Wastewater Reuse Applications

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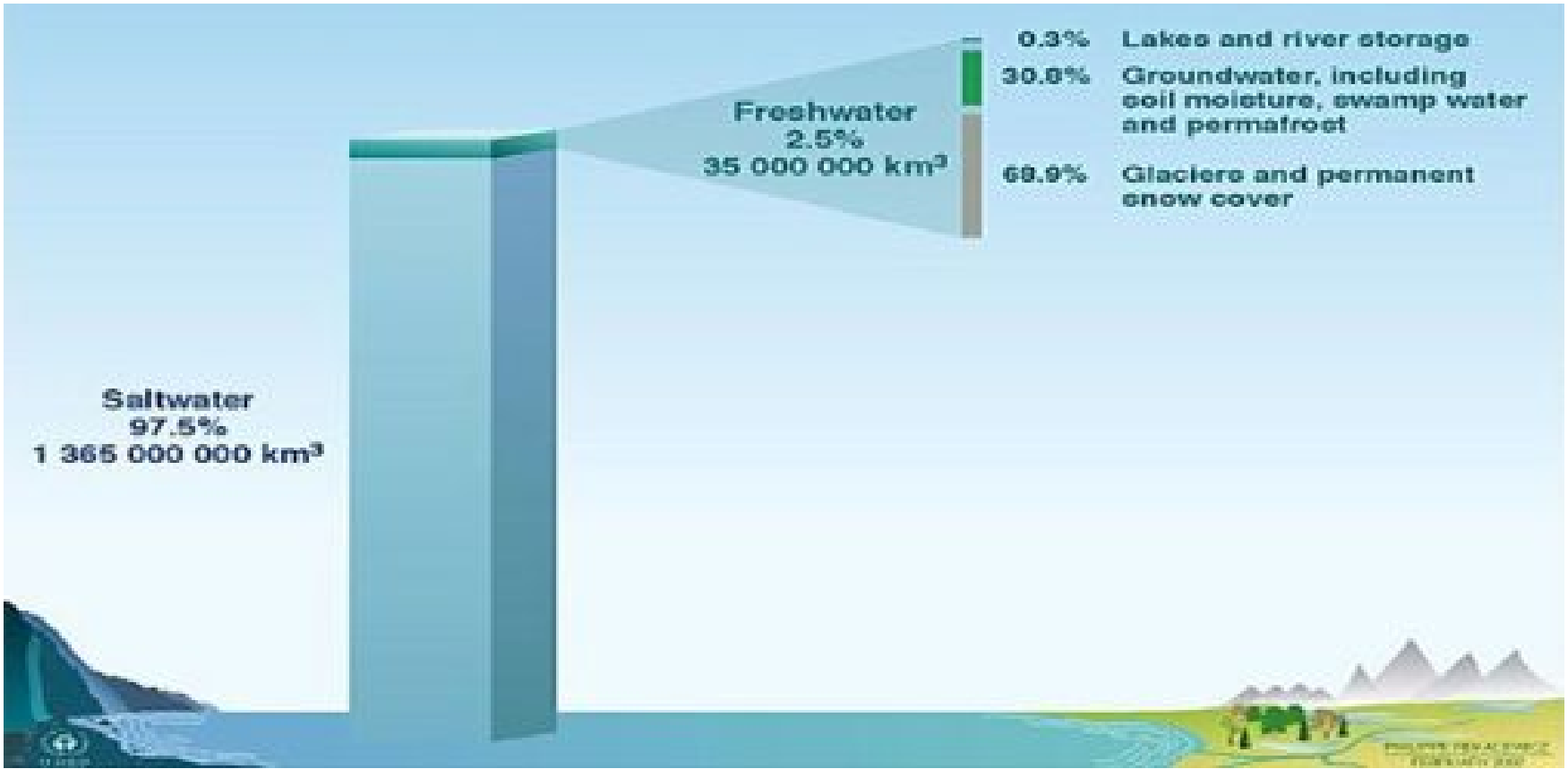
Water is Life

- Water resources are limited, definite and scarce



Water

- Water is a finite, precious and scarce resource
- Water is a Universal Solvent and supports and sustains all life forms
- Water is Life
- Multiple and Beneficial uses of water
  - Human consumption
  - Livestock
  - Agriculture
  - Industrial use
  - Aquacultural
  - Pisciculture
  - Recreational
  - Navigational
- Demand for water is ever increasing

What is wastewater

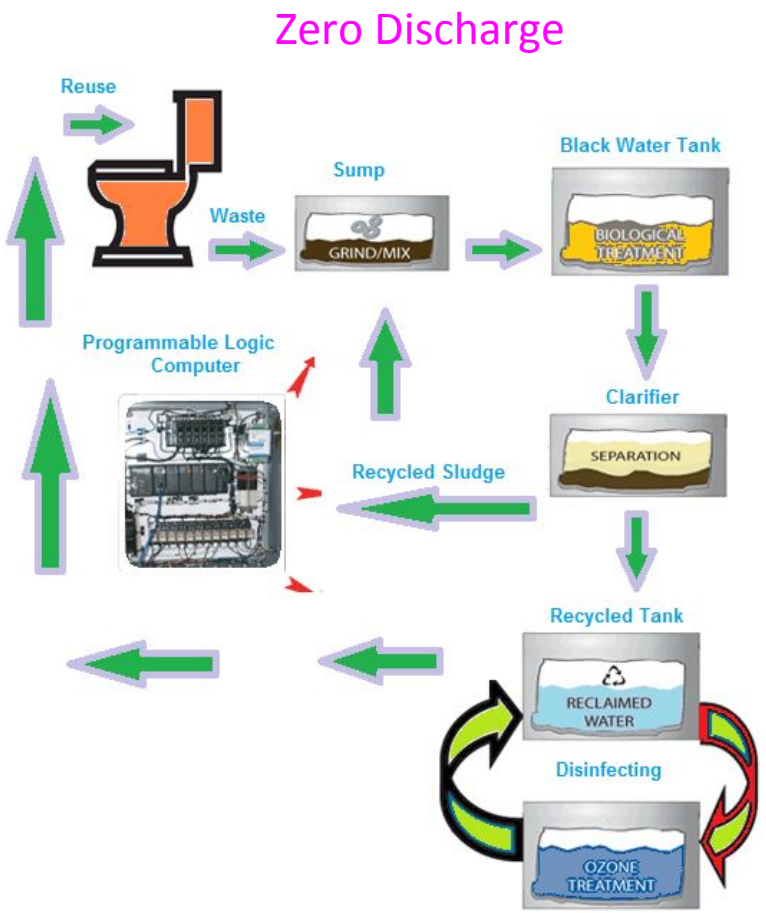
- Water after use becomes wastewater
- Uses are multiple. Performs intended and beneficial actions.
- Performance of actions results in acquiring or addition of materials which renders water as wastewater.
- Wastewater = water + acquired materials
- Typically materials would be in the range of 0.1% to 1.0%
- Waste water? or wastewater?

Why Reuse Wastewater?

- Water is a finite, precious and scarce resource
- Demand for water is ever increasing
- Wastewater, specifically domestic wastewater or sewage is 99% water
- Therefore, it is prudent to make beneficial use of water in wastewater – Wastewater Reuse

Paradigm Shift in Wastewater Reuse

- In the past, wastewater was a "problem"
- Now, it is considered as a "resource"
- Example:
  - "Newater" scheme in Singapore
  - Treated domestic wastewater for Industrial use
  - "Zero Discharge" norm for major industries
  - "Recycled water" for domestic use
  - Treated wastewater for groundwater recharge & irrigation



How to reuse?

- Materials or impurities in wastewater are toxic, pathogenic, inhibitory and affects human health, ecosystems and environment and hence are to be removed.
- Removal of materials, physical, chemical and biological impurities, from wastewater is wastewater treatment
- The extent or degree of treatment depends on reuse applications
- Each reuse application has its own quality and safety criteria
- Public health, protection and preservation of the ecosystems and environment are the guiding factors in wastewater reuse applications

Historical Examples of Reuse

- 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

Reuse Applications-EPA Guidelines

- Disinfected, Tertiary Treated Effluent can be used in all of these Applications
  - Urban Reuse
  - Restricted-Access-Area Irrigation
  - Agriculture Reuse
  - Recreational Impoundments
  - Landscape Impoundments
  - Construction Uses
  - Industrial Reuse
  - Groundwater Recharge
  - Indirect Potable Reuse

Types of Reuse

- Urban reuse- irrigation of public parks, school yards, highway medians, residential landscapes, fire protection, toilet flushing in commercial and industrial buildings
- Agricultural reuse -irrigation of non food crops, such as fodder and fiber, commercial nurseries and pasture lands. High-quality reclaimed water is used to irrigate food crops
- Recreational impoundments-such as ponds and lakes
- Environmental reuse-creating artificial wetlands, enhancing natural wetlands, and sustaining stream flows
- Industrial reuse-process or makeup water and cooling tower water

Application of Treated Wastewater

- Agricultural Irrigation
  - Crop irrigation
  - Commercial nurseries
- Landscape Irrigation
  - Parks
  - School yards
  - Highway medians
  - Golf courses
  - Cemeteries
  - Residential
- Industrial Recycling and Reuse
  - Cooling water
  - Boiler feed
  - Process water
  - Heavy construction
- Groundwater Recharge
  - Groundwater replenishment
  - Saltwater intrusion control
  - Subsidence control
- Recreational / Environmental Uses
  - Lakes & ponds
  - Marsh enhancement
  - Stream-flow augmentation
  - Fisheries
- Non-Potable Urban Uses
  - Fire protection
  - Air conditioning
  - Toilet flushing
- Potable Reuse
  - Blending in water supply reservoirs
  - Pipe-to-pipe water supply

Parameters to be monitored in treated wastewater

- Conventional parameters (mg/L; removed in conventional WWTPs)
  - TSS
  - BOD; COD
  - TOC
  - Nitrogen (Ammonia; Nitrate; Nitrite)
  - Phosphorus
  - Microorganisms: Bacteria; Viruses ; Protozoan cysts, etc.
- Non-conventional parameters (to be removed or reduced by advanced treatment processes)
  - Refractory organics
  - VOC
  - Surfactants
  - Metals
  - TDS

Wastewater reuse applications

Wastewater reuse categories	Issues/ constraints
Agricultural irrigation crop irrigation Commercial nurseries	Surface and groundwater contamination Marketability of crops and public acceptance
Landscape irrigation Parks, School yards, Freeway medians, Golf courses, Cemeteries Green belts, Residential	Effect of water quality, particularly salts, on soils and crops Public health concerns related to pathogens Use area control including buffer zone may result in high user costs
Industrial recycling and reuse Cooling water Boiler feed Processes water Heavy construction	Constituents in reclaimed water related to scaling, corrosion, biological growth, and fouling Public health concerns, particularly aerosol transmission of pathogens in cooling water Cross connection of potable and reclaimed water
Groundwater recharge Groundwater replenishment Saltwater intrusion control Subsidence control	Possible Contamination of groundwater aquifer used as a source of potable water Organic chemicals in reclaimed water and their toxicological effects Total dissolved solids, nitrates, and pathogens in reclaimed water

Wastewater reuse applications

Wastewater reuse categories	Issues/ constraints
Recreational/environmental uses Lakes and ponds Marsh enhancement Stream-flow augmentation Fisheries, Snowmaking	Health concerns related to presence of bacteria and viruses Eutrophication due to nitrogen and phosphorus in receiving water Toxicity to aquatic life
Nonpotable urban uses Fire protection Air conditioning Toilet flushing	Public health concerns about pathogens transmitted by aerosols Effect of water quality on scaling, corrosion, biological growth, and fouling Cross connection of potable and reclaimed water lines
Potable reuse Blending in water supply reservoirs Pipe-to-pipe water supply	Constituents in reclaimed water, especially trace organic chemicals and their toxicological effects Aesthetics and public acceptance Health concerns about pathogens transmission, particularly enteric viruses

Agricultural Reuse of Wastewater

- Nearly 80 % of water supply ends up as wastewater.
- Wastewater requires treatment before disposal.
- Sewage farming is one of the types of Land treatment systems/Soil aquifer treatment where water and nutrients are utilized by the crops.
- One tenth of world's crop grown in sewage.
- Wastewater is an increasingly important and reliable source of water in Urban /Peri Urban areas.

Agricultural Reuse of Wastewater

- Crops could make use of nutrients, which saves money to the farmer and reduces the need for expensive (tertiary) treatment.
- Requires appropriate irrigation techniques and nutrient management to be environmentally sound
- Should ideally be designed in a joint effort between agriculturists & environmental engineers

Facts of Wastewater Irrigation

- In many regions of the world, illegal (informal), unguided or unplanned direct and indirect use of raw, partially treated or diluted wastewater is practiced.
- As the urban wastewater volumes generation will double, if not triple, in the coming 20-25 years. So will food requirements.

Positive Aspects of Wastewater Irrigation

- Conserves water
- Low-cost method for sanitary disposal of municipal wastewater
- Reduces pollution of rivers, canals and other surface water resources
- Conserves nutrients, reducing the need for artificial fertilizer
- Often increases the crop yield
- Provides a reliable water supply to the farmer

Negative Aspects of Wastewater Irrigation

- Health risks for irrigators and communities with prolonged contact with untreated wastewater and consumers of vegetables (raw) irrigated with wastewater
- Contamination of groundwater (nitrates)
- Creation of habitats for disease vectors
- Eutrophication of canals due to wastewater runoff

History of Wastewater Irrigation

- Wastewater irrigation is practiced for a very long time since 1860's, this being one of the land treatment systems.
- In India sewage farming was initiated in Bombay, as early as 1877 and in Delhi, from 1913.
- In modern times , the most intensive use of wastewater for irrigation has been made in Israel.
- In India, modern use of sewage effluents for irrigation is reported to be about six decades old.
- China's sewage irrigation systems have developed rapidly since 1958.

Early Land Treatment Systems

Location	Date started	Type of system	Area, ha	Flow, m^3/s
Berlin, Germany	1874	Sewage farming	2720	
Braunschweig, Germany	1896	Sewage farming	4400	0.7
Croydon-beddington, England	1860	Sewage farming	252	0.2
Leamington, England	1870	Sewage farming	160	0.04
Melbourne, Australia	1893	Irrigation	4160	2.19
Mexico city, Mexico	1900	Irrigation	44800	24.97
Paris, France	1869	Irrigation	640	3.46
Wroclaw, Poland	1882	Sewage farming	800	1.23
United States	1888	Irrigation	4.8	0.005

Wastewater Irrigation Across the World

- 47 % of population lives in urban area with 100 to 150 Lpcd consumption of water.
  - * Africa - 45 million m^3/day and
  - * Asia – 200 million m^3/day of water is consumed
- According to IWMI, 20 million hectares are irrigated with wastewater and it is estimated that 10 % of crops irrigated around the world are watered with sewage.
- Wastewater Irrigation is common throughout the Middle East and North Africa.
- Planned reuse of wastewater can be found in Israel and Tunisia.

Wastewater Irrigation Across the World ….

- Unplanned reuse can be found in Jordan where the wastewater is partially treated.
- In places like Morocco, Algeria, West Bank, Gaza, Syria, Yemen untreated wastewater is used for irrigation.
- Developed countries like USA, Australia, Germany are using treated wastewater for irrigation purpose

Other Interesting Facts About Growing Food Worldwide With Sewage

- A fourth of the vegetables grown in Pakistan, including salad crops, are irrigated with sewage. In fact, land watered by sewage is twice as valuable as that by clean water
- One African farmer grows 12 crops of lettuce each year in his sewage farm
- Some countries (Mexico, Israel, Tunisia and Jordan) treat sewage to remove pathogens for safer irrigation but in others (Indian, China and Pakistan) treatment is rare
- In one Indian city (Hyderabad), virtually all the crops grown there are watered with sewage (disposed to Musi River)

Wastewater Irrigation In India

- It is estimated that 22,900 MLD of municipal wastewater is generated from urban centers and the treatment capacity available is only for 5,900 MLD.
- In India sewage farming was initiated in Bombay, as early as 1877 and in Delhi, from 1913.
- Currently exact figures on the extent and importance of wastewater are unavailable, though Shuval et al. (1986) mentioned an area of over 12,000 hectares, while Strauss and Blumenthal (1990) estimated that an area of over 73,000 hectares were irrigated by untreated wastewater in India.
- In the city of Hyderabad alone, an area of over 40,000 hectares is being irrigated by untreated wastewater (Buechler et al., 2002; van der Hoek, 2004).

Water Quality for Irrigation

Water parameter	Symbol	Unit	Usual range in irrigation water
Salinity/Salt Content			
Electrical Conductivity	EC	dS/m	0 - 3
Total Dissolved Solids	TDS	mg/L	0 - 2,000
Cations and Anions			
Calcium	Ca^{2+}	mg/L	0 -800
Magnesium	Mg^{2+}	mg/L	0 -120
Sodium	Na^{+}	mg/L	0 -900
Carbonate	$CO3^{2-}$	mg/L	0 -6
Bicarbonate	$HCO3^{-}$	mg/L	0 -600
Chloride	Cl^{-}	mg/L	0 - 1,100
Sulphate	$SO4^{2-}$	mg/L	0 - 2,000

Water Quality for Irrigation

Nutrients			
Nitrate-Nitrogen	NO_3-N	mg/L	0 - 10
Ammonium-Nitrogen	NH_4-N	mg/L	0 - 5
Phosphate-Phosphorus	PO_4-P	mg/L	0 - 2
Potassium	K^+	mg/L	0 - 2
Miscellaneous			
Boron	B	mg/L	0 - 2
Acid/Basicity	pH		6.0 - 8.5
Sodium Adsorption Ratio	SAR		0 -15

The Hyderabad Declaration on Wastewater Use in Agriculture
14 November 2002, Hyderabad, India

1. Rapid urbanization places immense pressure on the world's fragile and dwindling fresh water resources and over-burdened sanitation systems, leading to environmental degradation. We as water, health, environment, agriculture, and aquaculture researchers and practitioners from 27 international and national institutions, representing experiences in wastewater management from 18 countries, recognize that:

1.1 Wastewater (raw, diluted or treated) is a resource of increasing global importance, particularly in urban and peri-urban agriculture

1.2 With proper management, wastewater use contributes significantly to sustaining livelihoods, food security and the quality of the environment

1.3 Without proper management, wastewater use poses serious risks to human health and the environment.

2. We declare that in order to enhance the positive outcomes while minimizing the risks of wastewater use, there exist feasible and sound measures that need to be applied. These measures include:

2.1Cost-effective and appropriate treatment suited to the end use of wastewater, supplemented by guidelines and their application

2.2 Where wastewater is insufficiently treated, until treatment becomes feasible:

(a) Development and application of guidelines for untreated wastewater use that safeguard livelihoods, public health and the environment

(b) Application of appropriate irrigation, agricultural, post-harvest, and public health practices that limit risks to farming communities, vendors, and consumers

(c) Education and awareness programs for all stakeholders, including the public at large, to disseminate these measures

2.3 Health, agriculture and environmental quality guidelines that are linked and implemented in a step-wise approach

2.4 Reduction of toxic contaminants in wastewater, at source and by improved management.

3.We also declare that:

3.1 Knowledge needs should be addressed through research to support the measures outlined above

3.2 Institutional coordination and integration together with increased financial allocations are required.

Therefore, we strongly urge policy-makers and authorities in the fields of water, agriculture, aquaculture, health, environment and urban planning, as well as donors and the private sector to:

Safeguard and strengthen livelihoods and food security, mitigate health and environmental risks and conserve water resources by confronting the realities of wastewater use in agriculture through the adoption of appropriate policies and the commitment of financial resources for policy implementation.

Additional Benefits of Agricultural Reuse

- High concentrations of nutrients
- May eliminate need for fertilizer
- Long-term soil enrichment
- Decreases demand on potable water supply
- Additional treatment in soil
- Water not discharged to receiving waters

Disadvantages of Agricultural Reuse

- Health risk from associated pathogens
- Health risk from other contaminants (e.g. metals, chemicals, pharmaceuticals)
- Decrease in soil quality from accumulation of metals and acidification
- Infiltration of groundwater

Urban Wastewater Reuse

- Treated/reclaimed wastewater can be used for
  - Irrigation - public parks, schools, road medians, any landscaped areas, golf courses
  - Commercial - vehicle washing facilities, laundry facilities, window washing, mixing pesticides and herbicides
  - Construction - dust control, concrete production
  - Toilet and urinal flushing
  - Fire protection
  - Drinking water??

Urban Wastewater Reuse

- Treated wastewater or reclaimed water system consists of
  - Water reclamation facility - provides treatment in addition to secondary treatment
  - Distribution system - dual distribution system
  - Network of pipes to deliver reclaimed water to the public
  - lincludes pipelines, storage facilities, pumping facilities
  - Run separate but parallel to potable water pipelines
- Potential problem????

CROSS CONNECTIONS!!!

Urban Wastewater Reuse

- Major considerations are public health and reliability of the system
  - Water must be of acceptable quality for intended uses
  - System must be maintained and operated properly
  - Reclaimed water pipes must be clearly marked

Urban Wastewater Reuse

- Retrofitting reclaimed water system in existing cities can be expensive
- BUT can be cost-effective if:
  - Water supply is of poor quality
  - Water supply does not meet demand
  - Advanced wastewater treatment already required

Residential Wastewater Reuse

- Why reuse wastewater at home?
  - Conserve precious drinking water supply
    - Droughts
    - Arid climates
    - Overuse or population overwhelming supply
  - Save money
  - Reduce environmental impact associated with wastewater treatment & disposal

Residential Wastewater Reuse

- Grey water:
  - Wastewater from sinks, bathtubs, showers, dish washer, laundry (anything except toilets)
  - May contain pathogens, likely to contain other microbes, detergents, bleach, hair, food particles, suspended solids
  - Not for potable reuse unless tertiary treatment

Residential Wastewater Reuse

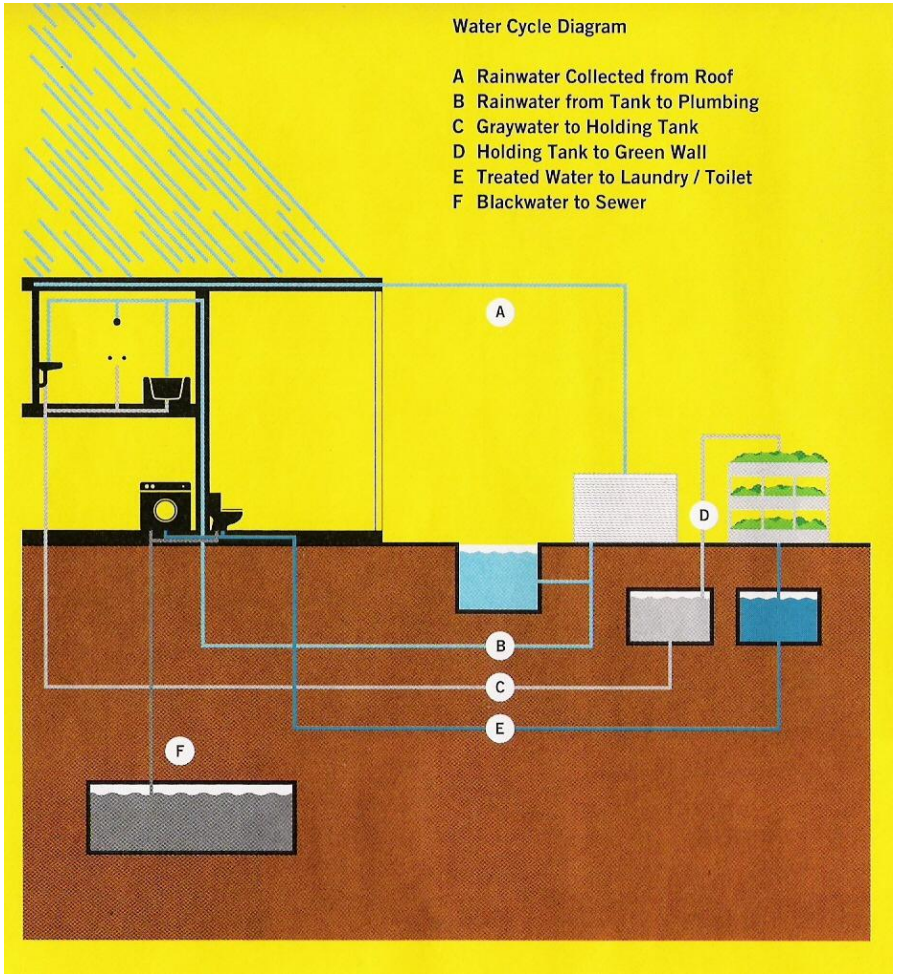
- Simple home water reuse:
  - Collecting in containers for use
  - Hose from sink drain to outdoors
- More complex home water reuse:
  - Divert grey water to underground lawn/garden irrigation system
  - Commercial treatment & reuse systems

Residential Wastewater Reuse

Commercially available grey water treatment & recycling

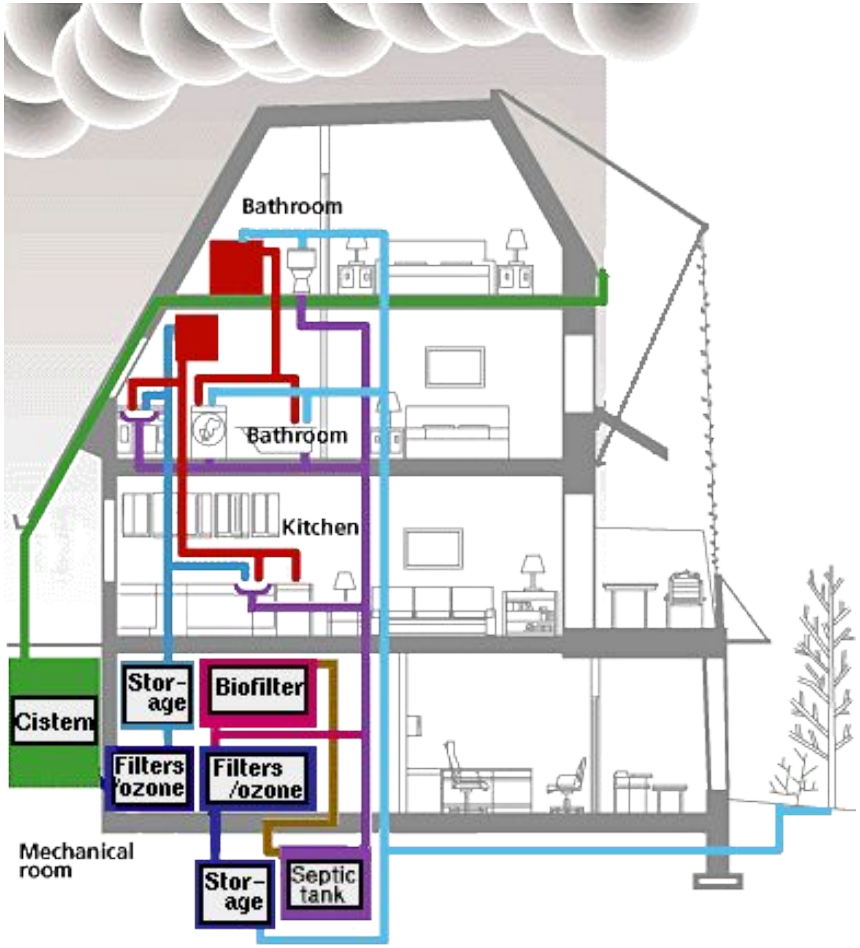
Residential Wastewater Reuse

Custom designed system in Sydney, Australia



Residential Wastewater Reuse

Healthy Home System in Toronto, Canada



Groundwater Recharge: Purpose

- Establish saltwater intrusion barriers
- Provide further treatment for future reuse
- Increase potable or non-potable aquifers
- Provide storage of reclaimed water for subsequent retrieval and reuse
- Control or prevent ground subsidence

Groundwater Recharge: Advantages

- Less cost than equivalent surface water reservoirs
- The aquifer serves as an eventual natural distribution system
- No evaporation, taste and odor problems occurr in surface reservoirs
- Suitable sites for surface water reservoirs may not be available or environmentally acceptable

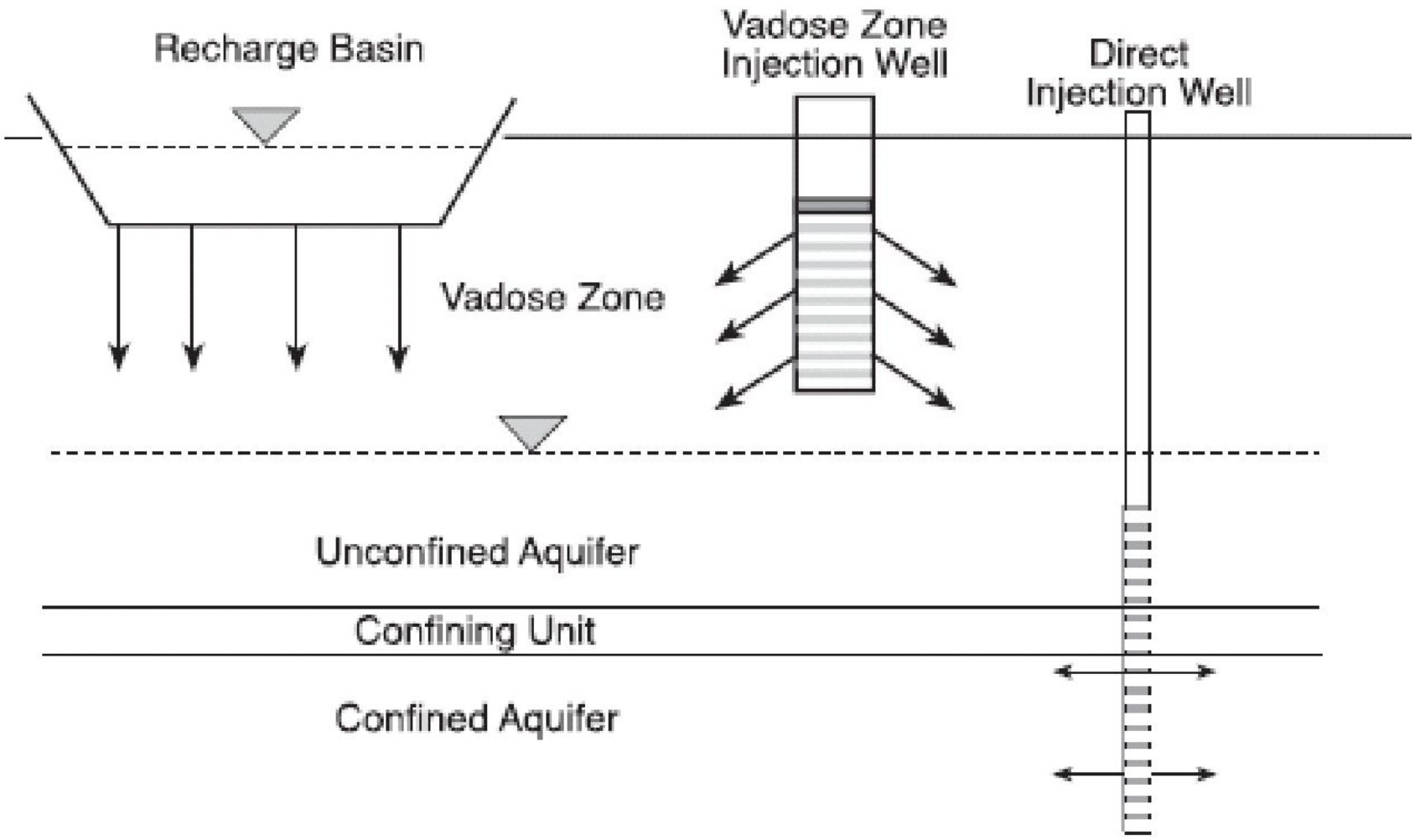
Groundwater Recharge: Limitations

- Extensive land areas may be needed for spreading basins
- Costs for treatment, water quality monitoring, and injection/infiltration facilities operations may be expensive.
- Recharge may increase the danger of aquifer contamination due to inadequate pretreatment.

Groundwater Recharge: Limitations

- Not all recharged water may be recoverable
- Hydrogeologic uncertainties may reduce the effectiveness of the recharge project in meeting water supply demand
- Inadequate institutional arrangements or groundwater laws may not protect water rights

Groundwater Recharge – Techniques



Source: US EPA. Guidelines for water reuse

Selection of Treatment Technologies

- The treatment system should be Economically viable, Environmentally Friendly and Sustainable.
- Life Cycle Analysis of wastewater treatment systems
- Develop guidelines for life cycle analyses of wastewater treatment systems considering Pros and cons of the systems like Energy consumption, Residual pollution left over, Environmental degradation, contribution to global warming etc..

Conclusions

- Many current uses for recycled wastewater
- Varying levels of treatment required
- Pros:
  - Conserve potable water
  - Reduce effluent to environment
- Cons:
  - Health & safety precautions necessary
  - Careful planning needed
- Potential for much greater use in future

Thankyou