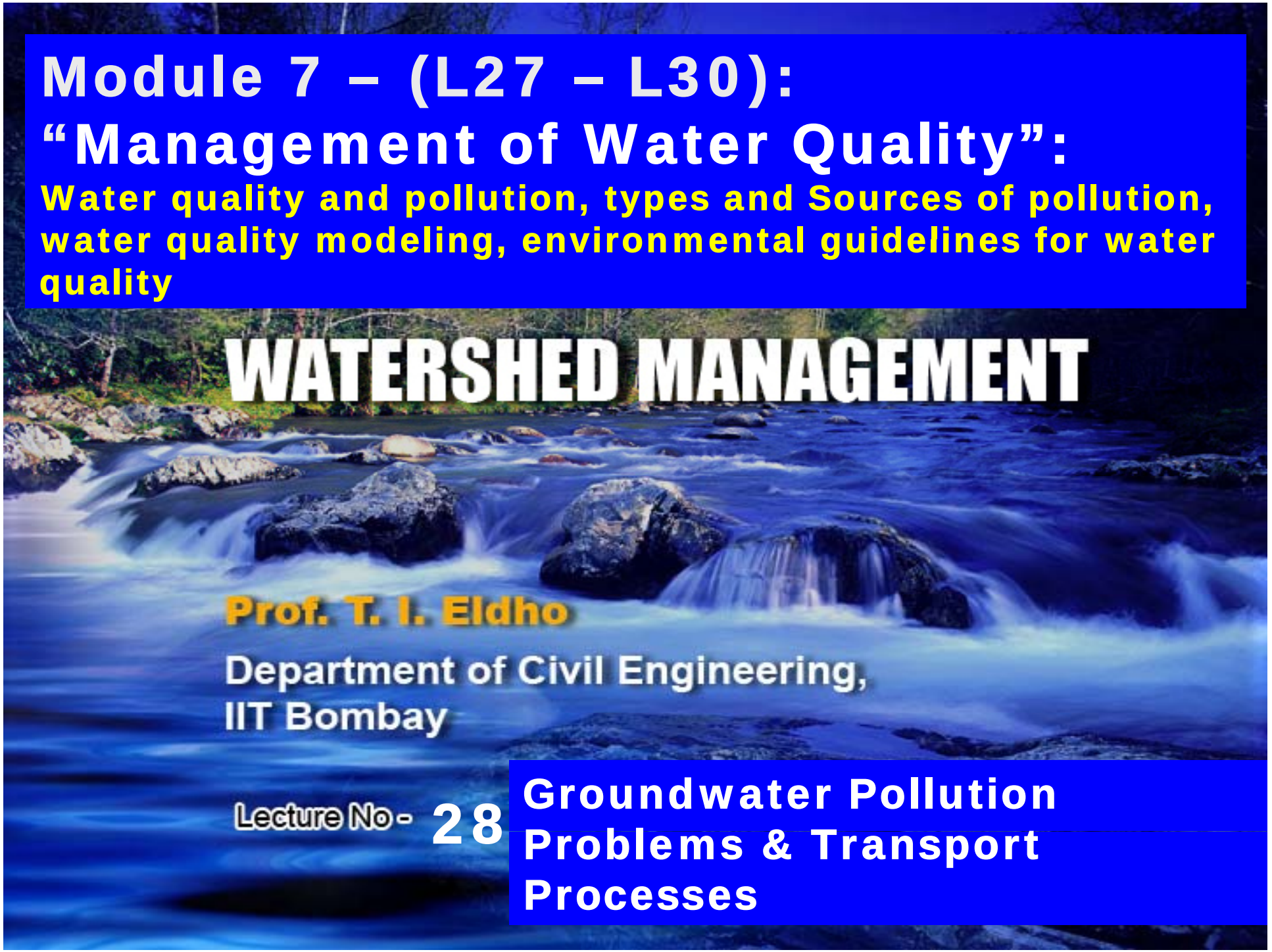
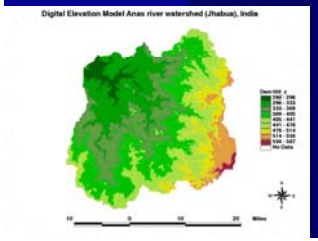
Module 7 – (L27 – L30):
"Management of Water Quality":

Water quality and pollution, types and Sources of pollution, water quality modeling, environmental guidelines for water quality



L28– Groundwater Pollution Problems & Transport Processes

- **Topics Covered**
- Groundwater pollution sources, pollution control, remediation, transport processes in surface & groundwater.
- Keywords: Groundwater pollution, Control, Remediation, Transport Processes.



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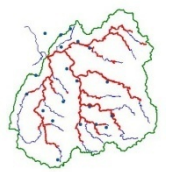
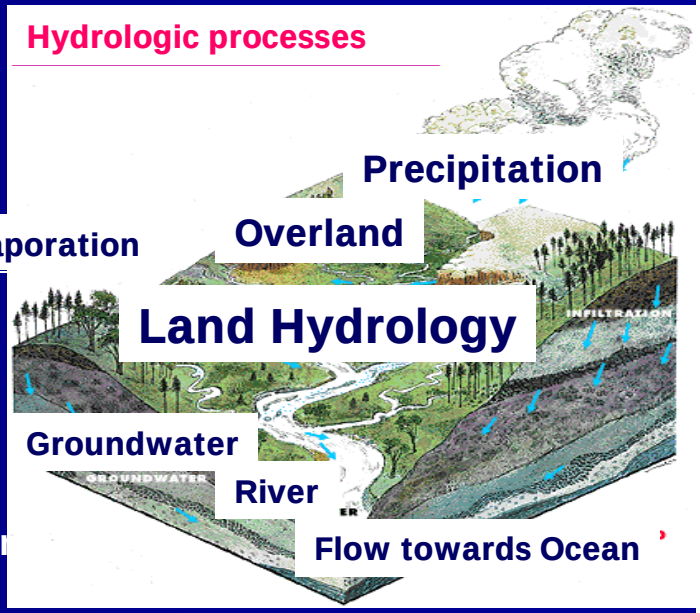


Watershed Management & GW Quality

- Watershed management – Groundwater major component- quantity & quality
- Groundwater assessment - monitoring of water quality
- Depending on use of water: Physico-chemical, chemical & microbiological analyses of water
- **Common issues of Groundwater**
- Pathogenic Pollution; Salinity
- Toxicity (micro-pollutants and other industrial pollutants)



Groundwater Problems

- **Problems with groundwater**
- Groundwater overdraft / mining / subsidence
- Water logging
- Seawater intrusion
- Groundwater pollution
- Conservation & preservation of groundwater is important task.
- Groundwater quality - very much deteriorated due to rapid industrialization and human mismanagement.

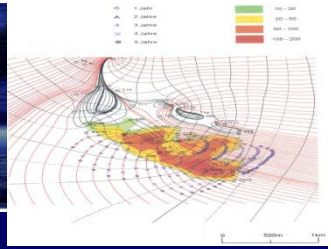
Management of Groundwater Systems

- The total volume that may be withdrawn annually from the aquifer.
- The location of pumping and artificial recharge wells, and their rates.
- Decisions related to groundwater quality.

- **Groundwater contamination by:**
- Hazardous industrial wastes
- Leachate from landfills
- Agricultural activities such as the use of fertilizers and pesticides

Management of GW Systems...

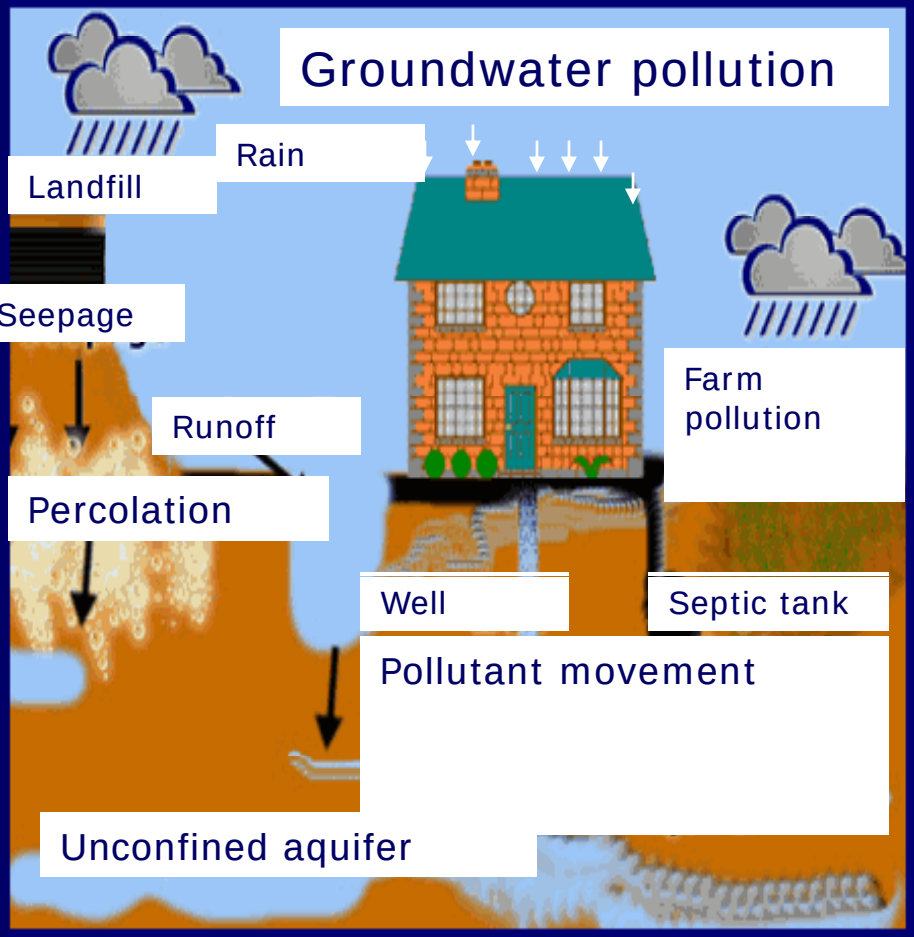
- MANAGEMENT means making decisions to achieve goals without violating specified constraints.
- Good management requires information on the response of the managed system to the proposed activities.
- This information enables decision-maker, to compare alternatives & ensure that constraints are not violated.
- Any planning of mitigation or control measures, once contamination has been detected requires the prediction of the path and the fate of the contaminants, in response to the planned activities.
- Any monitoring or observation network must be based on the anticipated behavior of the system.



Groundwater Pollution Problems

- Groundwater Quantity & Quality
- Useful Only if Quality is Safe
- Quality Indicated by Dissolved or Suspended Solids
- Pollution Sources
- Form of Pollution - dissolved salts, domestic or industrial waste, heat, radioactive materials, pesticides, manures
- Solute transport - with flowing water
- Convection, Hydrodynamic Dispersion
- Groundwater Pollution Issues: Pollution sources, movement, Control & Protection, Pollution Remediation

Groundwater Contamination Sources



http://www.filterwater.com/asp/cs/images/gwcont.gif

- Natural contamination
- Agricultural contamination
- Industrial contamination
- Underground storage tanks
- Land application and mining
- Septic tanks
- Waste disposal injection wells
- Landfills

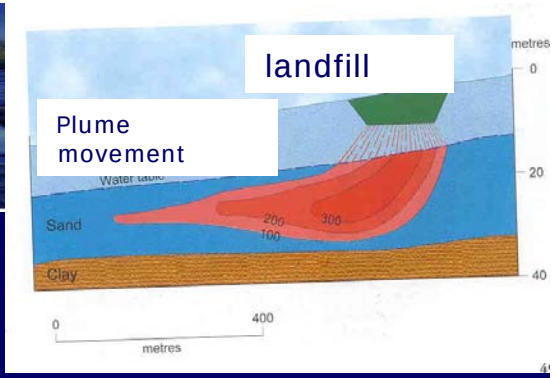
Groundwater Pollution Sources

- Domestic Waste: Household wastes; Septic tanks; Liquid fraction from septic tank pollutes groundwater; Inefficient design - increases pollution
- Agriculture Pollution: Artificial manure, Pesticides, Herbicides; Nitrate pollution - Eutrophication, Health problem - in drinking water - long term problem; Pesticides - insecticides, herbicides, fungicides - beneficial to farming - serious threat to health
- Leachates from Landfills: Land filling - cheapest - commonly used - solid waste disposal; Domestic, Commercial, Industrial; Polluting liquids – leachates
- Industrial Pollution: Petrochemical, Pharmaceutical Industries - Complex organic wastes - NAPL (DNAPL, LNAPL); Spills or leaks from tanks, pipelines; Eg. In Germany - 240,000 NAPL contaminated sites

Groundwater Pollution Sources

- Contaminated Land & Urban Pollution: Effect of Industrial Revolution - wastes disposed in and around urban areas . Eg. Mining & foundry wastes, tars, oils, phenols etc. Contaminated land - pollutes water. Eg. UK - 500 sq.km land in 50,000 sites
- Mining & Sea Water Intrusion Pollution: Water draining from mines - acids, sulfates, iron, cyanides etc. in solution pollutes surface and groundwater; Abandoned mines - a serious threat
- Sea water intrusion - excessive pumping in coastal aquifers
- Proper management of coastal aquifers
- Dissolved salts & minerals - eg. Arsenic contamination in Bengal basin

Groundwater Contamination Mechanism



- **Changes in chemical concentration occurs in groundwater system by four distinct processes**

1. Advective transport

Dissolved chemicals are moving with the groundwater flow.

2. Hydrodynamic dispersion

Mechanical , hydraulic, molecular and ionic diffusion

3. Fluid sources

Water of one composition is introduced in to and mixed with water of different composition.

4. Reactions

Some amount of a particular dissolved chemical species may be added or removed from groundwater as a result of chemical, biological and physical reactions in the water or between the water and the solid aquifer materials.

Groundwater Protection & Pollution Control

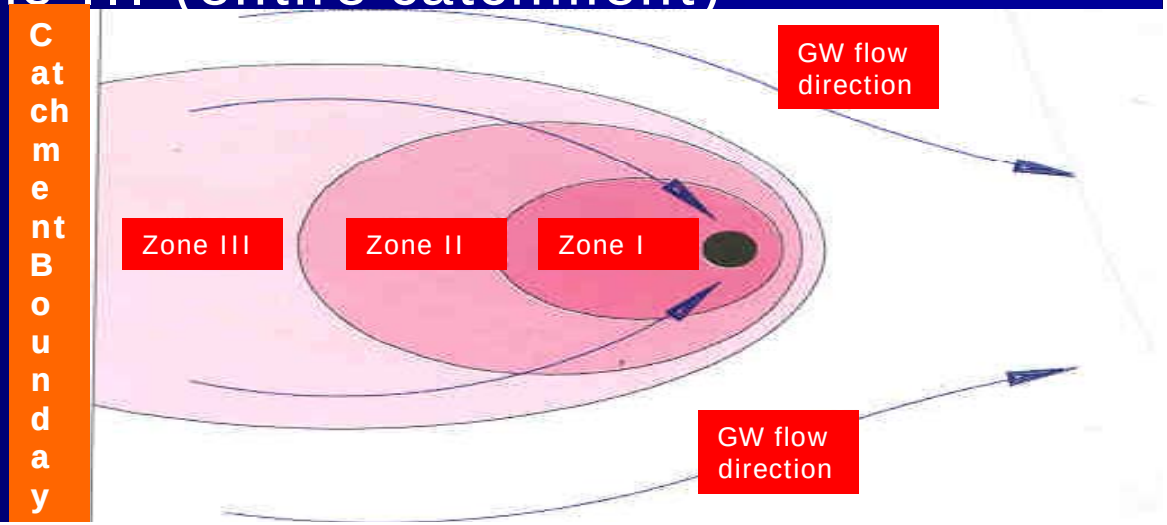
- Once aquifers contaminated - very difficult to restore - expensive
- Sensible to prevent pollution
- Vulnerability of pollution depends on aquifer nature, flow speed and unsaturated thickness
- Vulnerability maps showing - possibility of aquifer contamination - essential for aquifer protection
- USA and European Union - Models

Source Control Strategies

- To minimize or prevent pollution before a contamination
- Volume of waste reduced or threat due to waste reduced
- Most applicable in new sites, old sites - abatement
- Depends on site, situation & type of waste
- Advantages - reduce threat, accelerates time for stabilization of waste disposal
- Disadvantages - Increased capital & maintenance costs, monitoring & skilled operator requirements

Source Protection Zones

- Protection of individual groundwater sources (wells, boreholes or springs)
- Protection zones defined around sources (eg. UK, USA, Germany etc.)
- Within the protection zones - pollution activities prohibited or restricted
- Three zones - Zone I (50 days of travel), Zone II (400 days of travel) , Zone III (entire catchment)

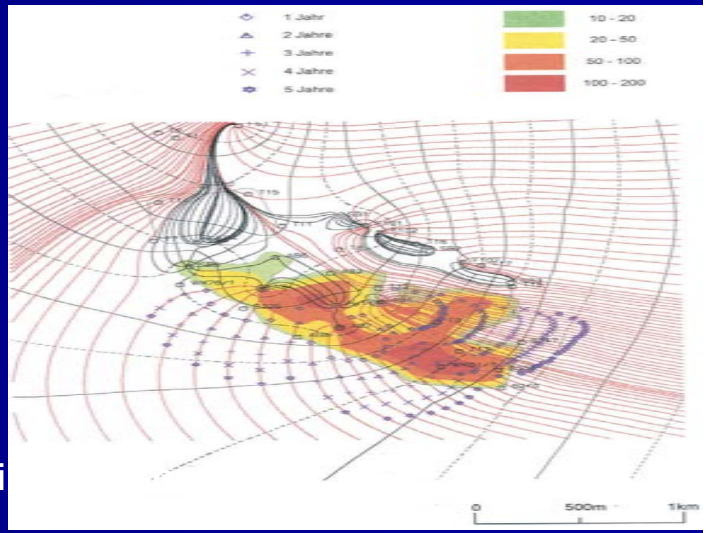


Stabilization / Solidification Strategies

- Isolating the waste materials in a solid matrix before land filling - Stabilization / Solidification
- Popular for hazardous and radioactive waste disposal
- Chemically fix the waste in a solid matrix
- Important stabilization / solidification processes include: cement adding, addition of lime or pozzolanic materials, embedding wastes in thermoplastic materials (bitumen, parafin etc), addition of organic polymer, encapsulation in inert coating, glass formation of wastes with silica

Hydraulic Control - Well Systems

- Manipulating the subsurface hydraulic gradient through pumping or recharge
- Plume management
- Control movement of water phase and hence plume
- Three common classes of well system: withdrawal through shallow system, deep system, injection of water
- Most assured system
- More understanding of the system
- Demerit - High operation & maintenance costs, monitoring



Surface Water Control, Capping & Liners

- Surface water control, capping & liners used in conjunction
- Surface water control (diversion berms, drainage ditches etc.) - minimize the amount of water flowing into a site reducing amount of infiltration
- Capping - minimizes percolation
- Impermeable liners inhibit downward flow of low quality leachate or pollutant by adsorption process
- Used as preventive measures

Sheet Piling, Grouting, Slurry Walls

- Sheet piling - involves driving lengths of steel, concrete or timber that connect together - a thin impermeable barrier to flow - effective & economic, piles can be reused
- Grouting - Injecting a liquid, slurry or emulsion under pressure into soil - occupy available pores - injected fluid solidify - permeability reduces - materials used are cement, asphalt, clay - reduce water and contaminant movement
- Slurry walls - used to encapsulate an area to either prevent groundwater pollution or contaminated water - digging a trench around the area and backfilling with impermeable material - prevent movement of plume

Groundwater Pollution Remediation

- Once groundwater polluted, how to restore or improve to acceptable standard?.
- First determination of distribution of pollution
- Then remediation strategy
- Restoration to original level impossible
- First step - containment of pollution, second step - remediation

Remediation Technologies

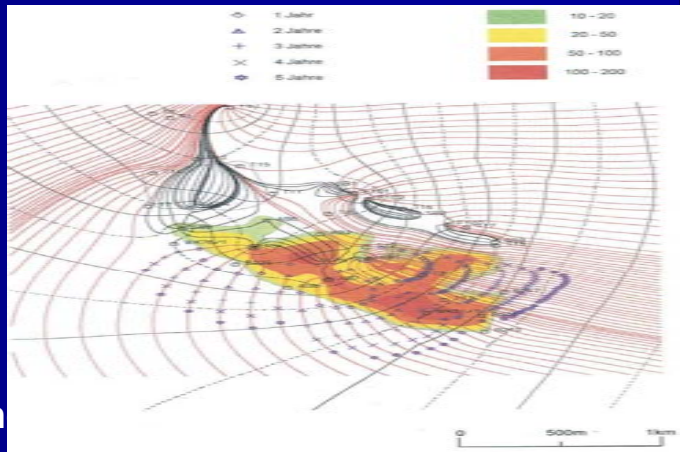
- On-site techniques
- In-situ techniques

Groundwater Pollution Remediation..

- On-site techniques - Pump polluted water, treat and recharge back to the aquifer
- Most commonly used method is - Pump and treat
- In-situ techniques - directly remediate the contaminated water in the aquifer itself
- In-situ technologies - not well developed - site characterization is complex, expensive - many technologies are under development

WATERSHED MANAGEMENT

- Contaminated groundwater is captured, pumped, treated and re-infiltrated back
- For effective installation - accurately determine the location of plume, determine hydrogeological parameters of aquifer, chemical properties of plume, design of capture system, installation of extraction and infiltration wells
- Pump and treat also contains plume movement
- Advantages - simplicity of operation and design
- Limitations - long time requirement, design failure, expenses, not efficient for VOCs



In-situ Technologies - Bioremediation

- Microbial process used to degrade or transform contaminants to less toxic or non-toxic forms - mitigating or eliminating contamination
- Aerobic conditions - sufficient oxygen presence, micro-organisms convert organic contaminants into CO2, water and microbial cell mass
- Anaerobic conditions - nutrients such as sulfate, nitrate are provided and contaminants converted to methane and other compounds
- Bioremediation - mainly for organic compounds
- Important parameters - biodegradability, phase distribution, soil type and properties

In-situ Flushing

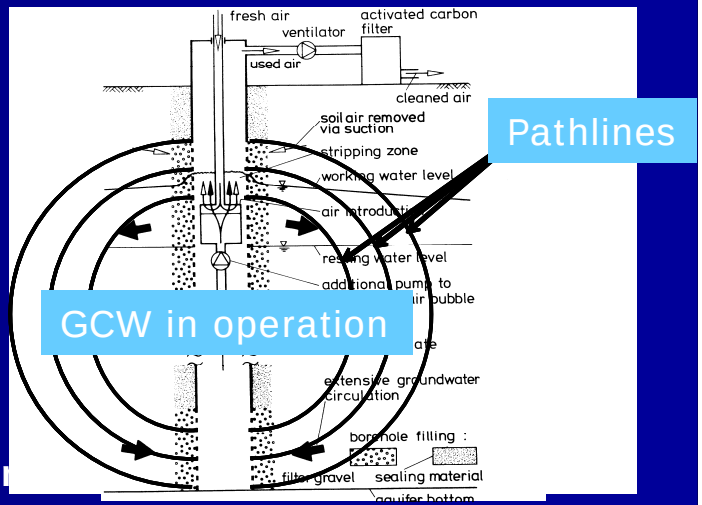
- Injection of an aqueous solution into a zone of contaminated soil or groundwater - down gradient extraction of groundwater and elutriate - above ground treatment - re-injection
- Flushing solution - water, surfactants, co solvents
- In-situ flushing enhances conventional pump & treat
- Success - site specific
- Parameters – hydrogeology, contaminant nature
- Efficiency depends on solubility and mobility of plume
- Advantages - acceleration in site clean up, broad range of contaminants; Limitation - possibility of spreading

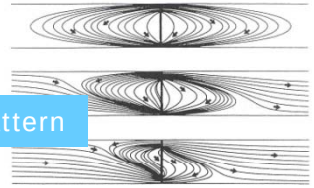
Air Sparging

- Injecting air / oxygen under pressure into saturated zone to volatilize groundwater contaminants and to promote biodegradation in saturated/ unsaturated soils by increasing subsurface concentration
- Volatilized vapor migrate vadoze zone - collected by vacuum pumps
- Also known as bio- sparging - bioremediation aspects
- Used to remediate volatile or semi-volatile contaminants - petrol, BTEX, chlorinated solvents
- More pervious areas, homogeneous soils and large saturated thickness - more favorable
- Advantages - A low maintenance in-situ remediation, min. disturbance to site, remediation in reasonable time
- Limitations - not efficient for pollutants which form complexes with soil, not efficient in low permeable areas

Groundwater Circulation Wells

- In-situ technique for VOCs amenable to air stripping
- GCW - creates an artificial flow fields that flushes and transforms the contaminants from aqueous phase to gaseous phase - subsequently treating the air stream
- Typical GCW system consists - single well with two hydraulically separated screened sections installed within one aquifer
- Pumping in the lower followed by air stripping and reinfiltration in the upper screen - creates a recirculation pattern in aquifer




GCW flow pattern

Groundwater Circulation Wells

- Pumping mechanism controls the circulation process - exchange of large pore volumes
- Continuous flushing - dissolution, diffusion and desorption
- GCW creates complex 3D flow field
- Efficiency depends on radius of influence of the well - aquifer structure, anisotropy, natural flow gradient, well screen lengths, number of screens, quantity of water circulated etc.
- Advantages - less investment & operating cost, no extraction, no lowering of groundwater level, continuous remediation process, Most suitable in hot spots
- Limitations - not suitable in thin aquifers (less than 1.5 m), not efficient in low permeable regions or multi-layered aquifers

Transport Processes

- Surface & groundwater
- Process involved – in transport of chemicals from watersheds – very complex- Physical, chemical & biological
- Physical Processes – Convection; suspension & deposition; Dispersion, Diffusion, Tillage etc.
- Chemical Processes – Sorption, Ion exchange, Crystallization, Hydrolysis, Oxidation-reduction, Photochemical reactions etc.
- Biological & Biochemical processes

Transport Processes- Physical

- Convection: transporting fluids carries the constituent (dissolved or suspended); water – principal carrier- rainfall, overland flow & subsurface movement
- Suspension & deposition: processes by which solid particles moved into & returned from water; rainfall & overland flow major factors; materials held in suspension depends on turbulence of flow; turbulence reduced – particles settles.
- Dispersion – result of irregular or unequal transport; eddies & other turbulence in streams; porous media pathways; some constituents move ahead or lag behind.
- Diffusion – net movement of a constituent in response to concentration difference or gradient
- Tillage – affects chemical transport indirectly by modifying water & sediment movement.

Transport Processes- Chemical

- Sorption: movement of a constituent between the solid & solution phases – Adsorption – occurs when chemical leaves the solution & adheres to some solid; Desorption – reverse process; at equilibrium – a balance between processes.
- Ion exchanges: exchange of an ion in solution for an ion of similar charge on the surface of an oppositely charged solid.
- Crystallization – occurs when concentration of a chemical in solution exceeds its solubility.
- Hydrolysis – reaction of a chemical with water to form a different compound.
- Oxidation-reduction – reactions occur when one chemical loses an electron & is oxidized while another gains the electron and is reduced.

Transport Processes

- Biochemical Processes: Enzymes that various microorganisms contain can accelerate reaction rates; Organic chemicals can be transformed into other chemicals by oxidation, reduction, hydrolysis & other reactions occurring in microorganisms
- Biological processes
- Chemical Constituents: Sediments, salts, nutrients, pesticides, oxygen-demanding materials, heavy metals, microorganisms, water temperature etc.

References

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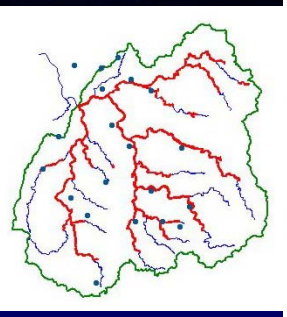
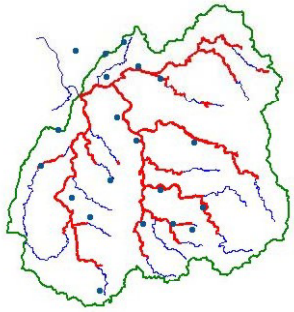


Tutorials - Question!.?.

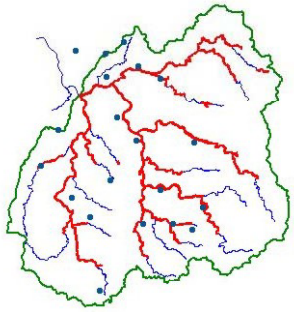
- Critically study the groundwater pollution problems in India. Study various sources and causes (details can be obtained from Internet: http://cpcb.nic.in; http://wrmin.nic.in, http://cgwb.gov.in/)

- Study the various measures that can be adopted to reduce the groundwater pollution in India.



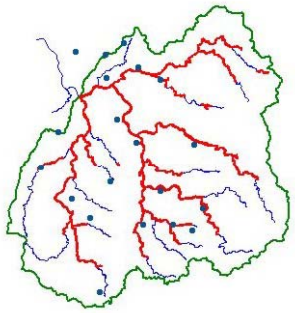
Self Evaluation - Questions!.

- Illustrate the groundwater quality issues on watershed scale.
- What are the important sources of groundwater pollution?.
- What are the different source control strategies for groundwater pollution?.
- Describe the on-site groundwater pollution remediation.
- Describe the in-situ “groundwater circulation wells” system for groundwater pollution remediation.



Assignment- Questions?.

- Describe the groundwater management systems for quantity & quality.
- Discuss the various measures of groundwater protection and pollution control.
- What are the important techniques of groundwater pollution remediation?.
- Describe the in-situ groundwater pollution remediation.
- What are the various transport processes involved in pollutant movement in surface water & groundwater?.



Unsolved Problem!.

- Critically study the possible groundwater pollution problems in your watershed area.
- Identify the possible causes of groundwater pollution such as point source or Non-point sources.
- How the pollution problems can be controlled?.

WATERSHED MANAGEMENT

THANK YOU

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