship b/w areal BOD_5 removal (L_r) & areal BOD_5 loading (L_o) as:

$$L_r = 9.23 + 0.725 L_o$$

The regression eqn above gave a coefficient of correlation of 0.995 & a 95% confidence interval of 32.8 Kg ~~BOD_5 removal~~ BOD_5/ha.d removal. This eqn has been reported to be valid for any loading b/w 34 & 560 kg BOD_5/ha.d.

- Larsen (1974) Proposed the empirical model

$$MOT = \left(2.468 RED + 2.468 TTC + \frac{23.9}{TEMPR} + \frac{150.0}{DRY}\right) 10^6$$

in which

$$MOT = \frac{\text{Surface area (solar radiation)}^{1/3}}{\text{Influent flow rate (Influent } BOD_5)^{1/3}}$$

$$RED = \frac{\text{Influent } BOD_5 - \text{Effluent } BOD_5}{\text{Influent } BOD_5}$$

$$TTC = \frac{\text{Wind Speed (Influent BOD)}^{1/3}}{\text{(Solar Radiation)}^{1/3}}$$

$$TEMPR = \frac{\text{Lagoon Liquid Temperature}}{\text{Air temperature.}}$$

DRT = ~~Lagoon Liquid~~ Relative temperature.

- Gloyna (1976) given as

$$V = 3.5 \times 10^{-5} \varphi L_0 (\theta_2^{35-T}) f f_1$$

where V = Pond volume (m^3); φ = Influent flowrate (L/d);
L_0 = Ultimate influent BOD_5 or COD (mg/L)
f = algal toxicity factor
f_1 = Sulphide oxygen demand
θ_2 = Temperature Coefficient

c. Mention & describe 4 types of ~~was~~ wsp that you know. & discuss within what depth they should be.

— High rate algal pond: It is designed to maximize algal growth & so achieve high protein yields. It has high area to volume ration, shallow depth of 0.2-0.6m & 2-3m wide.

— Maturation Pond: It usually follows the facultative pond in series. With a depth ranging from 1m to 2m, it is principally designed for removal of faecal bacteria. It is less stratified biologically & physicochemically & is well oxygenated throughout the day.

— Anaerobic Ponds: Depth of 2-5m; are devoid of dissolved oxygen & contain little or no algae. These are usually suitable for the treatment of strong waste water (BOD_5 > 300mg/L) & those containing high concentrations of ~~anaerobic~~ suspended solids (SS > 300 mg/L).

— Facultative ponds: It is designed principally for BOD removal of 60-80% with a depth of 1-2m & 1.5m average.

1 d. Discuss the advantages of waste stabilization pond over the conventional waste treatment plant.
~~WSPs~~

- Low construction & operation costs: They use natural processes for treatment, significantly reducing the costs associated with energy & chemicals required in ~~convention~~ conventional ~~waste~~ systems. WSPs are simple to construct & do not require advanced machinery.
- Ease of maintenance: They are less susceptible to mechanical failures as they do not involve complex machinery.
- High Efficiency for Pathogen Removal: WSPs are highly effective in reducing pathogens due to prolonged retention times & exposure to sunlight.
- Sustainability & Environmental friendliness: WSP ~~suppor~~ support natural ecosystems & can provide habitats for various aquatic & avian species. WSP has lower carbon footprint compared to conventional plants that depends on fossil fuel-based energy sources.
- Long lifespan: WSPs are durable & can operate effectively for decades with minimal maintenance.

1e. Design the pond assuming a dispersed flow condition of the dispersion number & the reaction rate constant are 0.400 & 0.16 day^{-1} respectively.

$$\frac{C_e}{C_o} = \left[\frac{4a\exp(1/2d)}{(1+a)^2\exp(a/2d)}\right]^{2}$$

where $a^2 = 1 + 4K\theta d$

$$\left(\frac{80}{450}\right)^{1/2} = \frac{4a}{(1+a)^2}\exp\left[\frac{1-a}{2(0.4)}\right]$$

$$= 0.4216(1+a)^2 - 4a\exp\left[\frac{1-a}{0.8}\right] = 0$$

Newton Raphson iterative formula, is given by

$$a_{n+1} = a_n - \frac{f(a_n)}{f'(a_n)}$$

Assuming $a = a_n = 1.5$

~~not use~~ a_1 If $n = 0$;

$$a_1 = a_0 - \frac{f(a_0)}{f'(a_0)}$$

$$f(a) = 0.4216(1+a)^2 - 4a\exp\left[\frac{1-a}{0.8}\right]$$

$$f'(a) = 0.4216[2(1+a)] - 4\exp\left[\frac{1-a}{0.8}\right] + 5a\exp\left[\frac{1-a}{0.8}\right]$$

$$= 0.8432(1+a) + (5a-4)\exp\left(\frac{1-a}{0.8}\right)$$

If $a_0 = 1.5$, $f(a_0) = -0.57657$ (i.e the error) &

$f'(1.5) = 3.981414$

$$\therefore a_1 = 1.5 - \frac{-0.57657}{3.981414} = 1.64482$$

$f(1.64482) = 0.01062$ = Error in using 1.64482 as the root.

$f'(1.64482) = 4.116721$

$$a_2 = 1.64482 - \frac{0.01062}{4.116721} = 1.64224$$

$f(1.64224) = 8 \times 10^{-7}$ = Error in using $a_2 = 1.64224$ as root.

$a_2^2 = 1 + 4K\theta d$ → assumption

$$\theta = \frac{a^2 - 1}{4Kd} = \frac{1.64224^2 - 1}{4(0.16)(0.4)} = 6.629 \text{ days.}$$

(

$V = Q\theta,\ L/W = 3,\ LWh = V$

$\therefore 3W^2h = Q\theta$

If $h = 1.2,\ 3.6W^2 = 662.9$

$\therefore W = 13.560\,m$ *

The dimensions of each are $40.68 \times 13.560 \times 1.2\,m$

The above model can also be used in designing for bacteria removal in ponds.

(3b) Determine the slope & diameter of sewer, if $Q = 1500\,L/s$ & $V = 1.5\,m/s$

$Q = A \cdot V$ $\qquad Q = 1500\,L/s = 1.5\,m^3/s$

$A = Q/V = \frac{1.5}{1.5} = 1.0\,m^2$

$A = \frac{\pi D^2}{4}$; $D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \times 1}{\pi}} = 1.13\,m$

$V = \frac{1}{n} R^{2/3} S^{1/2}$

Assuming $n = 0.013$ (for concrete pipes)

hydraulic radius — $R = A/P$; $P = \pi D$

wetted perimeter — $P = \pi \times 1.13 = 3.55\,m$

$R = 1/3.55 = 0.282\,m$

$S = \left(\frac{nV}{R^{2/3}}\right)^2 = \left(\frac{0.013 \times 1.5}{(0.282)^{2/3}}\right)^2$

$R^{2/3} = (0.282)^{2/3} = 0.241$

$\frac{nV}{R^{2/3}} = \frac{0.013 \times 1.5}{0.241} = 0.081$

$\therefore S = 0.006m/m$ (or 0.66%)

$\therefore S = 0.66\%$
$D = 1.13m$

(4.) Design a primary sedimentation tank to remove discrete particles if the flow is $1500m^3/d$

(5a) Design a Septic tank System for an estimated Population of 150 Persons. Estimated water Consumption is $120L/c/d$ and Percentage of water Consumption that is waste water is 80%. Design also the soakaway pit if the infiltration rate is $1500L/m^2/d$.

(5b) The flow of sewage from a combined sewage system through grit chambers is $10000m^3/d$. Determine the dimensions of the grit chambers

(5c) Derive the Equation for the discharge, Q for a radial flow in unconfined & confined aquifer explaining all the terms used.

(6) A drainage system is to be designed for an estate in Uyo. The main drain stretches from an elevation of 98.1 at chainage 0+0.5 to 95.7 at a chainage of 0+105m. Other information given as follows: Length of drainage path = 800m

Catchment area = $0.30Km^2$

$T = 5yrs$

(5b) Let the flow velocity (U_s) $= 0.25 m/s$

$$\varphi = 10000 m^3/d = \frac{10000}{24 \times 3600} m^3/s$$

$$= 0.116 m^3/s$$

Assume a detention time (θ) of $1 min = 60 sec$

$$\therefore Volume = \varphi\theta = 60(0.116)$$

$$= 6.96 m^3$$

$$\text{Cross-section area} = \frac{\varphi}{U_s} = \frac{0.116}{0.25} = 0.464 m$$

Assume the depth $= 1m$

$$A = \underbrace{D}_{Depth}\underbrace{w}_{width} \quad \therefore width = \frac{0.464}{1} = 0.464 m$$

$$L = U_s\theta = 0.25 \times 60 = 15m$$

(4.) Assume $t = 2 hrs$ & depth $= 3m$

flow $= 1500 m^3$ x hrs ~~[illegible]~~

$$Volume = \frac{2 \times 1500}{24} = 125 m^3$$

$= lwh$ $V = Lbh$.

$$A = \frac{125}{3} = 41.7 m^2 \text{ where } A = \text{Surface area.}$$

Let $L/W = 4 \rightarrow 4W^2 = 41.7 m^2$

~~$W = 3.18m$~~ $W^2 = \frac{41.7}{4}$; $W = \sqrt{\frac{41.7}{4}} = 3.2 m$

$L/W = 4$; $\frac{L}{3.2} = 4$; $L = 4 \times 3.2$
$= 12.8m$

Check (a) overflow rate (Q/A)

$$= \frac{1500}{41.7} = 35.97 m^3/m^2 d \text{ OK}$$

(b.) weir loading (Q / wetted perimeter)

wetted perimeter $= w + 2D$ $\quad \dfrac{1500}{3.2 + 2(3)} = 163.04 \, m^3/m.d$ ok.

Hence, use ~~12~~ 18m × 3.2m × 3.0m tank

Design Criteria for S.T

Perimeter	Range	typical
Detention time (hr)	1.5 – 2.5	2
Overflow rate ($m^3/m^2.d$)	12 – 48	30
weir loading $m^3/m.d$	125 – 500	250
Depth, m	3 – 5	3.6
Length, m	15 – 90	25 – 40
width, m	3 – 24	6 – 10

(5c) Dercy's law: $q = -K \dfrac{dh}{dr}$

q = specific discharge
K = hydraulic conductivity
$\dfrac{dh}{dr}$ = Hydraulic gradient

$Q = q \cdot A$

Q = total discharge (m^3/s)
A = Area of the Cylindrical surface through which water flows (m^2)

for confined aquifers, $A = 2\pi r b$
" Unconfined aquifers, $A = 2\pi r h$

Confined Aquifers; $Q = -K\frac{dh}{dr}(2\pi r b)$

$$Q\frac{dr}{r} = -K\,dh\,(2\pi b)$$

$$\int_{r_1}^{r_2}\frac{dr}{r} = \frac{-2K\pi b}{Q}\int_{h_1}^{h_2} dh$$

$$(\ln r)_{r_1}^{r_2} = \frac{-2K\pi b}{Q}\left[h\right]_{h_1}^{h_2}$$

$$\ln r_2 - \ln r_1 = \frac{-2K\pi b}{Q}\left[h_2 - h_1\right]$$

$$\ln(r_2/r_1) = \frac{2K\pi b}{Q}(h_1 - h_2)$$

$$Q = \frac{2K\pi b\,(h_1 - h_2)}{\ln(r_2/r_1)}$$

where h_1, h_2 : Hydraulic heads at radii r_1 & r_2 (m)

r_1, r_2 : Radii of the well (m)

b : Saturated thickness of confined aquifer.

K = Hydraulic conductivity

Unconfined Aquifer

$$Q = -K \cdot \frac{dh}{dr} \cdot 2\pi r h$$

$$\frac{dr}{r} = \frac{-2K\pi}{Q}h\,dh \qquad \int x^n = \frac{x^{n+1}}{n+1}$$

$$\int_{r_1}^{r_2}\frac{dr}{r} = \frac{-2K\pi}{Q}\int_{h_1}^{h_2} h\,dh$$

$$\left[\ln r\right]_{r_1}^{r_2} = \frac{-\cancel{2}K\pi}{\varphi}\left[h^2/\cancel{2}\right]_{h_1}^{h_2}$$

$$\ln r_2 - \ln r_1 = \frac{-K\pi}{\varphi}\left[h_2^2 - h_1^2\right]$$

$$\ln(r_2/r_1) = \frac{K\pi}{\varphi}\left[h_1^2 - h_2^2\right]$$

$$\varphi = \frac{K\pi(h_1^2 - h_2^2)}{\ln(r_2/r_1)} \quad //$$

K : hydraulic conductivity (m/s)

h_1, h_2 : Saturated thickness of aquifer at r_1 & r_2 respectively.

r_1, r_2 : Radius of the well or inner boundary & outer boundary respectively.

(5a) Population, $P = 150$ persons

φ_c, water consumption $= 120\,L/P/d$

wastewater generation $= 80\%$

Infiltration rate for soakaway: $I = 1500\,L/m^2/day$

Total Daily wastewater flow, $\varphi_w = P \times \varphi_c \times$ wastewater Percentage

$$= 150 \times 12\cancel{0} \times \frac{8\cancel{0}}{1\cancel{00}}$$

$$= 14{,}400\,L/day$$

Septic tank determination:

Retention volume: retention time, $t = 24$

$$V_{retention} = \varphi_w \times t = 14{,}400\,L$$

5 a) Sludge storage volume (It is typically designed 3-5 yrs of operation)

Assume sludge accumulation rate: $0.04 m^3/p/yr$

Design Period: 5yrs

$V_{sludge} = P \times \text{sludge rate} \times \text{Design Period}$

$V_{sludge} = 150 \times 0.04 \times 5$

$= 30 m^3$

Total septic tank volume; $V_{total} = V_{retention} + V_{sludge}$

$= 14.4 + 30$

$= 44.4 m^3$

Selection of septic tank Dimension:

Assume the tank is a rectangle with a length : width $= 2:1$

Depth $= 1.5m$

Let width $= w$

Length $= 2w$

$Volume = LWD \Rightarrow 2w \times w \times 1.5 = 44.4$

$3w^2 = 44.4$

$w^2 = \frac{44.4}{3} = 14.8$

$w = \sqrt{14.8} = 3.85m$

$\therefore L = 2(3.85) = 7.7m$

$\therefore L = 7.7m,\ w = 3.85m,\ D = 1.5m$

<u>Soakaway pit</u>

~~Daily wastewater flow~~ Infiltration rate $= 1500 L/m^2/d$

Area required $= \frac{Q_w}{I} = \frac{14{,}400}{1500} = 9.6m^2$

Assume a Circular soakaway pit: Area $= \pi r^2$

$$9.6 = \pi r^2$$

$$r = \sqrt{\frac{9.6}{\pi}} = 1.75m$$

$\therefore$ Radius $= 1.75m$; Depth $= 1.5m$, Area $= 9.6m^2$

2(a) Why is water treatment necessary? What factors determine the type of treatment given the water?

Wastewater treatment is the cost-effective stabilization of wastewaters & resultant residuals for minimisation of environmental & public health hazards. Water treatment is essential to ensure the water is safe for ~~humans~~ human consumption, industrial use & environmental sustainability.

Factors: ~~Source~~ Source of water, water quality, water hardness, Contaminant levels, Local regulations & standards, Economic & technology constraints, ph levels, temperature, Turbidity & suspended solids, salinity & total dissolved solids (TDS)

(b) With good sketches, illustrate the different types of treatment units explaining the applications of each.

Raw work

↓

Screen — removes course particles

↓

Plain Sedimentation tank — removes discrete particle.

↓

Secondary ~~S~~ Sedimentation tank — removes flocculent particles

↓

filtration — removes finely ~~distributed~~ divided particles & some bacteria

↓

Aeration - Exposing H_2O to air to cause oxidation

↓

Zeolite Bed - Removal of hardness through ion Exchange

↓

Disinfection — Destroys the pathogens.

↓

Consumer

(c) Differentrate B/w

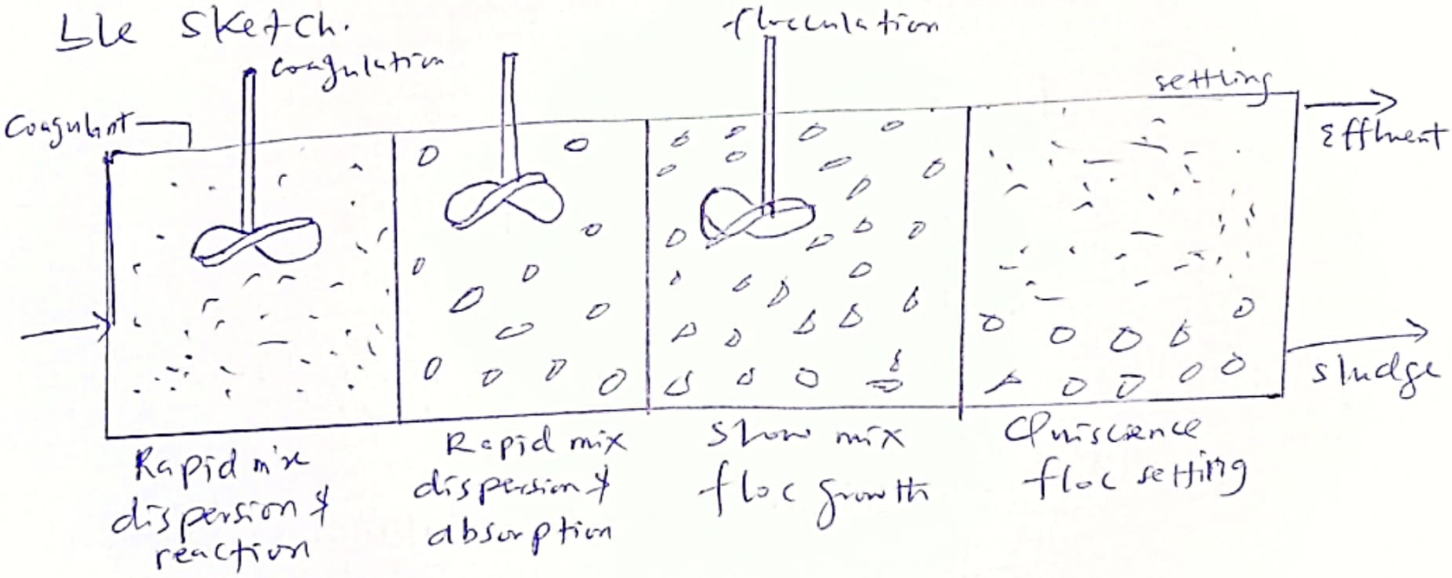
(i)

Plain Sedimentation	Secondary sedimentation
Removal of fine discrete particles which are allowed to settle under gravity & then be removed.	This is the settling tank with short detention time where the flocculent materials that have come together in process (3) settle down & are then removed.

(ii)

Coagulation	flocculation
It is the process by which colloidal particles are destabilized mainly by neutralizing their electrical charge.	It is the coalescing together of particles as they are brought into contact by mechanical stirring or use of baffles.

3(a) Describe the types I, II, III & IV settle using a suitable sketch.



3b Name four coagulants in common use & write their chemical Eqns requirements.

(i) Alum & Lime

$-\ Al_2(SO_4)_3 \cdot 14H_2O + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 14H_2O$

(ii) Alum & Soda Ash

$Al_2(SO_4)_3 \cdot 14H_2O + 3Na_2CO_3 + 3H_2O \rightarrow 2Al(OH)_3 + 3Na_2SO_4 + 3CO_2 + 14H_2O$

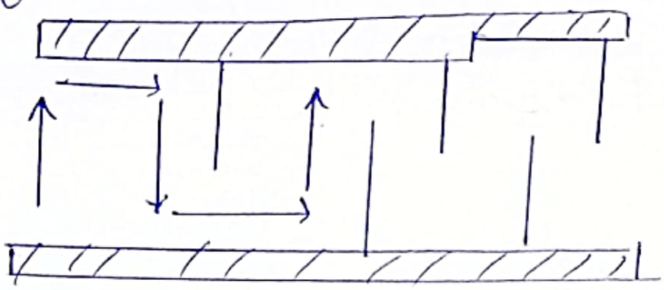
(iii) Ferric chloride

$2FeCl_3 + 3Ca(HCO_3)_2 \rightarrow 3CaCl_2 + 2Fe(OH)_3 \downarrow + 6CO_2$

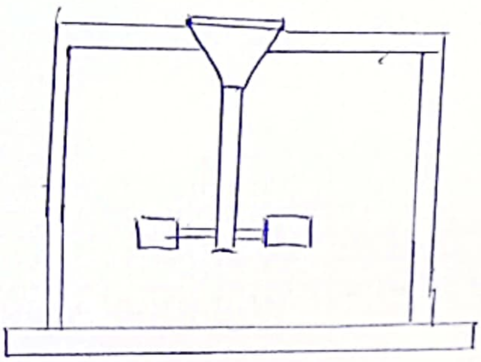
(iv) With Iron Sulphate

$$2FeSO_4 7H_2O + 2Ca(HCO_3)_2 + 0.5O_2 \rightarrow 2Fe(OH)_3 + 2CaSO_4 + 4CO_2 + 13H_2O$$

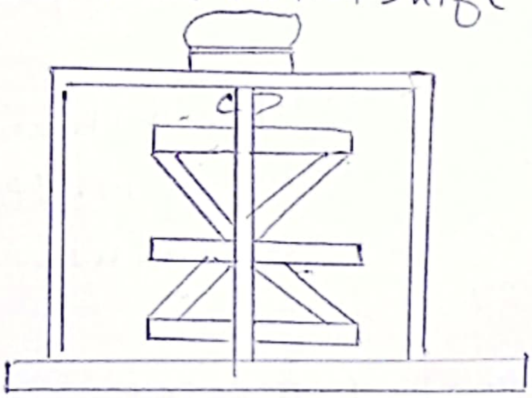
C (i) Plain of Pond - the bafflex in a channel



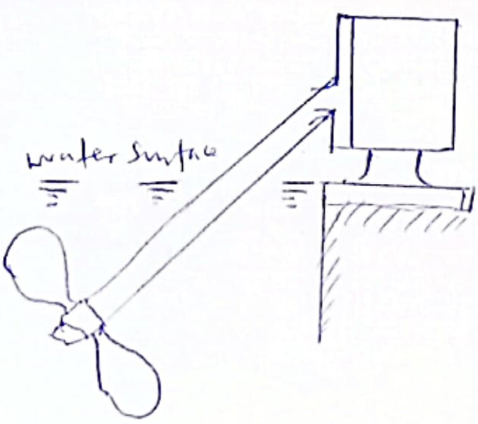
(ii) Flash mixer



(iii) Paddle mixer with vertical shaft



(iv) Mixing Propeller



d. Mention 5 steps for sewer & drain layout

- Planning & Data collection
- establishing the layout
- Calculating pipe sizes & slopes
- Hydraulic Design & load Analysis
- Detailed Drafting & Implementation.

4. Explain the following terms:

(i) Drainage:
(ii) Rainfall intensity
(iii) Run-off
(iv) Capacity of drain
(v) Time of concentration
(vi) Catchment area

- Drainage: It is the process of removing excess water from a surface or area, either naturally or through artificial systems. Effective drainage systems are essential to prevent water-logging & flooding.
- Rainfall Intensity: It is the rate at which rain falls over a Specific area, usually expressed in mm/hr. It is a key parameter in designing drainage systems & is used to predict potential runoff & flooding.
- Runoff: It is the portion of Precipitation that flows over the surface of the land instead of being absorbed into the ground. It eventually drains into rivers, lakes, or reservoirs. Runoff is influenced by factors like rainfall intensity, soil type, land lake and vegetation cover.
- Capacity of Drain: It refers to the maximum volume of water that a drainage system can handle or convey without overflowing. It depends on factors like the size, shape, slope & material of the drain

- Time of concentration: It is the time it takes ~~are~~ for water to travel from the furthest point of catchment area to a specific outlet or a drainage point. It helps estimate peak runoff during storm events & guides the design of drainage system.
- Catchment Area: It is the geographical region from which all precipitation collects & drains into a common outlet, such as a river, lake or reservoir. It is also called drainage basin or a watershed. The size & characteristics of a catchment area influence the amount of runoff & H_2O flow.

4b.) A drainage system is to be designed for an estate in Uyo. The main drain stretches from an elevation of 98.1 at chainage 0+0.5 to 98.7 at a chainage of 0+105m. Other information given as follows:
length of drainage path = 800m
Catchment area = $0.30km^2$, the intensity-duration graph is given & T = 5yrs

Determine the slope, $S = \frac{\Delta H}{L}$

$$\Delta H = 98.7 - 98.1 = 0.6m$$

$$L = 800m$$

$$S = \frac{0.6}{800} = 0.00075$$

$$Q = C \cdot I \cdot A$$

Q = peak runoff rate (m^3/s)
C = Runoff coefficient (depends on the land use & soil type; typically 0.3 - 0.9 for estates)
I = Rainfall intensity for the 5year return period
A = Catchment area in m^2 ($300,000m^2$)

Assuming $C = 0.5$; $I = 50\,mm/hr$ $(0.00001389\,m/s)$

$$Q = 0.5 \times 0.00001389 \times 300{,}000$$
$$= 3.75\,m^3/s$$

Hydraulic Design of the drain

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

n = Manning's roughness coefficient (0.013 for concrete)

A = Cross-sectional area of the drain

R = Hydraulic radius $= A/P$ where P = wetted perimeter

S = slope = 0.00075

Assume a rectangular drain:

width b & depth, d

$$A = b \cdot d$$
$$P = b + 2d$$

$$AR^{2/3} = \frac{Qn}{S^{1/2}}$$

$$\cancel{AR^{2/3} = \frac{2.08 \times 0.013}{(0.00075)^{1/2}} = 0.988\,m}$$

$$R = \frac{A}{P} = \frac{b \cdot d}{b + 2d}$$

$$Q = \frac{1}{n}(b \cdot d)\left(\frac{b \cdot d}{b + 2d}\right)^{2/3} S^{1/2}$$

$$3.75 = \frac{1}{0.013}(b \cdot d)\left(\frac{b \cdot d}{b + 2d}\right)^{2/3}(0.00075)^{1/2}$$

$$3.75 = \frac{1}{0.013}(b \cdot d)\left(\frac{b \cdot d}{b + 2d}\right)^{2/3}(0.0274)$$

$$3.75 = 2.108\, b.d \left(\frac{b.d}{b+2d}\right)^{2/3}$$

Assume a practical ratio b/w b & d

$b = 2d$

$A = b.d = 2d.d = 2d^2$

$P = b + 2d = 2d + 2d = 4d$

$R = \frac{A}{P} = \frac{2d^2}{4d} = 0.5d$

$3.75 = 2.108(2d^2)(0.5d)^{2/3}$

$3.75 = 2.108(2)(0.63d^3)$

$3.75 = 2.652d^3$

$d^3 = \frac{3.75}{2.652} = 1.414$

$d = \sqrt[3]{1.414} = 1.12m$

Depth, $d = 1.12m$

width, $b = 2d = 2(1.12) = 2.24m$

This drain can handle the Peak runoff of $3.75 m^3/s$. effectively.

4c. What is storm inlet? Draw the plan elevation & section of well a manhole showing a typical section

A storm inlet is a structure designed to collect surface runoff & direct it into a storm water drainage system. Storm inlets are commonly used in roads, Parking lots & other paved areas to manage stormwater & Prevent flooding.

6a In tabular form differentiate b/w slow & rapid sand filters.

b. State four problems of rapid sand filter that you know

c show by sketches a typical slow sand filter & label it parts

(i) state Darcy's law

Slow Sand	Rapid Sand
1. fine sand with a uniform grain size	Courser sand & gravel layers
2. operational cost is low	operational cost is high
3. Effective for low turbidity water.	suitable for water with higher turbidity
4 Requires large areas due to slow filtration rate	Requires less space due to faster filtration rate
5.) Suitable for small-scale rural or low-demand water systems	Suitable for large-scale urban or industrial water supply.
(6.) Produces high-quality, pathogen free water over time.	Produces high-quality water but may require additional disinfection.

Problems of rapid sand filter

- Frequent backwashing
- High Energy consumption
- Chemical Dependency
- Clogging with High turbidity water.

It helps in controlling the growth of algae, bacteria & other microorganisms; and it is often used to oxidize contaminants, making them easier to remove in later treatment stages.

- Post Chlorination: This involves adding chlorine to the water after it has been treated. It helps maintain a residual level of chlorine that ~~prevents~~ prevents microbial growth during storage & distribution.
- Super chlorination: This is the practice of adding an ~~uns~~ unusually high dose of chlorine to water to eliminate higher concentrations of microorganisms, ~~or~~ to remove large amounts of organic matter.
- Household Disinfection: Refers to the use of disinfectants, like chlorine or iodine to treat households water, typically in situations where water is contaminated. It ensures that the water used for cooking, drinking & washing is free from harmful microorganisms that could cause illness.

— Types of waste water pipes

- PVC (polyvinyl chloride) pipes
- CPVC (Chlorinated polyvinyl chloride) pipes
- ABS (Acrylonitrile Butadiene Styrene) pipes
- Cast ~~fro~~ Iron pipes
- Clay pipes
- Concrete pipes
- Stainless steel pipes
- HDPE (High-Density Polyethylene) pipes
- Fiberglass pipes
- Polypropylene pipes
- Polybutylene pipes
- Ductile Iron pipes
- Galvanized steel pipes

Darcy's law states the rate of flow of a fluid through a porous medium is directly proportional to the hydraulic gradient, the crosssectional area of the flow, & the permeability of the medium.

$$Q = -KA\frac{\Delta h}{L}$$

Q = Volumetric flow rate (m^3/s)

K = Hydraulic conductivity (m/s)

A = Cross sectional area perpendicular to the flow (m^2)

Δh = Hydraulic head difference (m)

L = Length of the flow path (m)

N/B: The negative sign indicates that the flow direction is opposite to the hydraulic gradient.

7a. Explain the following terms

(i) Backwashing

(ii) Pre-chlorination

(iii) Post chlorination

(iv) Household Disinfection

(v) ~~Super chlorination~~ Super-chlorination

(vi) Name 13 types of wastewater pipes

(vii) Sewer pipes must possess 6 characteristics. Name them.

(i) Backwashing: This is a process used in water filtration systems, especially in sand filters. It involves reversing the flow of water through the filter to clean it.

(ii) Pre-chlorination: This is the process of adding chlorine to water before it undergoes other treatment steps.

Characteristics of sewer pipes

- Strength & Durability
- Corrosion Resistance
- Leak Resistance
- Smooth interior surface
- Flexibility
- Cost - Effectiveness.