

MEDAWARE

Wastewater Reuse Systems and Problems

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Outline

■ Introduction

- The Hydrologic Cycle and reclaimed water
- Need for Wastewater Reuse

■ Wastewater Reclamation Technologies

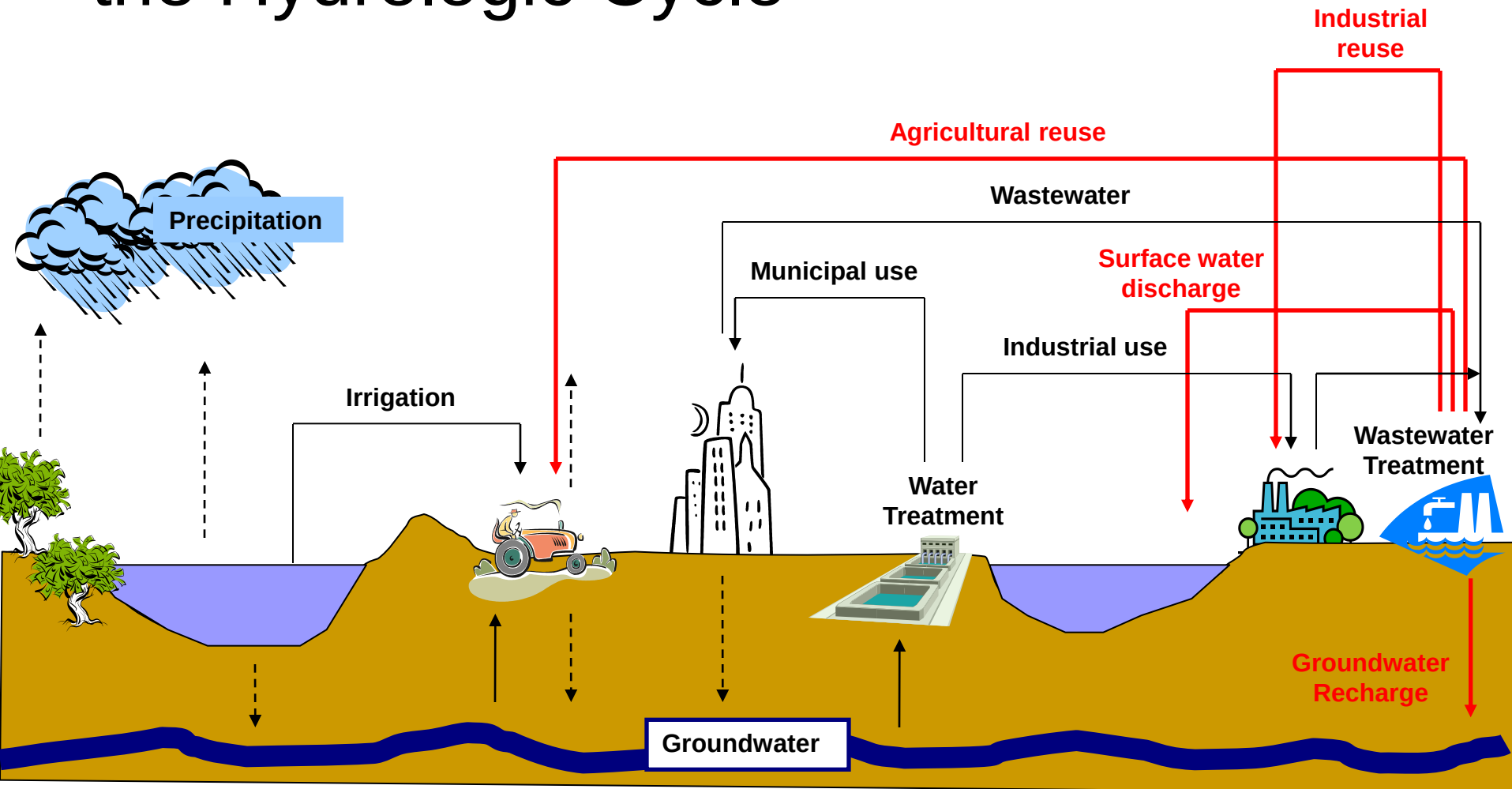
■ Wastewater Reuse Applications

- Historical Examples
- Agricultural and Landscape Irrigation
- Industrial Reuse
- Groundwater Recharge
- Planned Indirect & Potable Water Reuse

■ Public Health and Environmental Considerations

- Constituents in Reclaimed Water
- Public Health Issues
- Environmental Health Issues
- What level of treatment is necessary?
 - Risk Assessment

Wastewater Reclamation & Reuse and the Hydrologic Cycle



Need for Wastewater Reuse:

Mediterranean & Near East Countries examples

Country	Area (Km ²)	Total renewable fresh water (Km ³ /year)	1990		2050 ^a	
			Popln. (1000's)	Water availability (m ³ /capita year)	Popln. (1000's)	Water availability (m ³ /capita year)
Cyprus	9,250	0.90	702	1282	1006	895
Egypt	1,000,500	58.90	56312	1046	117398	502
Greece	132,000	69.00	10238	5763	8591	6868
Israel	20,700	2.15	4660	461	8927	241
Lebanon	10,360	4.98	2555	1949	5189	960
Spain	504,800	111.00	39272	2826	31765	3494
Syria	185,000	25.79	12348	2089	47212	546
Turkey	780,000	203.00	56098	3619	106284	1910

^a UN medium projection for population

Need for Wastewater Reuse:

Mediterranean Basin & Near East Countries

■ Agricultural Production

- Irrigation: the largest water user (~70-80% of total)
- 50% of food requirements are imported
- 30% of cultivated area is irrigated
 - But it accounts for 75% of total agricultural production

■ Capacity to Sustain Domestic Food Production

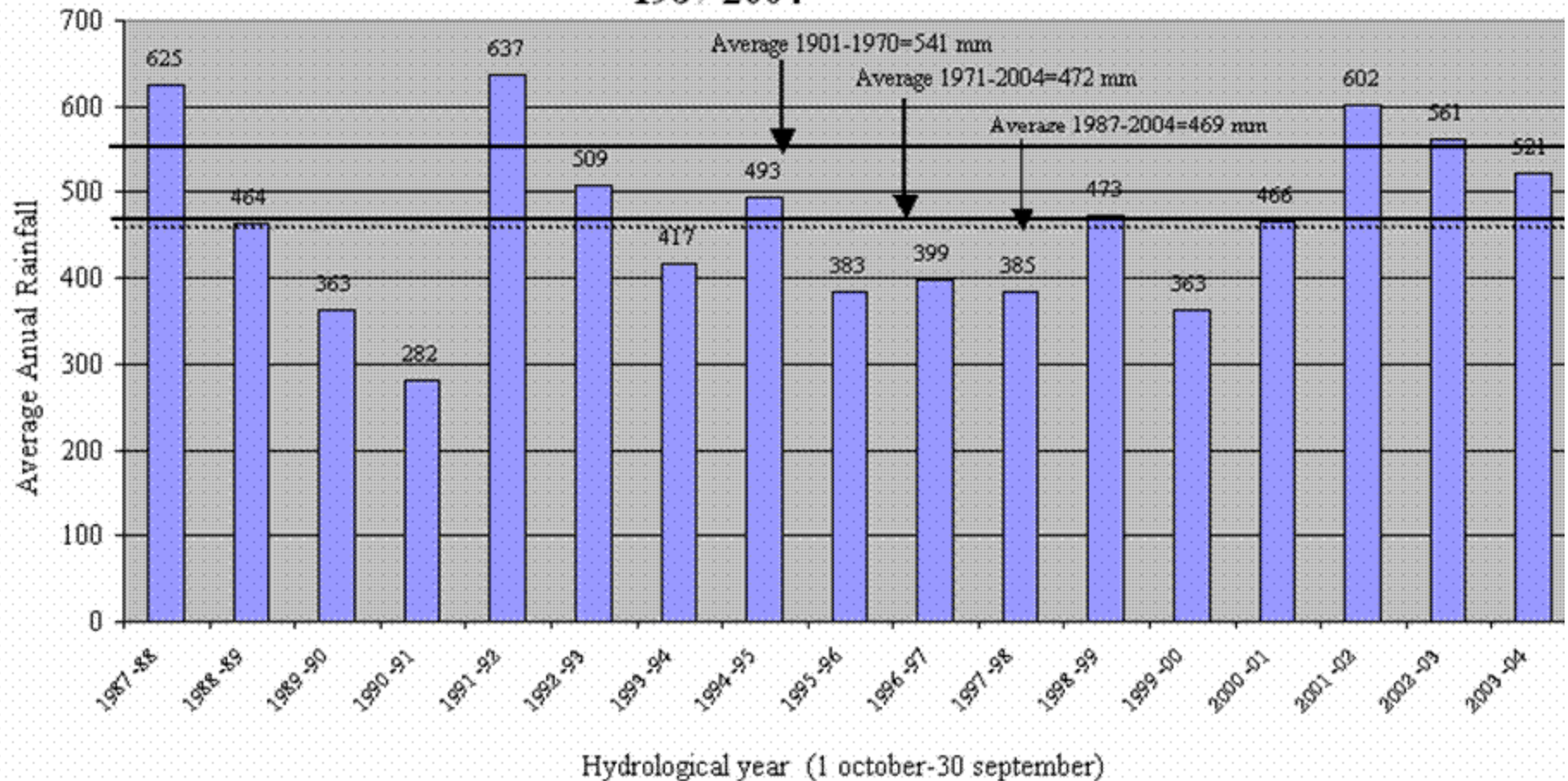
- 750 m³ / inhabitant year necessary
- 1990: 5 countries (Algeria, Israel, Jordan, Malta, Tunisia)
- 2050: 4 more countries (Egypt, Libya, Morocco, Syria)

■ Water Availability

- Temporal and Spatial Asymmetries
 - “..the main problem may **not** be **scarcity** of water in terms of average per capita, **but** the high cost of making **water available** at the **right place**, at the **right time** with the **required quality**...” — (Angelakis et al., 1999)
- “Misguided” agricultural practices

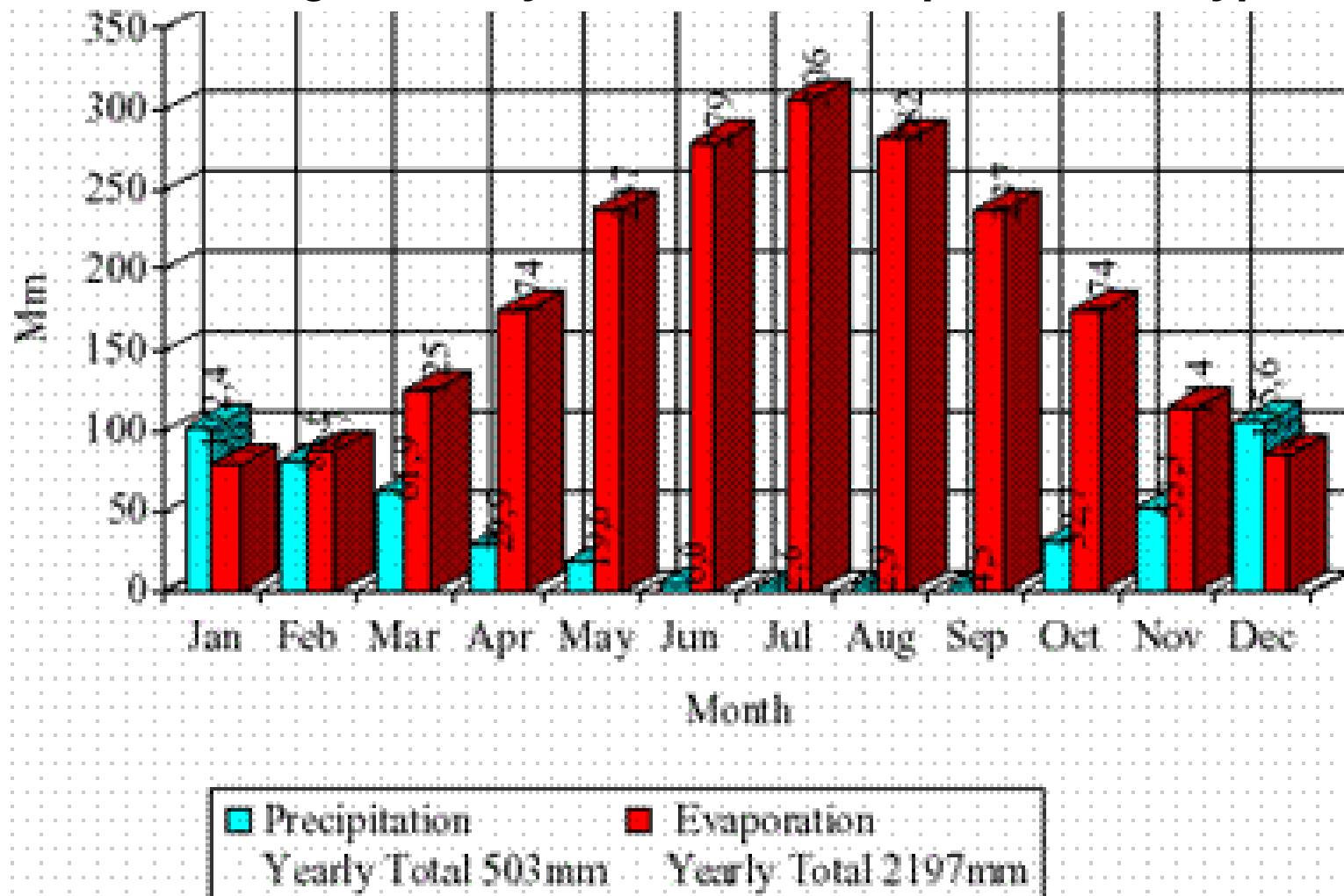
Need for Wastewater Reuse: The Example of Cyprus

**Average annual rainfall of Cyprus
(Area Under Government Control)
1987-2004**

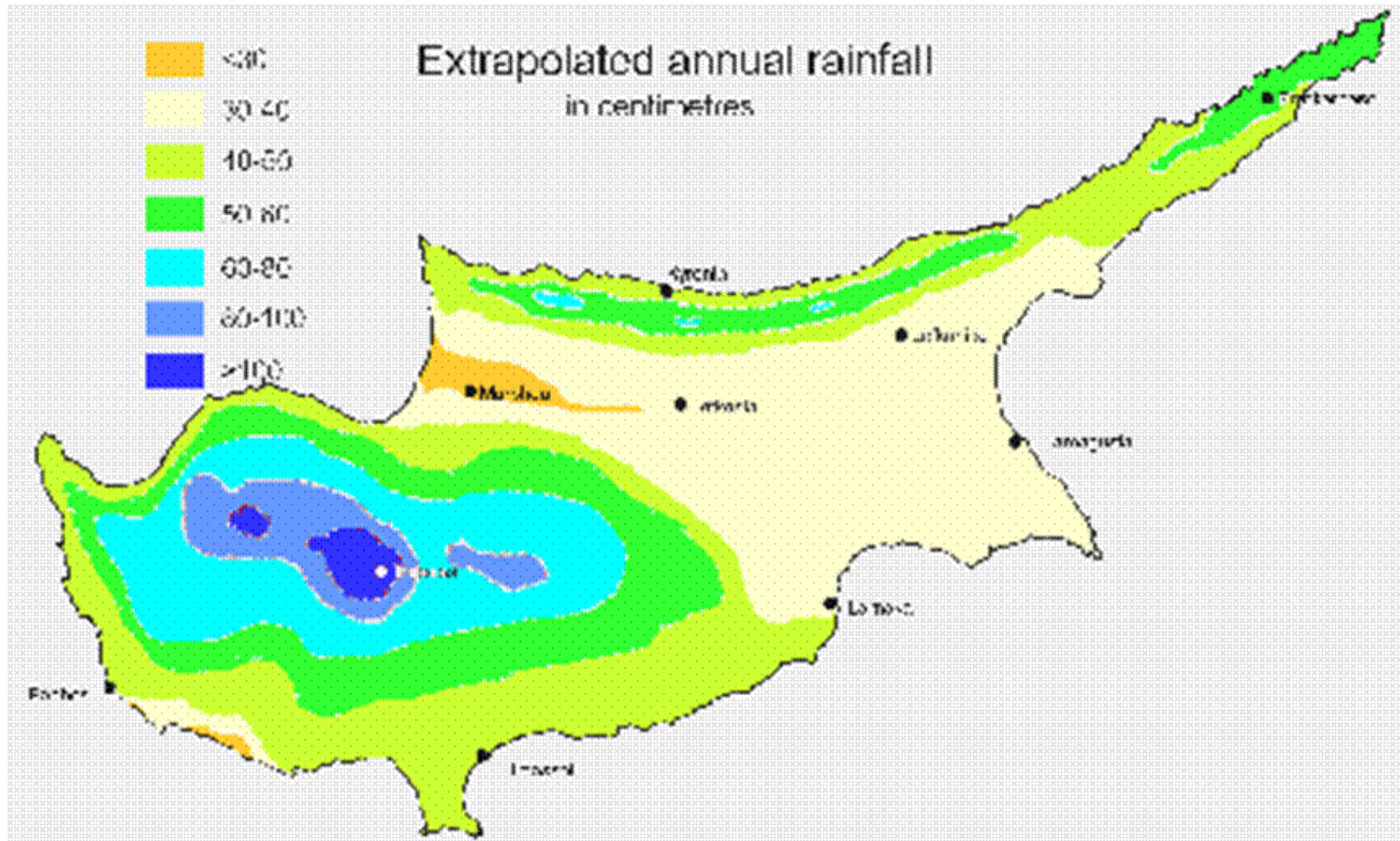


Need for Wastewater Reuse: The Example of Cyprus

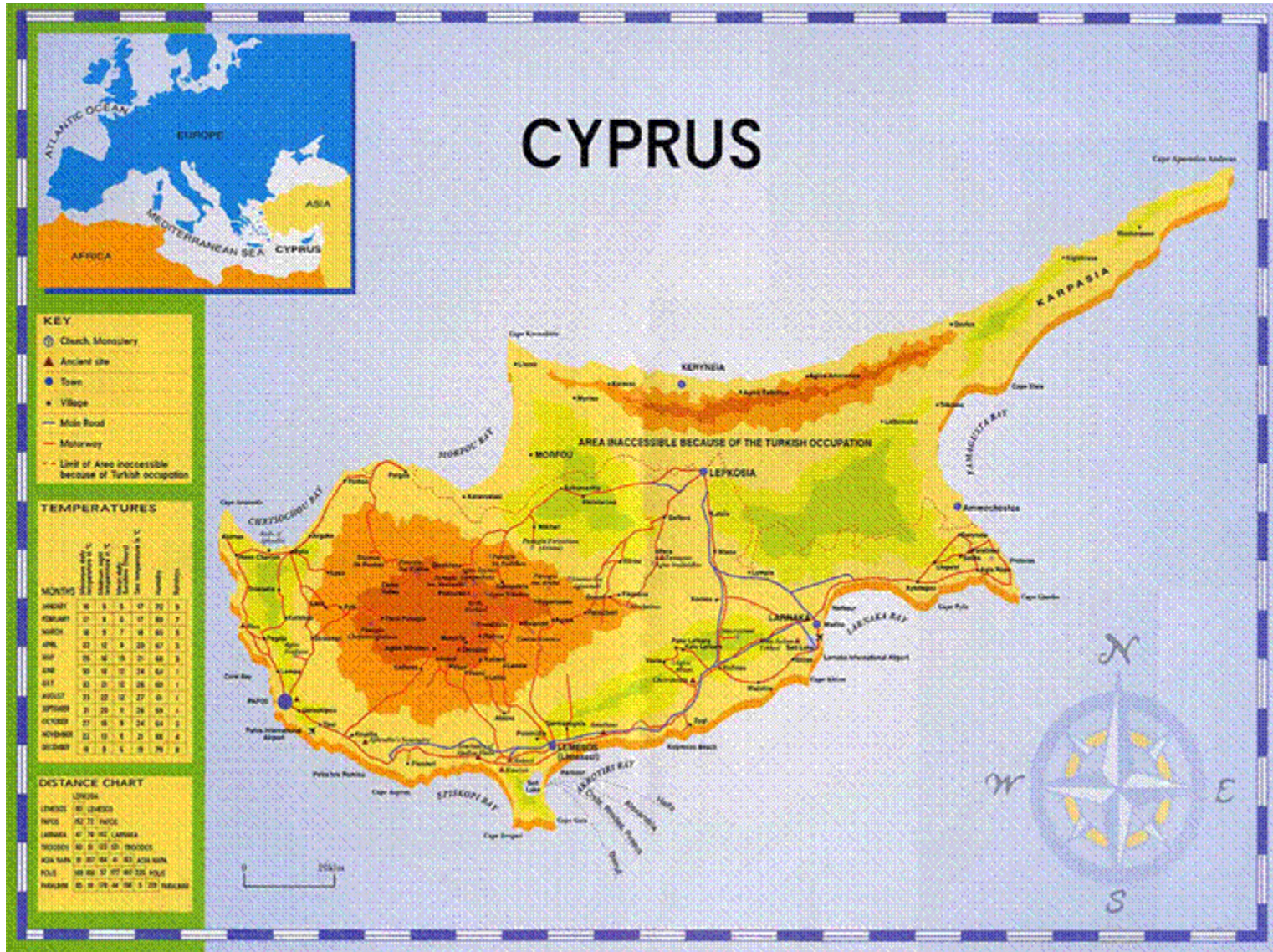
Average Monthly Rainfall and Evaporation in Cyprus



Need for Wastewater Reuse: The Example of Cyprus



Need for Wastewater Reuse: The Example of Cyprus



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Wastewater Reclamation Technologies

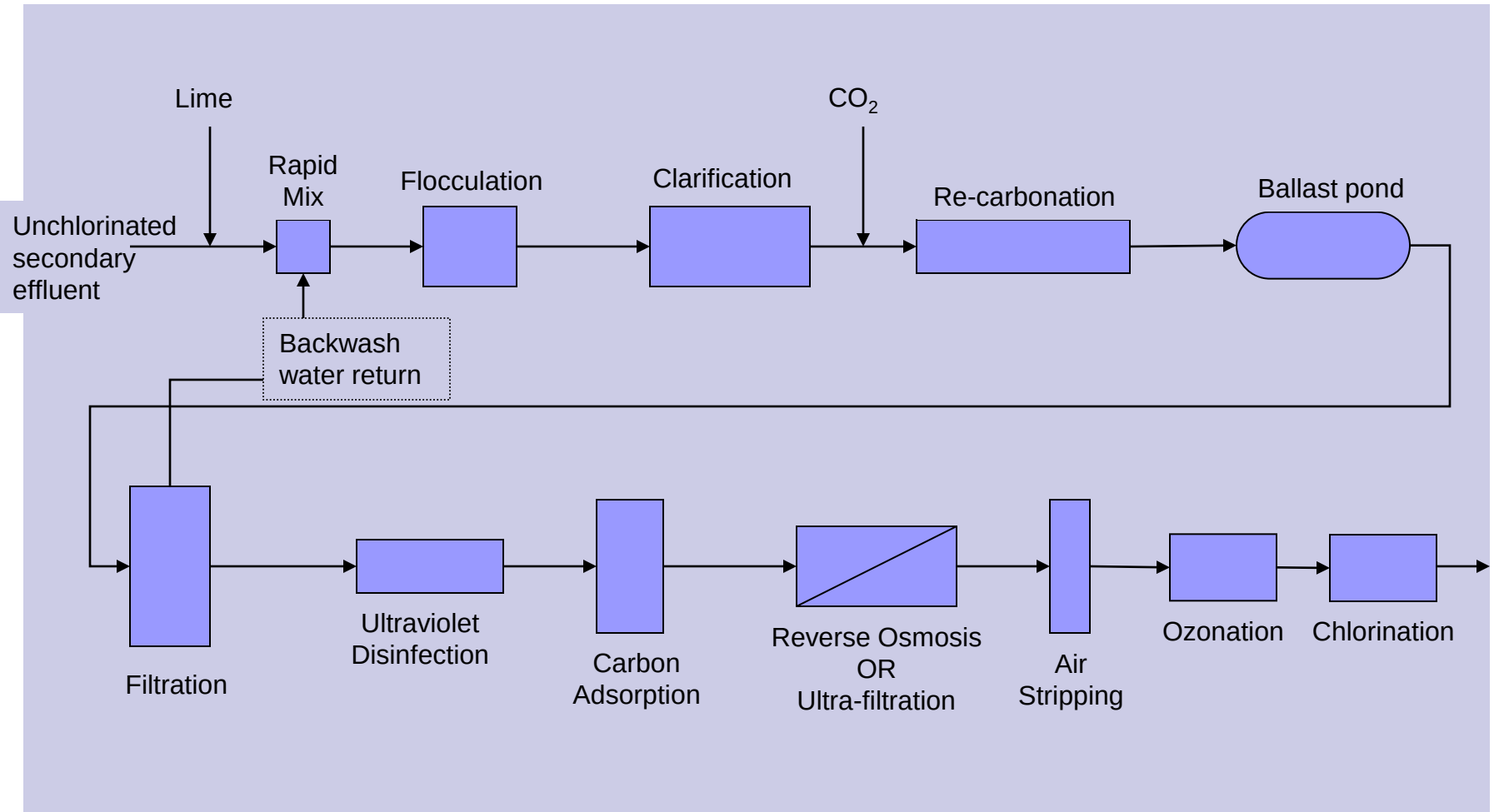
Conventional Methods

- Activated sludge (AS)
 - Aerobic
 - Anaerobic
- Filtration
- Biological nutrient removal (BNR)
- Combinations of the above unit processes

Wastewater Reclamation Technologies

Advanced Treatment Methods

(**Example:** Denver, Colorado, USA; 1 MGD plant, direct injection)



Wastewater Reclamation Technologies

Advanced Treatment Example

- El-Paso, Texas, USA
 - Use: Direct Injection of reclaimed municipal wastewater
 - Capacity: 38,000 m³/day
 - Unit processes:
 - Primary treatment →
 - Activated Sludge process with BNR →
 - Lime clarification →
 - Re-carbonation →
 - granular medium filtration →
 - activated-carbon adsorption →
 - demineralization by reverse osmosis →
 - chlorination



Wastewater Reclamation Technologies

Sustainability Issues

- Sustainability of treatment method
 - WW reclamation and reuse; a sustainable practice
 - Are the treatment technologies sustainable?
 - Natural Treatment Systems
 - Constructed Wetlands
 - Duckweed Ponds
- How much treatment is enough?
 - What is the source of wastewater?
 - Greywater vs. Blackwater
 - Who is the end user?
 - Agriculture
 - Industry
 - Communities
 - What are the risks associated with effluent use?



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Historical Examples

- 3000 BC – Crete (Minoan culture)
 - Collection of rainwater and sand “filtration” for reuse
- 1890 – Mexico
 - Agricultural irrigation
- 1912 – Europe & US
 - Landscape irrigation
- 1926 – US & Europe
 - Industrial uses: cooling processes & boilers
- 1960 – US; Europe; Africa; Australia
 - Landscape Irrigation (including golf-courses)
 - Groundwater Recharge
 - Advanced WW reclamation for potable water supply augmentation
- 1980 – US; Europe; Japan
 - Water recycling for toilet flushing in urban areas
 - Agricultural irrigation of food crops eaten uncooked



Uses of Reclaimed Water

- **Agricultural Irrigation**
- **Landscape Irrigation**

- | |
|--|
| |
| <ul style="list-style-type: none">■ Groundwater Recharge■ Recreational / Environmental Uses |
| |

Agricultural Irrigation

- Why reuse wastewater in agricultural irrigation?
 - Freshwater resources can be reserved for other uses
 - Chemical fertilizer usage can be minimized
 - Discharge of reclaimed wastewater to water bodies can be prevented
- Agro-irrigation = Largest Current User of Reclaimed Water
- Main uses (in order of “preference”)
 - Non-food crops
 - Commercial nurseries; Timber
 - Animal Fodder
 - Food Crops
 - Fruit-tree Orchards
 - Cereals
 - Vegetables
- ALSO: Consider the Type of irrigation system

Agricultural Irrigation

Yorkshire - England



Potato irrigation from
maturation pond



Agricultural Irrigation

Saudi Arabian Desert



Agricultural Irrigation

Negev Desert - Israel

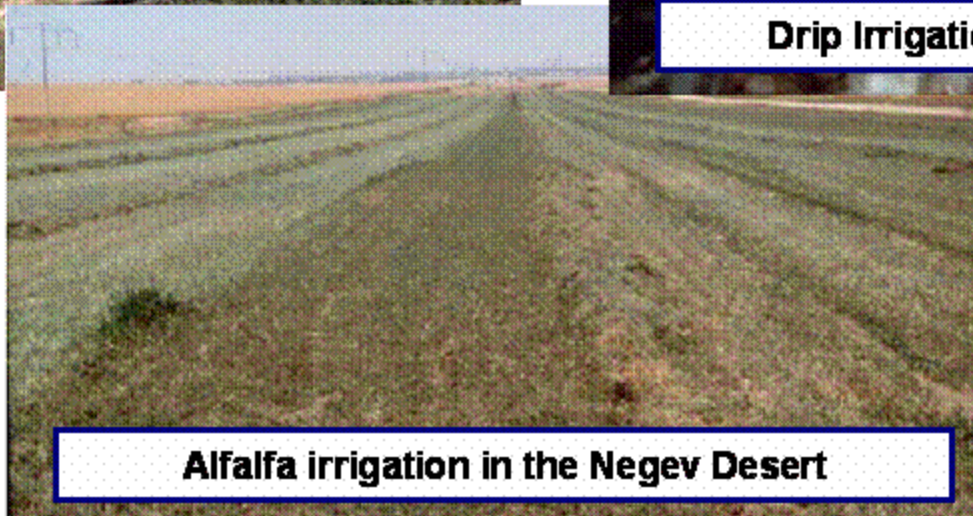
Winter wheat irrigation in the Negev Desert



Drip Irrigation of cotton plants



Alfalfa irrigation in the Negev Desert



Agricultural Irrigation

Alentejo - Portugal

**Lettuce irrigation with treated wastewater
(is this practice advisable?)**



Agricultural Irrigation & Reclaimed Wastewater: Mezquital, Mexico

Crop	Yield in tons/ha		Increase (%)
	Wastewater	Fresh water	
Maize corn	5.0	2.0	150
Barley	4.0	2.0	100
Tomato	35.0	18.0	94
Alfalfa	120.0	70.0	71
Wheat	3.0	1.8	67

Agricultural Irrigation

Larnaca - Cyprus

Jojoba shrubs irrigated with treated wastewater produced higher oil yields than shrubs irrigated with fresh water



Agricultural Irrigation

Larnaca - Cyprus

Government demonstration of wastewater reuse





Landscape Irrigation & Recreational / Environmental Uses

■ Landscape Irrigation

- ☐ Parks
- ☐ School yards
- ☐ Highway medians
- ☐ Golf courses
 - In Florida, 419 golf courses had been reported to use 110 MGD of reclaimed water in 2001.
- ☐ Cemeteries
- ☐ Residential

■ Recreational / Environmental Uses

- ☐ Lakes & ponds
- ☐ Marsh enhancement
- ☐ Stream-flow augmentation
- ☐ Fisheries

Landscape Irrigation



Sprinkler system irrigation of a golf course in Nevada, USA



Drip system irrigation of a football field (USA)

Fisheries

Calcutta - India



All the city's wastewater (550,000m³/day) is used to fertilize 3000 ha of fishponds, producing some 13,000 tons of fish per year.



Industrial Reuse & Urban Uses

■ Industrial Recycling and Reuse

- ☐ Cooling water
- ☐ Boiler feed
- ☐ Process water
- ☐ Heavy construction

■ Non-Potable Urban Uses

- ☐ Fire protection
- ☐ Air conditioning
- ☐ Toilet flushing

■ Potable Reuse

- ☐ Blending in water supply reservoirs (Namibia example)
- ☐ Pipe-to-pipe water supply



Groundwater Recharge

- Groundwater replenishment
 - The following must be considered:
 - the quality of the recharge water;
 - the recharge method used;
 - the physical characteristics of the vadose zone and the aquifer layers;
 - the water residence time;
 - the amount of blending with other sources;
- Saltwater intrusion control
- Subsidence control
- “Unintentional” groundwater recharge - Lebanon



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Constituents in Reclaimed Water

■ **Conventional** *(measured in mg/L; used in designing conventional WWTPs)*

- ☐ TSS
- ☐ BOD; COD
- ☐ TOC
- ☐ Nitrogen (Ammonia; Nitrate; Nitrite)
- ☐ Phosphorus
- ☐ Microorganisms: Bacteria; Viruses ; Protozoan cysts & oocysts

■ **Non-conventional** *(to be removed or reduced by advanced treatment processes)*

- ☐ Refractory organics
- ☐ VOC
- ☐ Surfactants
- ☐ Metals
- ☐ TDS

■ **Emerging** *(measured in $\mu\text{g/L}$; long-term health concerns possible; not easy to remove)*

- ☐ Pharmaceuticals
- ☐ Antibiotics (veterinary & human)
- ☐ Home-care, industrial, and household products
- ☐ Hormones (steroids) and Endocrine Disrupters

Effect and Pathways of various Pollutants on Public Health and the Environment

■ Pathogenic Microorganisms & Trace Organics

- Public Health - gastrointestinal disorders, bacillary dysentery, salmonellosis, shigellosis, infectious hepatitis, cholera, typhoid.
 - Infiltration into potable water supplies
 - Irrigation of crops that are eaten uncooked
 - Aerosols – from specific irrigation processes
- Environmental Impact - Effect on terrestrial life

■ Heavy Elements

- Public Health – nervous system disorders, mutagenesis, teratogenesis, carcinogenesis
 - Bioaccumulation (food chain on crops and animals)
 - Surface water pollution
- Environmental Impact – acute and chronic toxicity for plant and animal life, chronic degradation effect on soil

■ Nutrients (N & P)

- Public Health – blue-baby syndrome (from NO_3^-)
 - infiltration into potable water supplies
- Environmental Health – Eutrophication, crop yield effects (+ive & -ive)
 - Surface water pollution
 - Irrigation practices

Effect and Pathways of various Pollutants on Public Health and the Environment

■ Dissolved Solids (salinity)

□ Environmental Health

- Induce problems for the crops' yield selection and quantity
- Accumulation in soil
 - Effect on soil permeability
- Clogging drip-irrigation systems

■ Emerging Pollutants

□ Public Health

- Acute and chronic health effects – effect on growth, reproduction problems
- Inadequate, or no, information – forces questions:
 - Conserve water?
 - Develop new, environmentally costly, water resources?
 - Develop new water treatment processes?

Public Health Issues:

Agricultural Irrigation: Mexico

- **All of Mexico City's, which is the largest city in the world, wastewater is used for irrigation.**
- **The boy on the right is standing barefoot in a field of wastewater-irrigated crops. He's at risk of hookworm infection (among other pathogenic organism infection).**
 - Lack of monitoring of irrigation methods and safety precautions is a big problem.



Public Health & Environmental Issues:

Fisheries: Kisumu, Kenya



Public Health & Environmental Issues:

Agricultural Irrigation: North Carolina, USA



Public Health & Environmental Issues:

Agricultural Irrigation: North Carolina, USA

- Eutrophication
 - Increased nutrients in surface waters
 - *Pfiesteria piscicida* outbreak
- Groundwater contamination
 - Nitrate contamination on private drinking wells
- Biological Aerosols
 - Gastrointestinal problems in nearby communities
- Antibiotics
 - lower effectiveness of antibiotics if irrigation of fodder is involved
- Odor
 - Public health of neighboring communities
 - Aesthetic concern - Reduced land values
- Marketability of crops
 - Public acceptance

Environmental Health Issues:

Agricultural Irrigation

- The most relevant reclaimed water qualities for irrigation are
 - Salinity
 - Increased osmotic pressure on plants
 - Specific Ion Toxicity
 - Worse in hot and arid regions (due to high evapotranspiration)
 - Nutrients
 - Reclaimed wastewater must be applied according to agronomic scales (i.e. in the EU: Directive 91/676/EEC : “230 kg nitrogen / ha year on agricultural land cropped by grass, grass catch crops or beets and other crops being under-sown by grass with low nitrate leaching potential”)

Public Health & Environmental Issues:

LEBANON: Some reported problems

- Application of wastewater on agricultural land:
 - Soil toxicity from increased salinity
- Infiltration of pathogens in potable water springs:

Illness	# of reported cases (1995)	# of reported cases (1996)	# of reported cases (1997)
Dysentery	624	1097	626
Hepatitis	401	579	686
Typhoid	1279	871	853

Reclaimed wastewater can be safe for agricultural irrigation

- Reduce the pathogen levels
- Avoid direct contact of crops with reclaimed wastewater
- Restrict the type of crops irrigated
- Different treatment for safe irrigation of different crops:
 - For tree nurseries, pastures, industrial crops
 - Secondary treatment & detention in surface reservoirs
 - For fruits to be canned, vegetables for cooking and fruits with non-edible peels
 - Tertiary treatment (i.e. AS & Sand Filtration)
 - For edible crops (uncooked)
 - Tertiary treatment followed by soil aquifer treatment (or advanced)

Public Health & Environmental Issues: Landscape Irrigation Examples

■ Golf course irrigation

- Giardiasis cases in Arizona and Florida
- Leaching Losses
- Effect on turf grass
 - Nutrient effect & heat stress
 - Iron chlorosis
 - Salt effect
- Aesthetic problems
 - Eutrophication of ponds in the course

■ Public Park Irrigation

- Gastrointestinal illness in Colorado Springs, Colorado

■ Park and Residential garden irrigation

- St. Petersburg, Florida: Ornamental plants sensitivity

Public Health & Environmental Issues: Recreational / Environmental Use examples

- Iowa (Mississippi River):
 - Waterborne shigellosis outbreak
- Florida:
 - Hepatitis
 - viral gastroenteritis
 - Enterococcus levels should be monitored
- South Lake Tahoe, California
 - Gastrointestinal problems
- Israel
 - Ear & Urinary tract infections
 - Dermatitis
- South Africa
 - Various skin disease symptoms



Public Health & Environmental Issues: Industrial Reuse & Non-potable Urban Uses

■ Public Health Concerns

- Aerosol transmission of organics
- Pathogens in cooling
- Pathogens in boiler feed water

■ Concerns with industrial processes

- Scaling
- Corrosion
- Biological growth & fouling
 - Also associated with pathogenic microorganisms

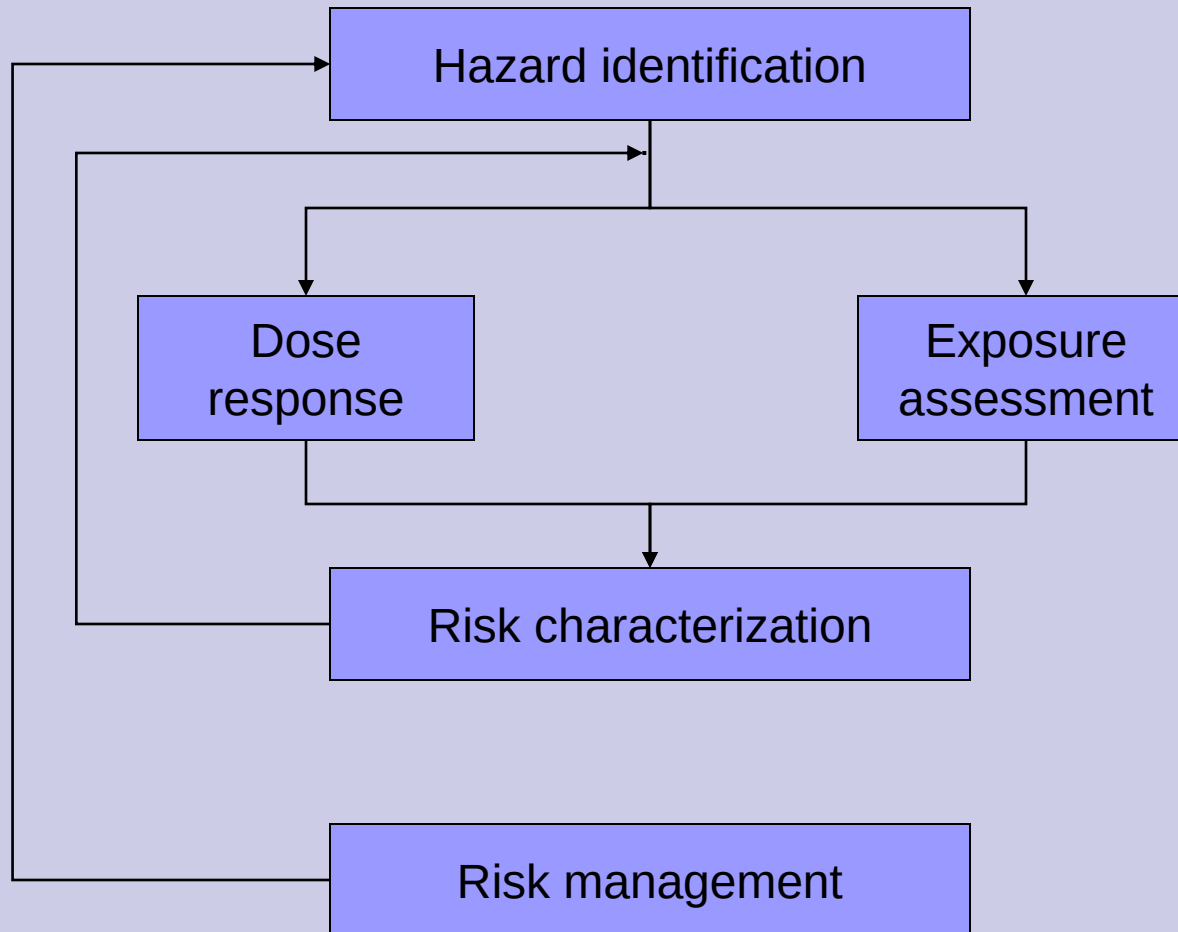


Public Health Issues: Groundwater Recharge

- Organic Chemicals
 - Toxicological effects
- TDS
- Metals
- Pathogens
- Nitrates
 - Methemoglobinemia

Health Effects Risk Analysis; a must!

(i.e. how much treatment is enough for what use?)





Wastewater reclamation and reuse is imperative for countries of the Middle East. If wastewater reuse is exercised properly (treatment, end user, safety measures, education), and if public misapprehension is expelled, the benefits that can be reaped are great and will far outweigh any associated costs.

However, if this important water resource is improperly managed, then the risks to both the public health and to the environment can be enormous.