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Challenges in sewage treatment and reuse opportunities in arid regions

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أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَاوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا
فَفَتَقْنَاهُمَا وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ

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Sewage treatment must be part of Integrated Water Resources Management (IWRM)

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WATER RESOURCES

Groundwater
Reservoirs
Oceans

Treatment → Water Supply

Discharge of non-treated sewage

Sewage Treatment

↓

Treated Sewage

↓

Fate ?

Criteria for compounds hazardous to waters (teratogen, mutagenic, toxic)

Non-removable by:

- Biodegradation
- Filtration
- Flocculation
- Sedimentation
- Oxidation
- Reduction

Antibiotics, Pain Releasing Compounds, Endocrine Disruptors

Treated Sewage : 0.1 mg/l range

Sludge : 250 mg/kg DW range

Oxygenizers in Fuels: MTBE/ETBE

None of the current sewage treatment technologies are able to remove those hazardous compounds sufficiently !

Research Required !

- Advanced Oxidation (?)

FATE OF TREATED SEWAGE

- Irrigation
- Release to the environment (Sea, Wadis, etc.)
- Reuse (?)

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Groundwater

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Groundwater is a treasure

and protection, depletion and prevention of pollution must have highest priority!!!

Groundwater depletion by overexploitation

- Shrinking Groundwater Bodies
- Land Subsidize
- Sinking Groundwater Levels

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Groundwater Recharge in Areas of Groundwater Depletion

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Requirements

Data aquisition

↓

Lab-scale experiments

↓

Modeling, feasability

↓

Pilot scale

Long term action !

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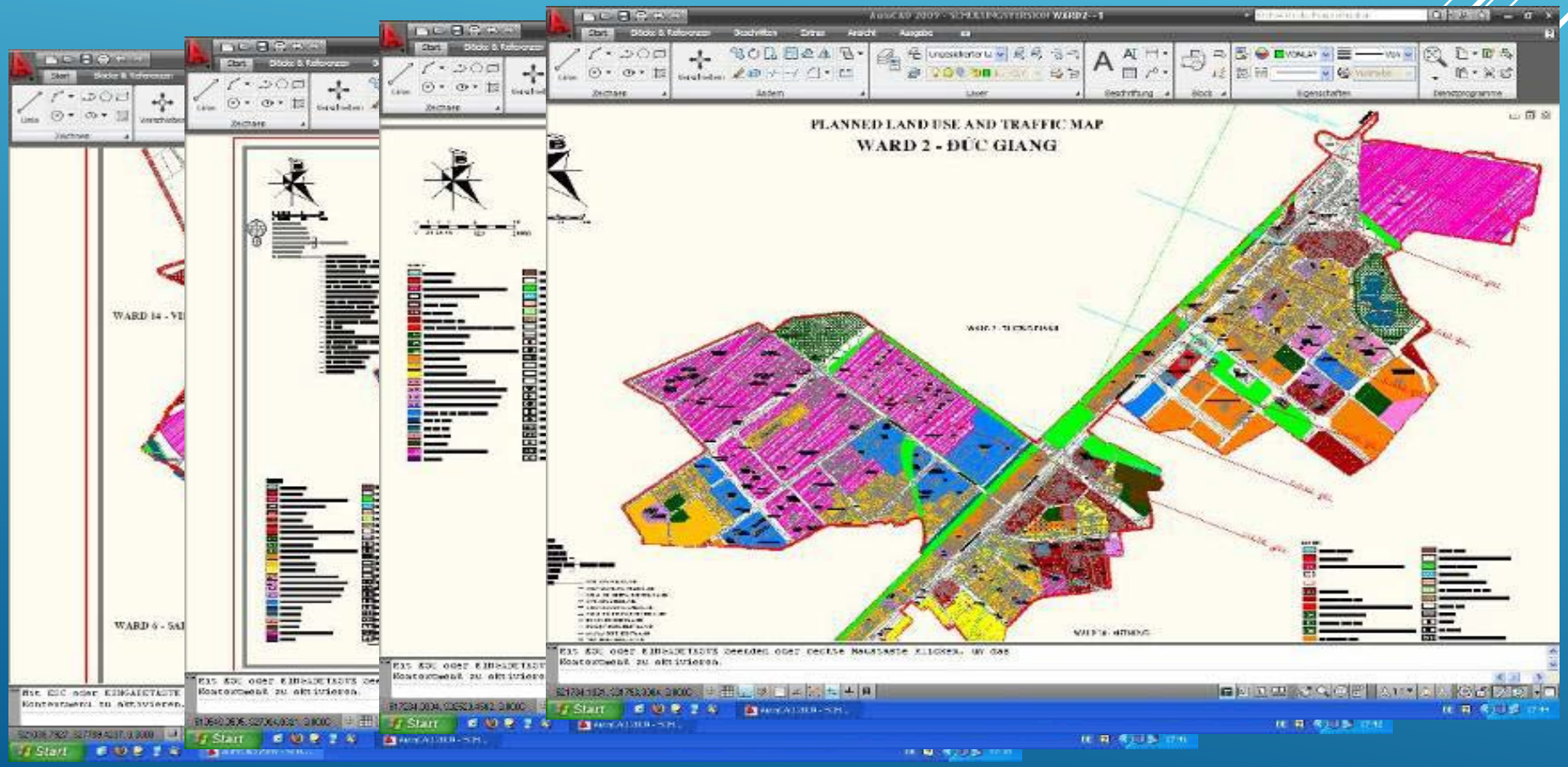
Data Acquisition



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SAT

SAT: Soil Acquifer Treatment (Process)

AGR: Artificial Groundwater Recharge for Treated Wastewater (Action)

The Subsurface is a Reactor Based on Natural Attenuation

Natural Attenuation

Naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media.

These in-situ processes include ***biodegradation***, dispersion, dilution, adsorption, volatilization, and abiotic transformation of contaminants

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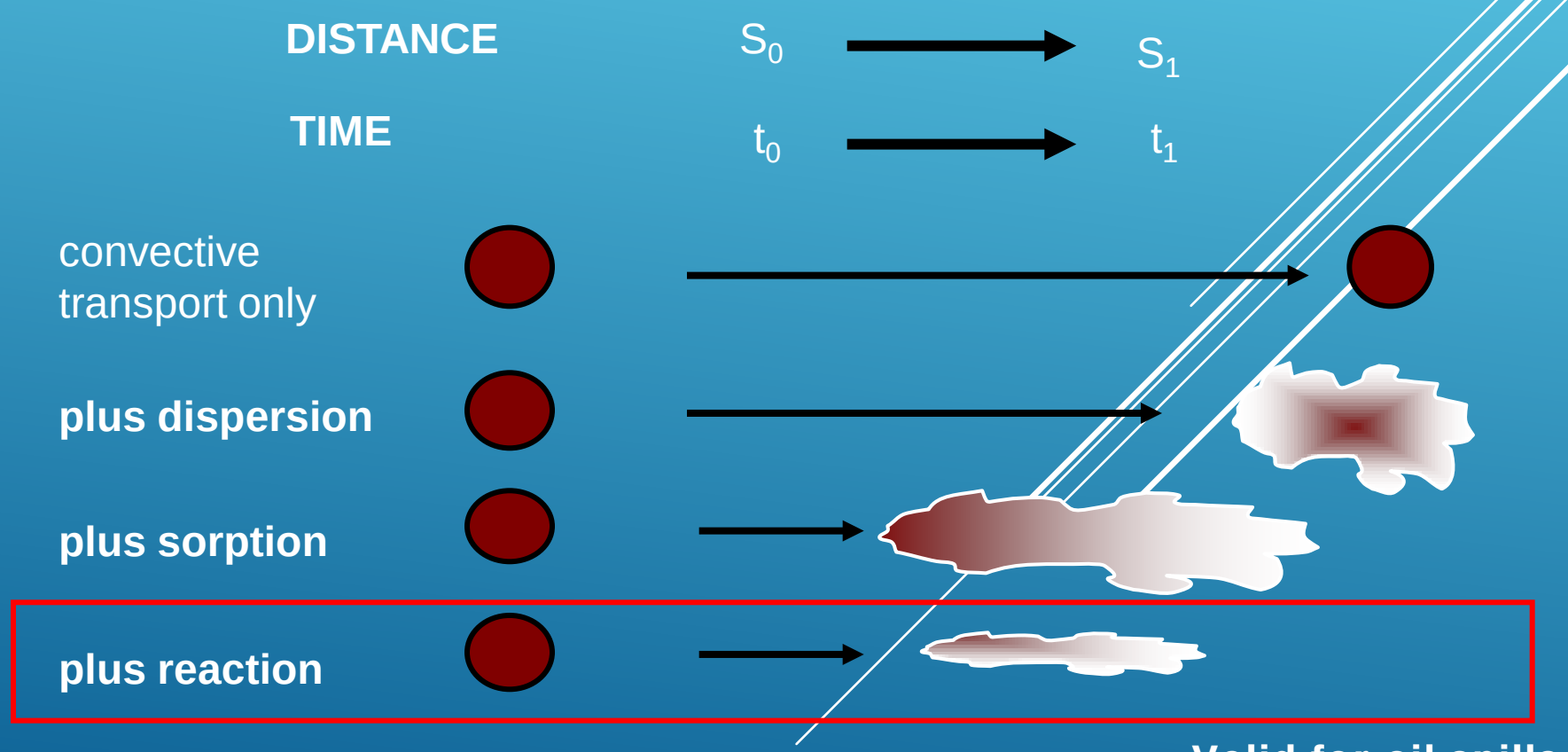
Fate of Pollutants in the Subsurface



Valid for oil spills

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Monitored Natural Attenuation (MNA)

THE NATURALLY OCCURING ELIMINATION PROCESSES ARE MONITORED BY A PROCESS RELATED ANALYTICAL PROGRAMME

Enhanced Natural Attenuation (ENA)

THE NATURALLY OCCURING ELIMINATION PROCESSES ARE SUPPORTED BY ENHANCING THE PROCESS OR ELIMINATING LIMITING FACTORS

Purpose of AGR and SAT

- Replenishment of groundwater resources in depleted aquifers
- Water storage for counter-balancing the negative seasonal effects
- Control of land subsidence
- Control of salt water intrusion in coastal areas

Part of wastewater management

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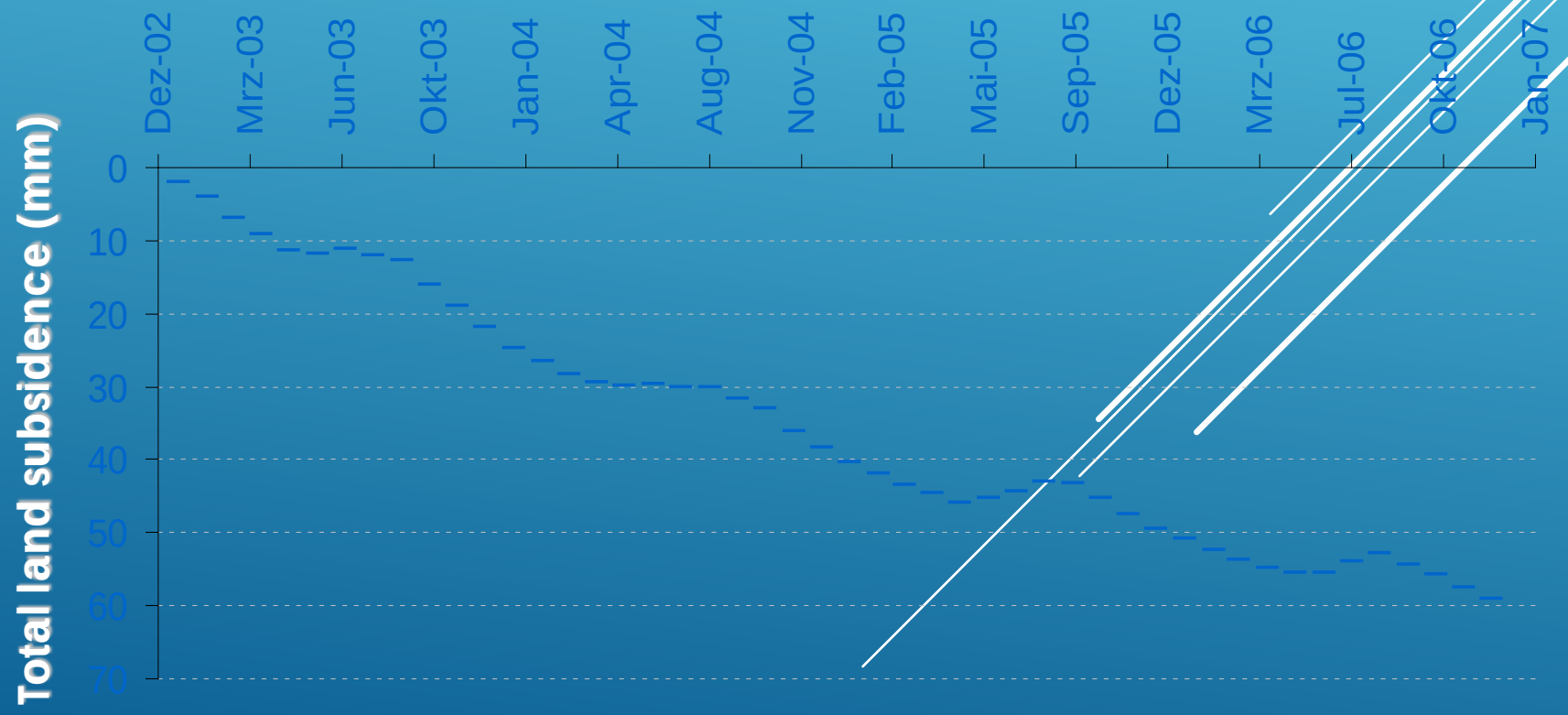
Demands and Reasons to Act

Land subsidence

Example: Giam Lam station (Long Bien), monitoring between Jan 03 – Dec 06



Sept. 2008

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Fast Growing Cities

e.g. Dubai, Abu Dhabi, Muscat and many others

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Population in Millions		
Cities	1960	2014
Delhi	2.3	25.0
Lagos	0.2	12.6
Kiushasa	0.4	11.1
Lima	1.2	9.7
Shenzhen	0.008	10.7
Dhaka	0.5	17.0
Sao Paulo	4.0	20.8
Paris	7.4	10.8
Berlin	3.3	3.5
Johannesburg	2.1	9.2
Hanoi	0.2	7.8

Ref. UN World Urbanization Prospects, the 2014 Revision.

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General Approach for Recharge

Limiting factors
- Time frame
- Costs *(investment, maintenance)*
- Location *(centralized, decentralized)*

Boundary conditions
- Climate
- Soil characteristics
- Groundwater level and quality
- Wastewater properties
- Saturation level
- Seasonal and daily fluctuations

Process understanding

Transport | Clean-up

Process parameters
- Flow + temporal evolution
- Water quality
- Aerobic, anaerobic conditions
- Saturated, unsaturated
- Temporal evolution of bio-film
- Steady/continuous flow

- **Subsurface treatment** of waste water effluent is controlled by the boundary conditions
- Identification of the **limitations of waste water infiltration** (quantity and quality)
- Identification of **treatable contaminants** by soil-aquifer treatment method

Lab scale → **Pilot scale**

Components of AGR Schemes

1. Determination of subsurface suitability for AGR
2. Determination of availability of water for recharge
3. Estimation of the demand for reclaimed water
4. Determination of the governing hydraulic parameters
5. Determination the main geochemical process parameters
6. Hydraulic and reactive modeling
7. Scenario analysis (AGR methods)

Impact assessment

Assessment of Subsurface Suitability

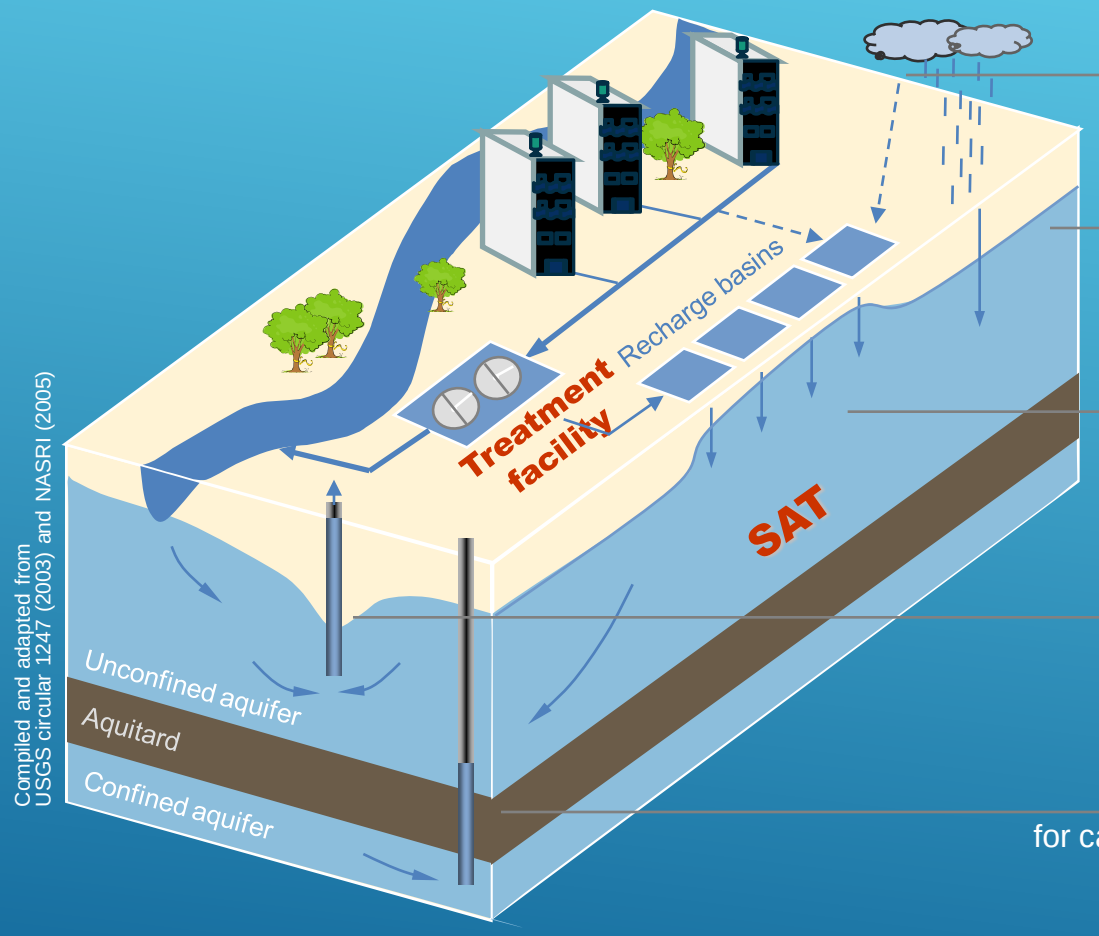
1.1 General hydrogeological conditions

- General geological formations
- Mineralogical characterisation
- Aquifer‘s confinement and isotropy
- Groundwater table levels (seasonal variations)
- Groundwater flow pattern (velocity and direction)
- Withdrawal from studied area
- Hydraulic connections with surface waters
- Vadose characteristics and variations

1.2 Other AGR related conditions

- Historical contaminations
- Climatic conditions
- Legislative aspects
- Socio-economic aspects etc.

Artificial groundwater recharge (AGR) concept



Compiled and adapted from USGS circular 1247 (2003) and NASRI (2005)

Artificial recharge
Storm water

Natural recharge
by precipitations

Artificial recharge
by artificial recharge basins

Monitoring
for calculation of the water balance as a management tool

COST / BENEFIT

Main Hydraulic Parameters

Infiltration characteristic parameters

- Porosity
- Hidraulic conductivity
- Transmisivity
- Permeability
- Storage-related coefficients
    - Storativity
    - Specific storage coefficient
    - Specific yield
    - Specific retention
    - Total storage capacity

Optimum infiltration rate

Main Hydraulic Parameters (cntd)

Clogging-related parameters

- Filtrations of suspended solids
- Microbiological growth (biofouling)
- Chemical precipitation
- Clay swelling and dispersion
- Air entrapment
- Mobilisation of aquifer sediments

Methods to restore the hydraulic properties
Clogging prediction methods

Modeling

Reactive and non-reactive modeling

- Spatial distribution of piezometric heads
- Groundwater table seasonal fluctuations
- Natural flow exchange with surface water
- Evapotranspiration models
- Hydraulic simulation of recharge cycles
- Solute transport modeling
- Hydraulic scaling for overall recharge estimation

Removal of compounds from sewage effluent by SAT

(example)

- Suspended solids: 91%
- Nitrogen (total): 30-70%
- Phosphate: 40-80%
- Heavy metals
  - Zn: 82%
  - Cu: 87%
  - Cd: 6.5%
  - Pb: 20%
- Fecal coliforms: from 10^5-10^6 to 10-500 per 100 ml
- Viruses: total removal
- Organic carbon: complete mineralisation
- TOC: from 10-20 mg/l to 5 mg/l
- AOX: 50-99%

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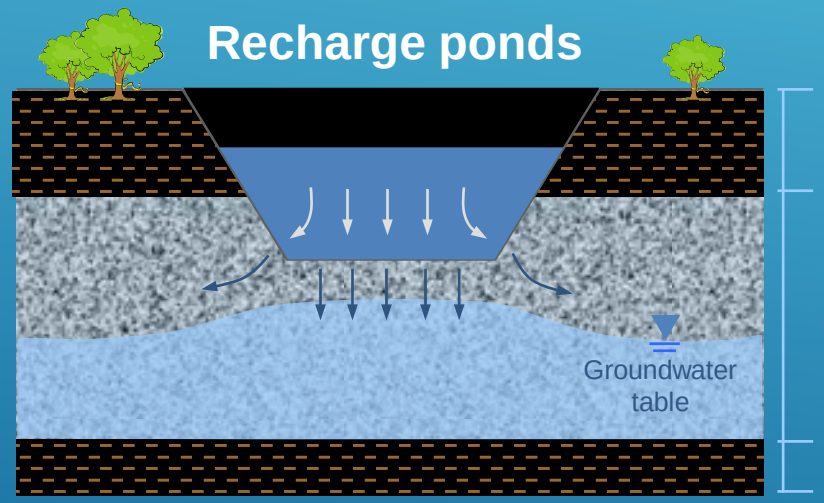
Scenario Analysis (methods of AGR)

Infiltration ponds and schafts

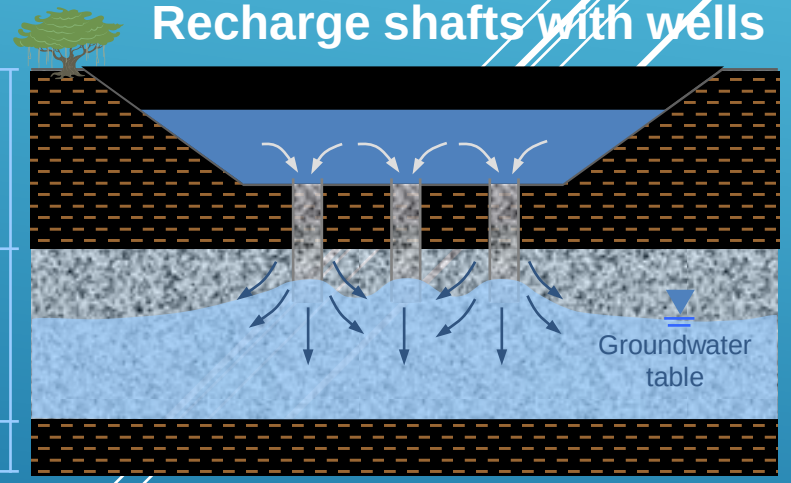
Recharge ponds



Adapted from Ministry of Water Resources, India (2007)

- vertical, as well as lateral infiltration
- can use existing water ponds or quarries
- bottom clogging can be prevented by sand layers

Recharge shafts with wells



- it can be dug manually
- large storage and recharge potential
- variable no. of wells to enhance the recharge
- very high efficiency

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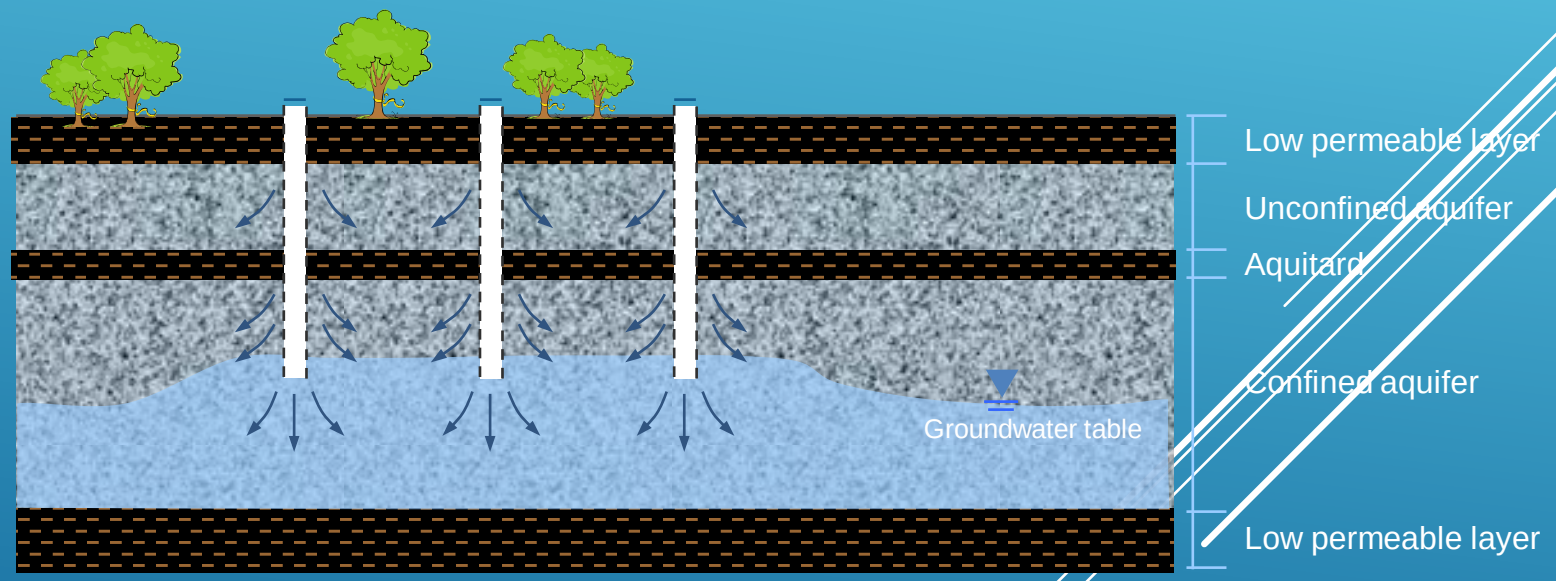
Scenario Analysis (methods of AGR)

Infiltration wells for soil aquifer treatment (SAT)



- requires much less land use
- it can be used for confined and unconfined aquifers
- instantaneous recharge
- requires higher quality water
- it can be used to recharge more than one aquifer

Examples for SAT Worldwide

Location	Infiltrated water	Polution load	Method
GERMANY Berlin	surface water, storm water, treated waste water (after oxidation)	9 mg/l DOC	Infiltration areas and ponds,
ISRAEL Tel Aviv	waste water effluents	18 mg/ DOC	Intermediate recharge by wells
FRANCE Grau du Roi	heavy and light polluted waste water	> 250 mg/l BOD5	Infiltration ponds
USA Madison	waste water after oxygen supply	150 mg/l BOD5	
USA California	treated reclaimed water	max 2 mg/l TOC	
ZAMBIA Lusaka	waste water from septic tanks	very high organic load	

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Berlin, GERMANY

75% of drinking water demand (220 mil. m³/year) covered by bank filtration and artificial groundwater recharge

1. Storage ponds
2. Slow sand filtration and infiltration basins

Natural and **A**rtificial **S**ystems for **R**echarge and **I**nfiltration

Cooperation project:

Berliner Wasserbetriebe
KOMPETENZZENTRUM Wasser Berlin
VEOLIA WATER

Advantages of AGR and SAT using Reclaimed Wastewater

- Groundwater recharge and Storage
- Environmental sound, Flood controlling
- Natural attenuation processes improve the water quality (additional treatment step)
- Natural close loop between recharge and discharge units, prevention of land subsidence
- Cost effective (not cheap) by profiting of the natural attenuation processes
- Needs detailed knowledge of the subsurface
- Monitoring and modeling is required

CONCLUSION

- Environmental sound water use must have highest priority essentially in arid areas.
- Integrated water resources management is the predominant requirement for sustainability in the water sector.
- Research in the elimination of emerging pollutants during sewage treatment is required.
- Secondary sewage treatment by SAT/AGR can be an opportunity to recharge aquifers.

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Thank you for your attention