CHAPTER (8)

Land Application & Reuse of Wastewater

Treating water as a resource, not a waste product

Land Application
&
Reuse of Wastewater

- **<u>Land Application:</u>**

Method of *secondary or tertiary* treatment of

A. Municipal wastewater , or
B. Biodegradable industrial wastewater

- **<u>Reuse of Wastewater</u> (Reclaimed Water):**

Utilization of water <u>and</u> nutrient resources in wastewater

a) during land application treatment, or
b) in the "reclaimed" water after treatment by other technology.

Land Application & Reuse

Merits:

1. Fresh water conservation in arid regions by using treated wastewater for irrigation
2. Greening and enhancing landscape by utilizing *nutrient-rich* treated wastewater
3. Replenishing groundwater supplies
4. Cost savings by using nature as bioreactor instead of expensive engineering equipment

As-Samra WWTP effluent to KTD, and then Reused for Irrigation in Jordan Valley farms

Land Application/Reuse: Jordan

Flowers, forest trees / Wadi Mousa Treated Wastewater Plant

Fodder crops/ Ramtha Treated Wastewater Plant

LAND APPLICATION SYSTEMS

Two Classes:

1. **LAND DISPOSAL SYSTEMS** :Used for pretreated municipal effluents.
2. **IRRIGATION AND LANDSCAPE USES** : Used for complete treatment by discharge of final effluent on vegetated plots.

Approach:

1. Land treatment involves applying the wastewater to land by *one of several irrigation techniques (see Next)*.
2. Treatment is provided by natural processes as the wastewater moves through the plant and soil system.

LAND APPLICATION (DISPOSAL) SYSTEMS

Three main land disposal systems used for pretreated municipal effluents:

1. **Slow-Rate Infiltration System (SR)**
2. **Rapid Infiltration Systems (RI)**
3. **Overland Flow (OF)**

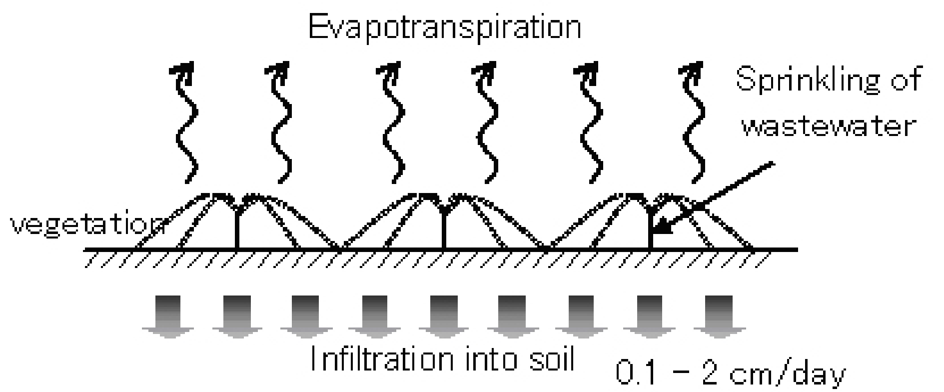
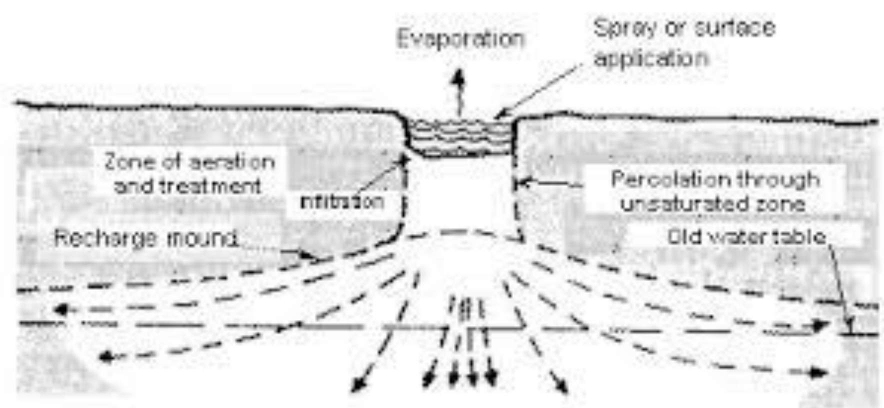
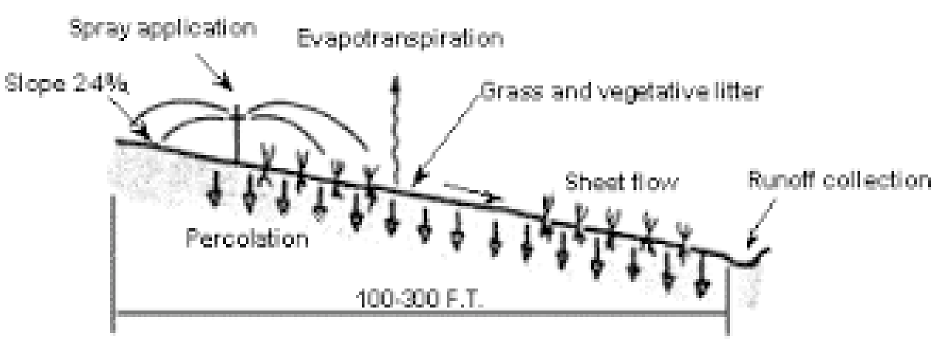


Fig 1 Slow rate system



(B) Infiltration percolation



(C) Overland flow

1. SLOW-RATE SYSTEMS

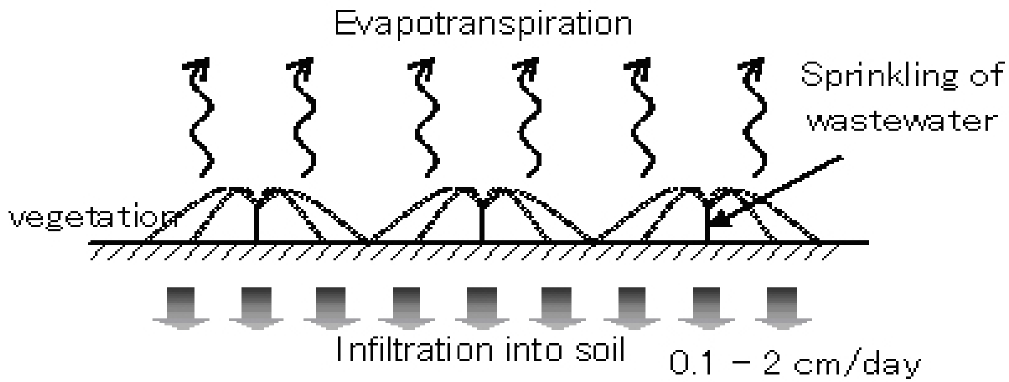


Fig. 1 Slow rate system

- Slow rate land application for wastewater treatment is a *proven technology* for municipal and other organic wastewaters.

- Used for *over one hundred years*, it has evolved from a 'disposal' method to one that can be used to recycle wastewater onto agricultural crops, forests or park lands.

- EPA 1992

1. SLOW-RATE SYSTEMS

1. The oldest and most widely used form of land treatment, requires largest land area compared to the other systems
2. Used to further treat wastewater effluent via contact with the soil-vegetation system
3. Used in agricultural, recreation (e.g., parks) and forest systems
4. **<u>Characteristics:</u>**
   - Offer wastewater **treatment** (BOD removal) while providing water and nutrients to agricultural and forest system (**reuse**).
   - Vegetation covers include **perennial grasses** due to high nitrogen uptake ability, long application season and low maintenance.
   - Limited by hydraulic capacity and nitrogen removal ability of soil.
   - Can *not be applied* to products consumed by humans.

1. SLOW-RATE SYSTEMS

Sprinkler Spray Irrigation:

Drip Irrigation:

1. SLOW-RATE SYSTEMS

1. Organics are removed mainly within the first 1 to 2 cm by **biological oxidation, filtration, and adsorption.**

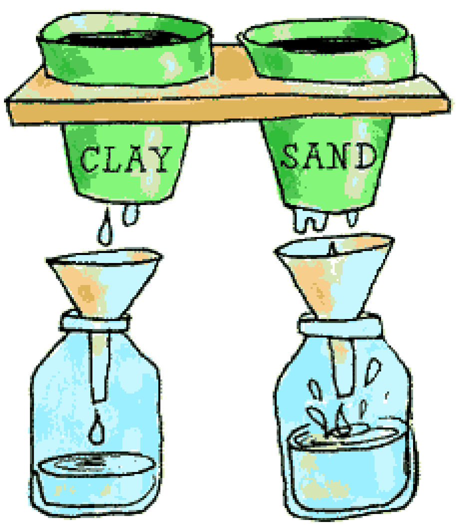
BIOOXIDATION:

Organic matter + O_2 + bacteria ----->

new cells + CO_2 + NO_3^- + H_2O

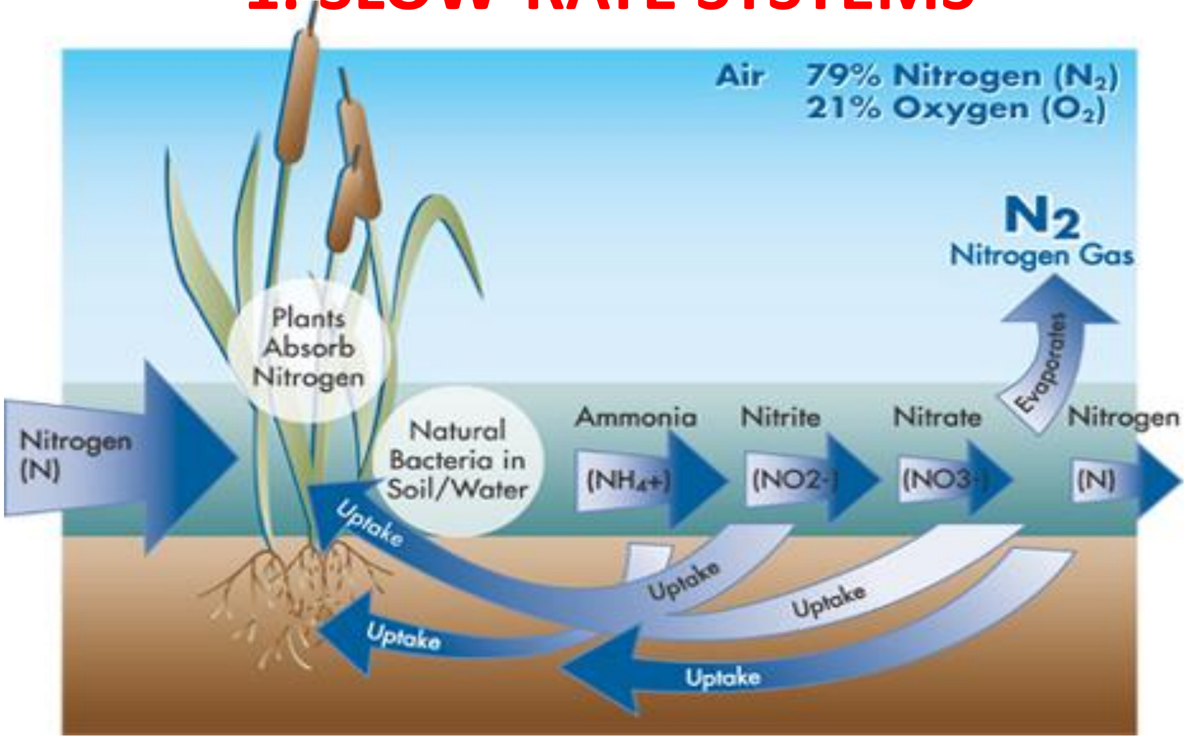
2. Particulate material is **filtered** through the soil matrix.

3. Nitrogen is removed by:
    1. Vegetation uptake
    2. Biological denitrification
    3. Ammonia volatilization
    4. Retention within soil matrix



4. Phosphorus removal via crop uptake and fixation in the soil matrix.

1. SLOW-RATE SYSTEMS



- SR Systems are very effective at removing harmful wastewater constituents
- N and P Removals: Plant uptake AND microbial nitrification-dentitrification

PARAMETER	PERCENT REMOVAL
BOD	90 to 99+ percent
TSS	90 to 99+ percent
TN	50 to 90 percent
TP	80 to 99+ percent
FECAL COLIFORM	99.99+ percent

1. SLOW-RATE SYSTEMS

ADVANTAGES:

1. Significantly reduced operational, labor, chemical and energy requirements compared to conventional wastewater treatment systems.
2. Economic return from the use and *re-use of water and nutrients* to provide marketable crops.
3. Little or no disposal of effluent production.

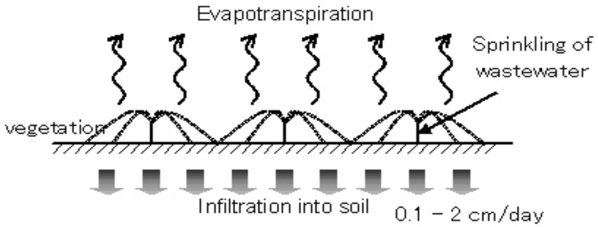
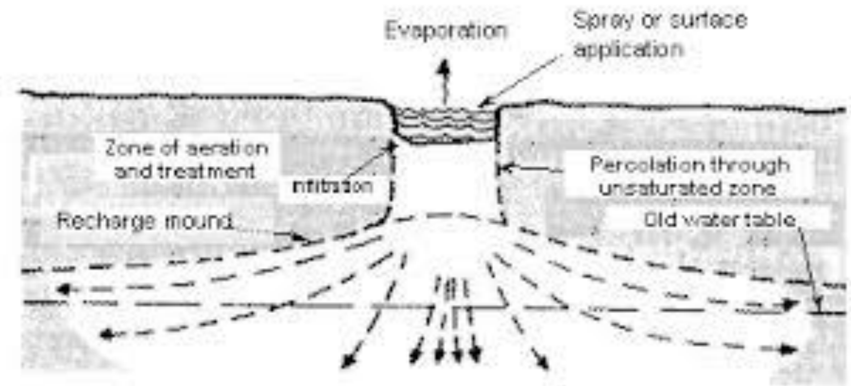


Fig 1 Slow rate system

DISADVANTAGES:

1. Large land requirements.
2. Specific problems of poor site selection (e.g. Improper soil structure, Runoff and erosion in steep areas and Inadequate soil or groundwater characterization resulting in operational hydraulic problems.

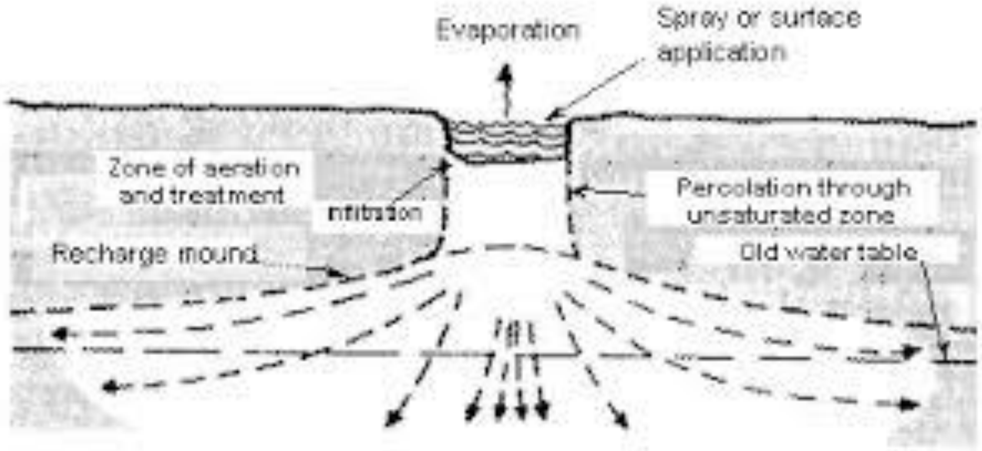
2. RAPID INFILTRATION



(B) Infiltration percolation

- Usually used for:
  1. Ground water recharge and,
  2. Recovery of renovated water (by wells or underdrains) for reuse
- Wastewater percolates through the soil and is treated through downward flow
- Vegetation is NOT a part of the treatment
- Removal rates (of BOD, nutrients, etc.) are dependent on:
  1. Both wastewater and soil characteristics
  2. Travel distance
  3. Climatic and seasonal variables (Rainfall, Evapotranspiration, Temperature)
- BOD, SS and Fecal Coliforms are almost completely removed
- *Nitrogen removal is 50-99% and Phosphorus removal is 70-99%.*

2. RAPID INFILTRATION

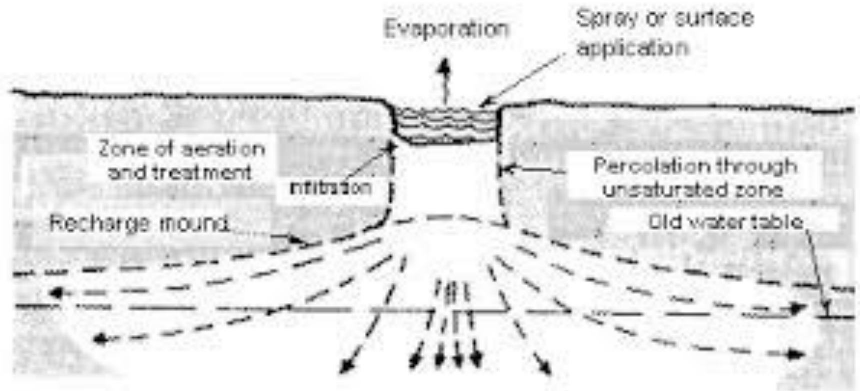


(B) Infiltration percolation

Advantages:

1. Gravity distribution methods consume no energy.
2. No chemicals are required.
3. RI is a simple and economical treatment.
4. Effluent is of excellent quality.
5. The process is very reliable with sufficient resting periods.
6. The process is suitable for small plants where operator expertise is limited.

2. RAPID INFILTRATION

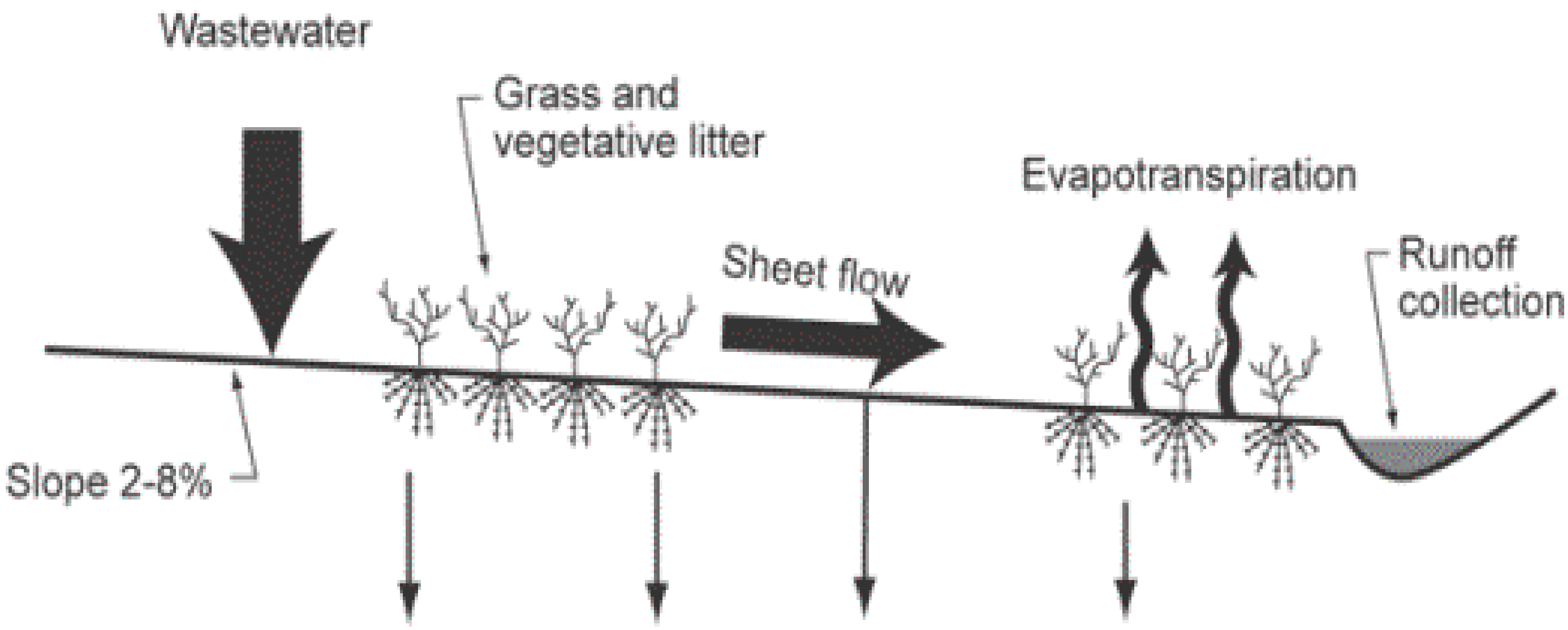


(B) Infiltration percolation

Disadvantages:

1. May *not meet nitrogen levels* required for ground -water aquifer discharge.
2. Requires long term commitment of significant land area
3. Requires *annual removal of accumulated deposits* of organic matter
4. May require occasional *removal and disposal of the top few inches of soil*
5. Clogging can occur when influent is received at *high application rates* from algal-laden lagoons and ponds

3. OVERLAND FLOW SYSTEMS



(a) Hydraulic pathway

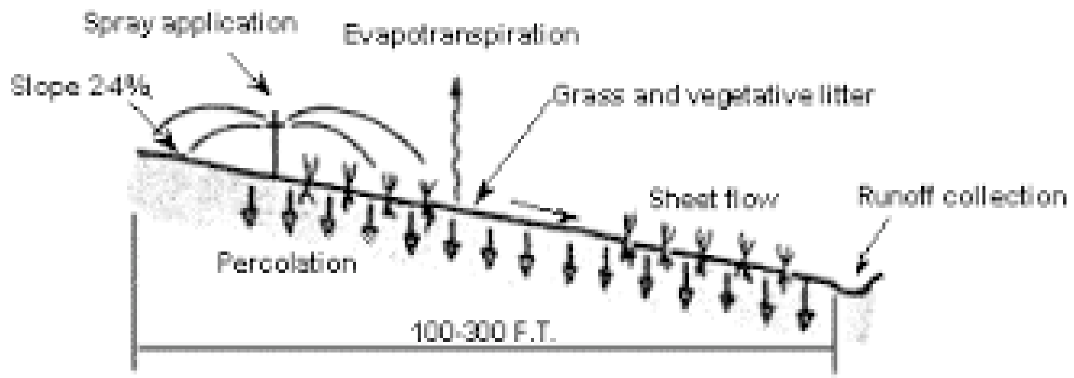
- Best suited for sites with relatively *impermeable soils*

3. OVERLAND FLOW SYSTEMS

1. Used to achieve secondary treatment effluent quality when applying effluents coming from primary treatment facilities.
2. High removal of Nitrogen, BOD and TSS.
3. Applying of previously- treated wastewater effluents to a vegetation-covered and graded land.
4. Applied via grated pipes /nozzles at top of slope or sprinkler systems within the site.

5. Perennial (long-life) grasses used for:
   - Soil erosion control, slope stability and effluent treatment
6. Removal mechanisms for BOD and Suspended Solids:
   - *Biological Oxidation, sedimentation, filtration.*

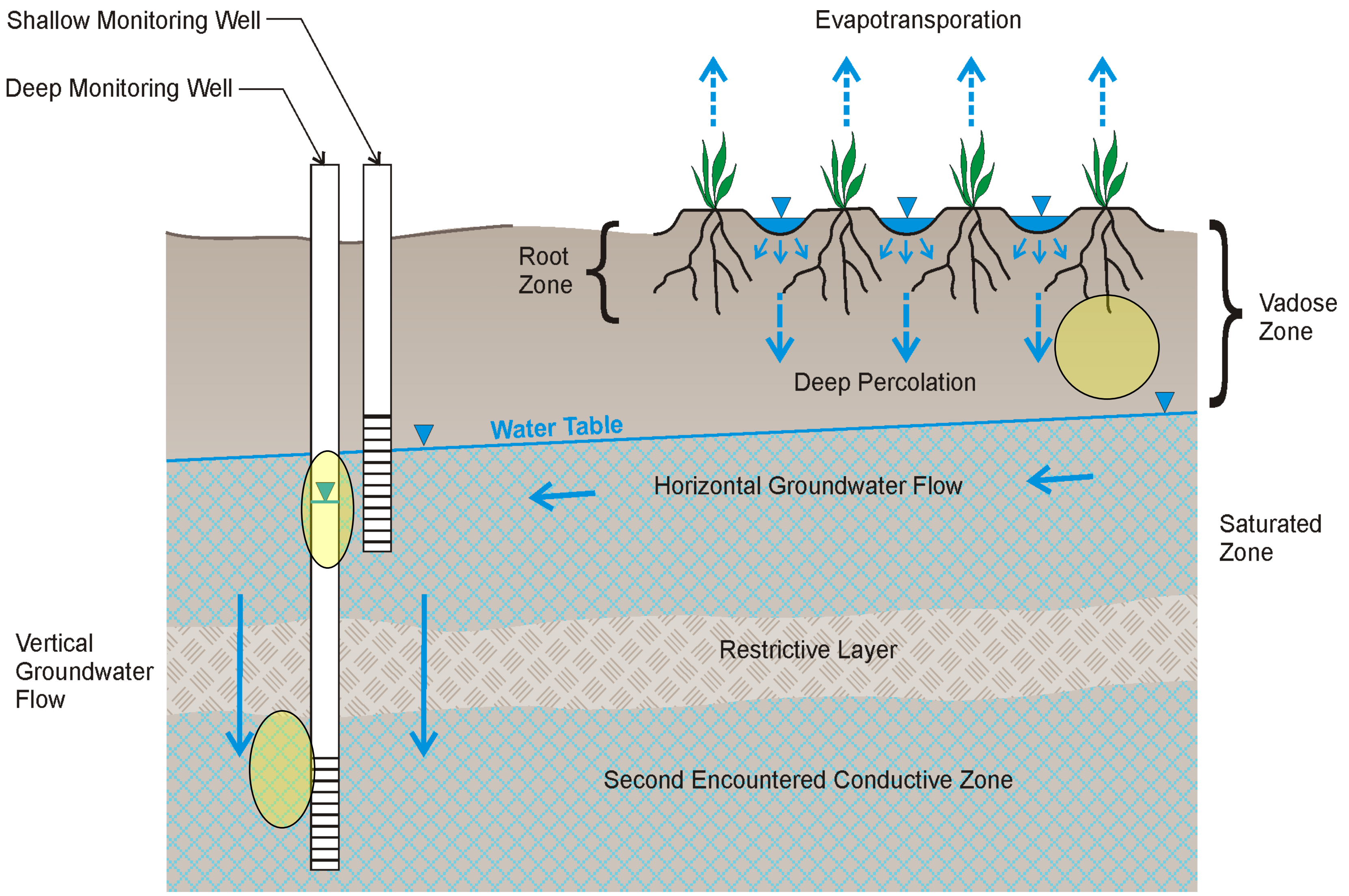
3. OVERLAND FLOW SYSTEMS



(C) Overland flow

1. Removal of Nitrogen:
   - Removal mechanisms: Plant uptake, Denitrification, Ammonia Volatilization
   - Typically 75-90%.
2. Removal of Phosphorus:
   - Fixation processes in the soil matrix, Crop uptake
   - Typically removes 50-70% and can be increased by addition of alum or ferric chloride prior to land application.
3. Effluent is collected in ditches and can be reused or discharged to a surface water body.

Groundwater Monitoring

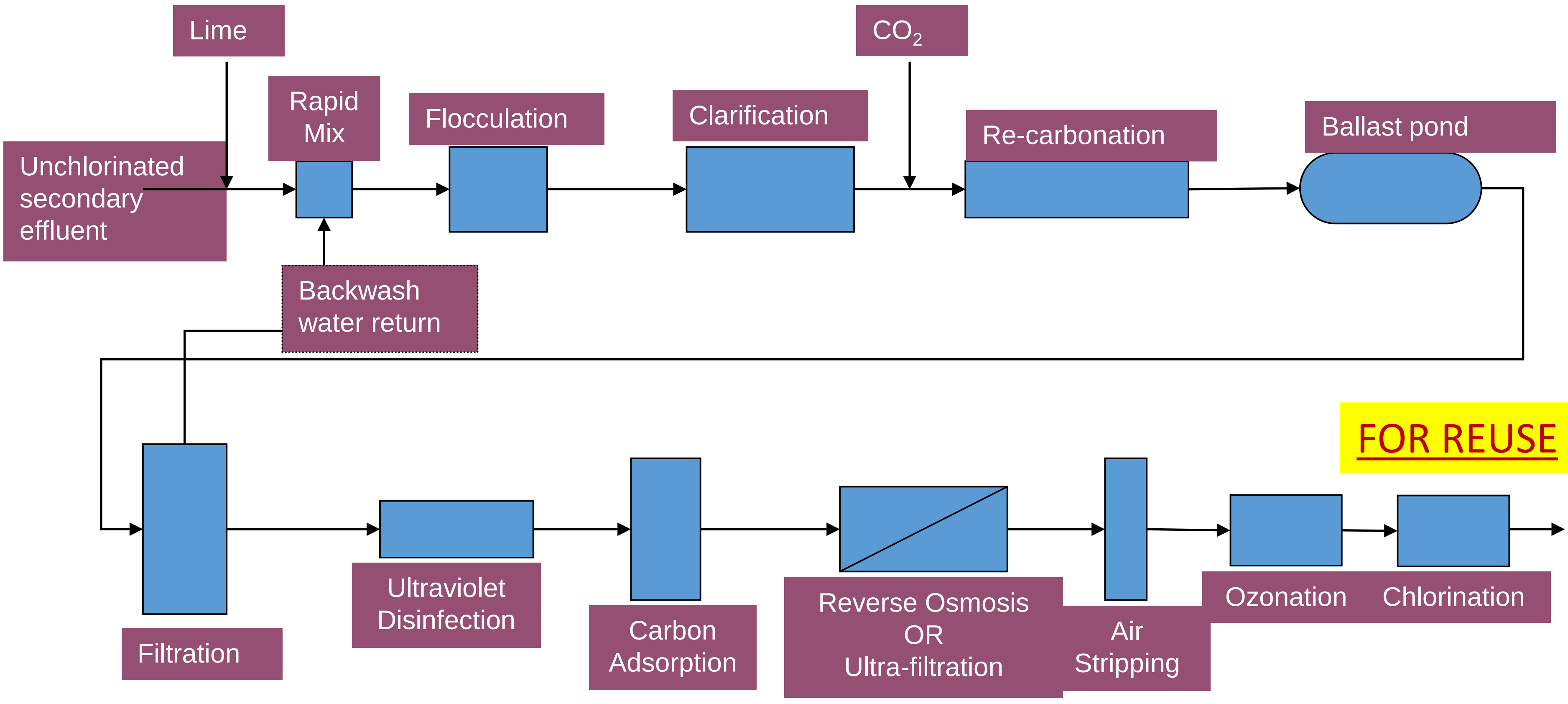


Reuse of Reclaimed Water

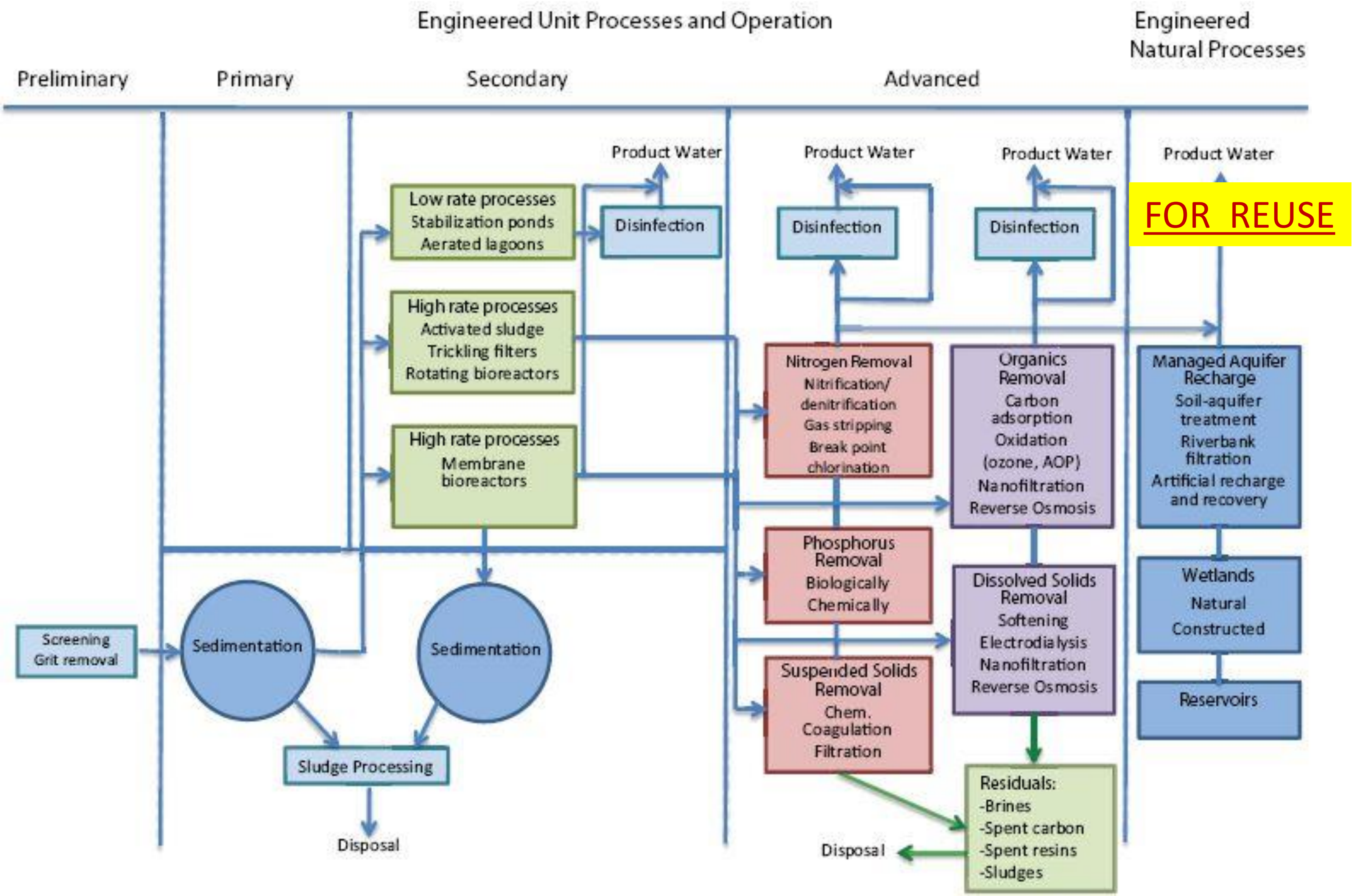
1. Reclaimed water reuse in now a large and growing practice in many countries possessing the technology and expertise.
2. Jordan has a successful experience and increasing interest in reclaimed water reuse, particularly in agriculture.
3. The treatment method for producing reclaimed water depends on the effluent quality and type of reuse.
4. High quality reclaimed water may require *advanced and thus expensive technologies* (see next).

Wastewater Reclamation Technologies:

Advanced Treatment Methods

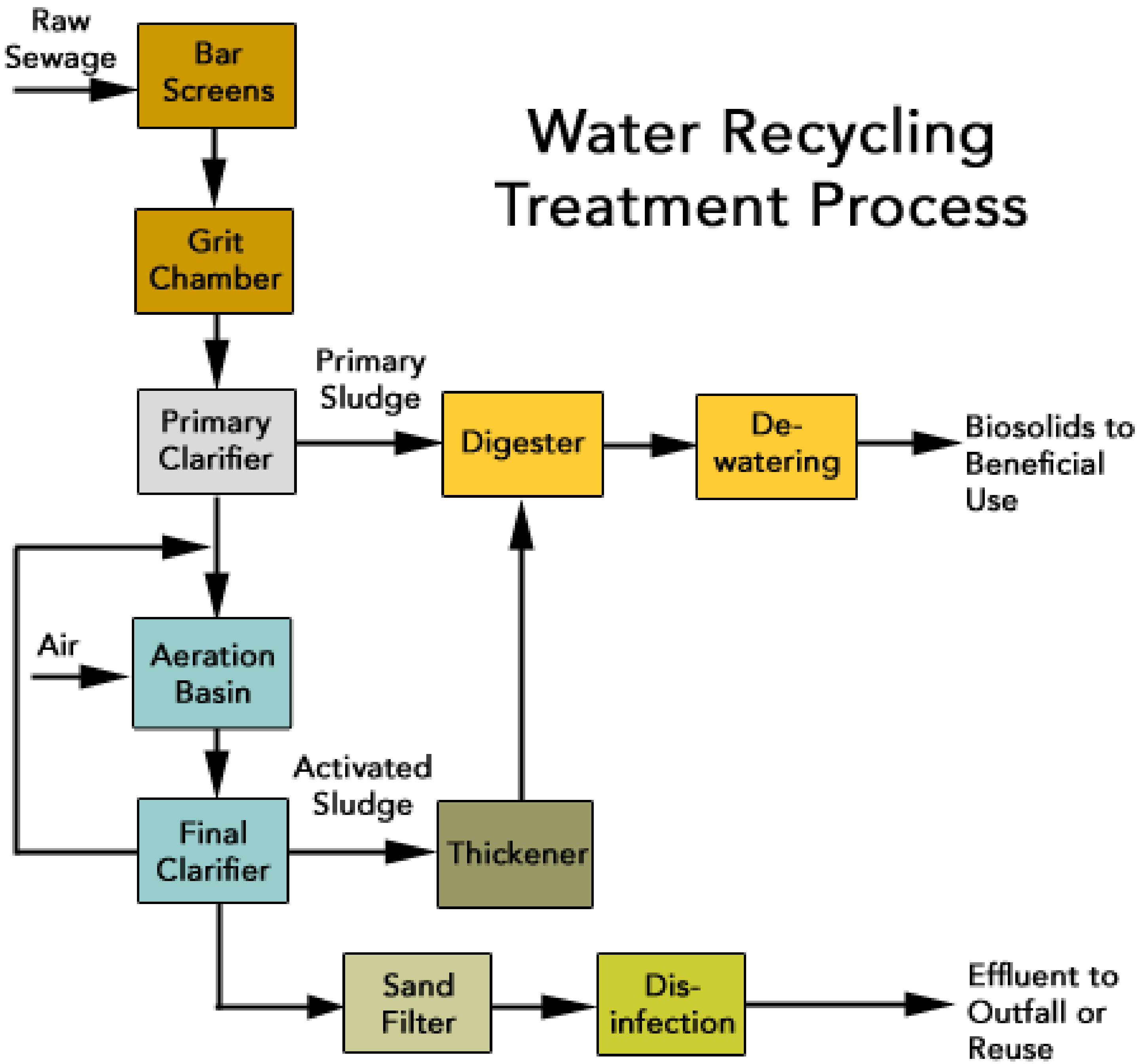


Wastewater Reclamation Technologies:
Advanced Treatment Methods



Reuse of Treated Wastewater

- ❑ Treatment of Wastewater for non-potable use in arid and other water-short regions.
- ❑ Often use advanced or additional treatment processes, sometimes referred to as "*reclamation*".
  1. Further biological treatment in "*polishing*" ponds and constructed wetlands.
  2. Physical-chemical treatment processes:
     - Coagulation-flocculation and sedimentation
     - Filtration: granular medium filters; membrane filters
     - Granular Activated Carbon (GAC)
     - Disinfection


Water Recycling Treatment Process
Raw Sewage
Bar Screens
Grit Chamber
Primary Clarifier
Primary Sludge
Digester
De-watering
Biosolids to Beneficial Use
Air
Aeration Basin
Activated Sludge
Final Clarifier
Thickener
Sand Filter
Dis-infection
Effluent to Outfall or Reuse

Reuse in Agriculture (Irrigation)

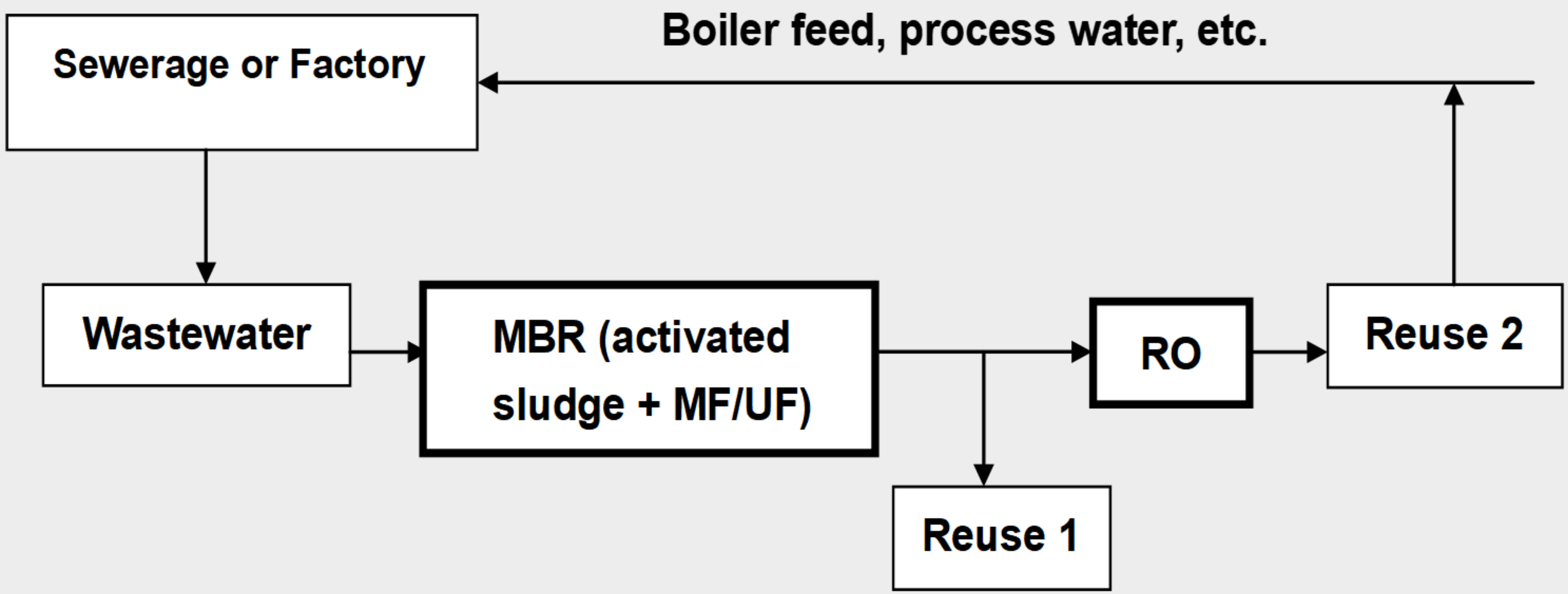
Advantages

1. Freshwater resources can be reserved for other uses
2. Chemical fertilizer usage can be minimized
3. Discharge of reclaimed wastewater to water bodies can be prevented
4. Agricultural crops can be produced and marketed.

Disadvantages

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

Wastewater Reuse



Basic Diagram of "Integrated Membrane System" for Treatment and Reuse

Groundwater Recharge – Guidelines (WA)

Treatment	Oxidized, coagulated, filtered, and disinfected
BOD_5	5 mg/l
TSS	5 mg/l
Turbidity	2 NTU (Avg); 5 NTU (Max)
Total Coliform	2.2/100 ml (Avg); 23/100 ml (Max)
Total Nitrogen	Not specified

Source: US EPA. Guidelines for water reuse

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 µg/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^-) thru infiltration into potable water supplies
  - **Environmental Health** – Eutrophication, crop yield effects (+ive & -ive)
    - Surface water pollution & Irrigation practices.

EPA Guidelines for Water Reuse

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

EPA Suggested Guidelines

- pH = 6-9
- $BOD_5 \leq 10$ mg/L
- Turbidity ≤ 2 NTU
- E. coli = NONE
- Res. $Cl_2 \geq 1$ mg/L

Nitrogen Control

- Nitrogen in any soluble form (NH_3, NH_4^+, NO_2^-, and NO_3^-, but not N_2 gas) is a nutrient and may need to be removed from wastewater to help control algae growth in the receiving body.

- In addition, nitrogen in the form of ammonia:
  - exerts an oxygen demand and
  - can be toxic to fish.

- Removal of nitrogen can be accomplished either biologically or chemically:
  - *The biological process is called nitrification/denitrification.*
  - *The chemical process is called ammonia stripping.*

Nitrification /denitrification (Bio)

- The natural nitrification process can be forced to occur in the activated sludge system by maintaining a cell detention time of <u>15 days or more.</u>

- The **nitrification step** is expressed in chemical terms as follows:

$$NH_4^+ + 2O_2 = NO_3^- + H_2O + 2H^+$$

- Nitrifying bacteria must be present to cause the reaction to occur. This step satisfies the oxygen demand of the ammonium ion.

- If the nitrogen level is <u>not of concern</u> for the receiving body, then
  - wastewater <u>can be</u> discharged after settling.
  - If nitrogen is of concern, the nitrification step *must be followed by anoxic denitrification* by bacteria:

$$2\ NO_3^- + \text{organic matter} = N_2 + CO_2 + H_2O$$

Nitrification /denitrification (Bio)