

WATER REUSE AND RECLAMATION



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1.0 INTRODUCTION

- A better management of the water resources.
- Attractive when water supply cannot meet water demands.
- Water reclamation : treatment of wastewater to make it reusable.
- Water reuse : use of treated wastewater for beneficial uses.
- Potential benefits ;
 - substitute reclaimed water
 - alternative source of supply
 - protect aquatic ecosystems by decreasing effluent discharges
 - reduce the need for water control structures such as dams/reservoirs
 - economic advantages by reducing the need for infrastructure

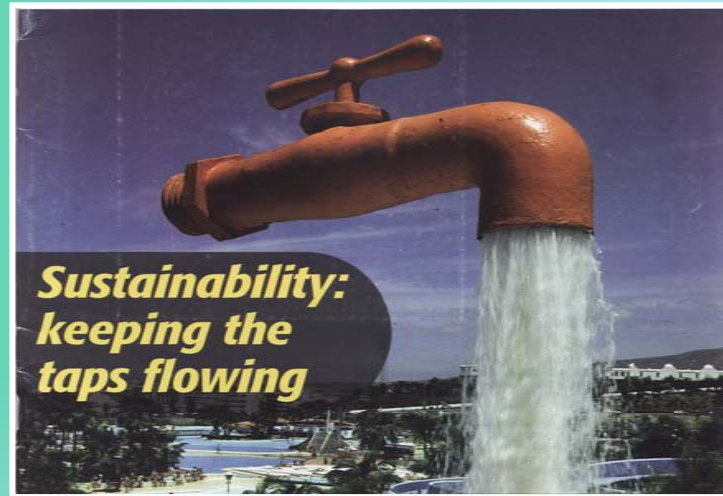
1.1 Water Conservation

- Role of water conservation : reduced energy, chemical inputs for water treatment, and reduced costs and impacts of wastewater management.

Table 1. Typical single family home water use, with and without water conservation

Water Uses	Without water conservation		With water conservation	
	L/capita.d	Percent	L/capita.d	Percent
Toilets	76.1	27.7	36.3	19.3
Clothes washers	57.2	20.9	40.1	21.4
Showers	47.7	17.3	37.9	20.1
Faucets	42.0	15.3	40.9	21.9
Leaks	37.9	13.8	18.9	13.8
Other domestics	5.7	2.1	5.7	3.1
Baths	4.5	1.6	4.5	2.4
Dish washers	3.8	1.3	3.8	2.0
TOTAL	274.4	100	187.8	100

Adapted from AWWA Research Foundation (1999)



Flowing tap



Leaking pipe



Unwashed dishes

Water becomes oil?



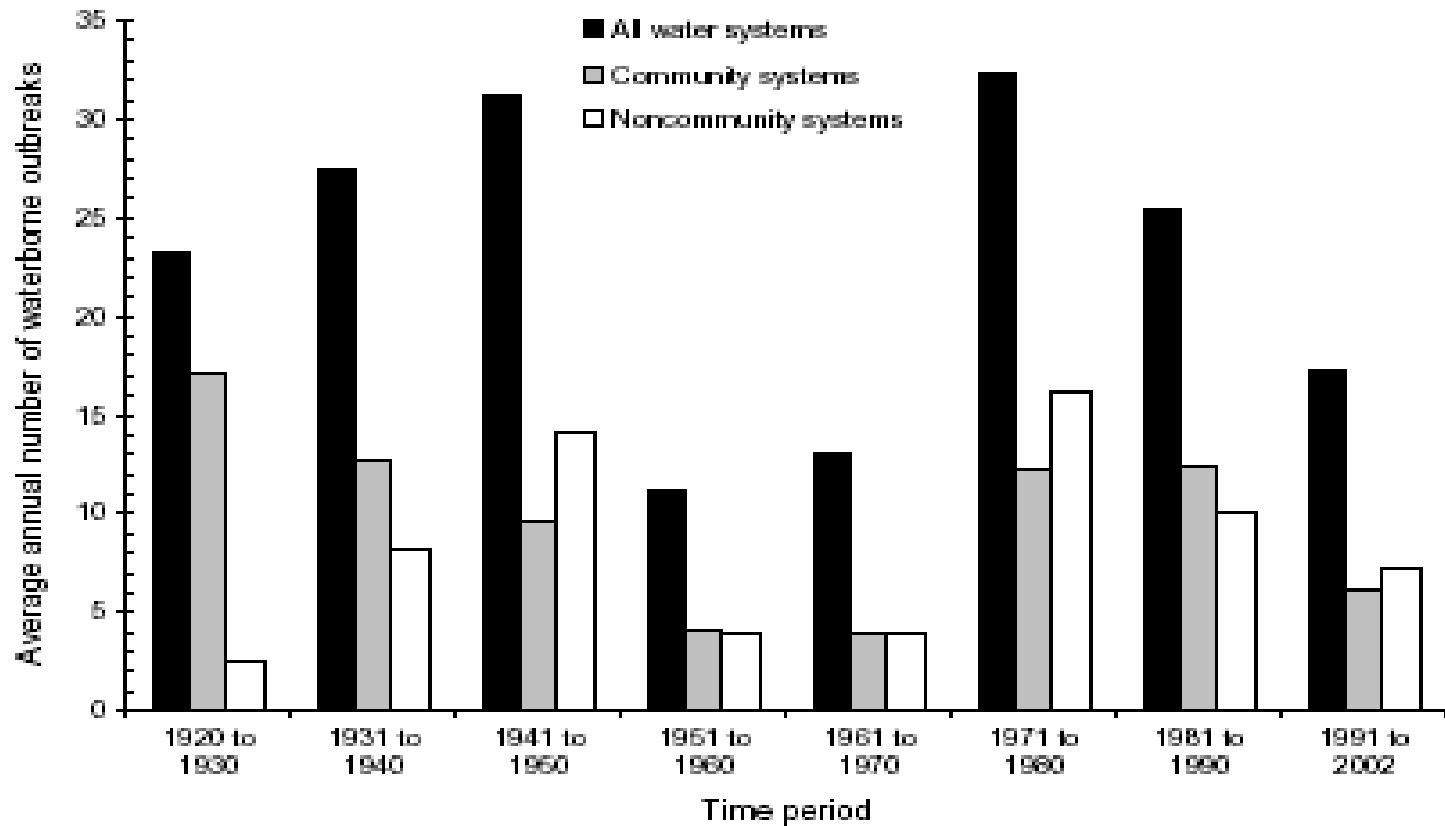
Drought



Water shortage

2.0 HEALTH AND ENVIRONMENTAL CONCERNS

- Reclaimed water from wastewater may contain hazardous material to human health.
- In many developing countries, the irrigation of vegetable crops with untreated or poorly treated wastewater is a major source of disease.
- Issues related:
 - wastewater treatment
 - reclaimed water quality
 - chemical/microbiological content in water
 - health risk assessment
 - public perception and acceptance



Reported waterborne outbreaks in US from 1920 to 2002 (M.F. Craun *et al.*, 2006)

Examples of major groups and genera of waterborne and water-based pathogen

Group	Pathogen	Disease and Symptoms Causes
Bacteria	<i>Salmonella</i>	Typhoid and diarrhea
	<i>Shigella</i>	Diarrhea
	<i>Campylobacter</i>	Diarrhea – foodborne outbreak
	<i>Escherichia coli O157:H7</i>	Diarrhea – hemolytic uremia syndrome in small children
Protozoa	<i>Naegleria</i>	Meningoencephalitis
	<i>Entamoeba histolytica</i>	Amoebic dysentery
	<i>Giardia lamblia</i>	Chronic diarrhea
Cyanocacteria (blue-green algae)	<i>Anabaena</i>	Microcystin toxin is implicated in liver damage

Adapted from Gerba (1996); Straub and Chandler(2003).

Examples of major groups and genera of waterborne and water-based Pathogens cont'd

Group	Pathogen	Disease and Symptoms Causes
Helminths	<i>Ascaris lumbricoide</i>	Ascariasis
	<i>Taenia saginata</i>	Beef tapeworm
	<i>Schistosoma manson</i>	Schistosomiasis – affect liver, bladder
Viruses	<i>Hepatitis A and E</i>	Infectious hepatitis
	<i>Rotavirus</i>	Diarrhea/gastroenteritis
	<i>Reovirus</i>	Respiratory and enteric infections

Adapted from Gerba (1996); Straub and Chandler(2003).



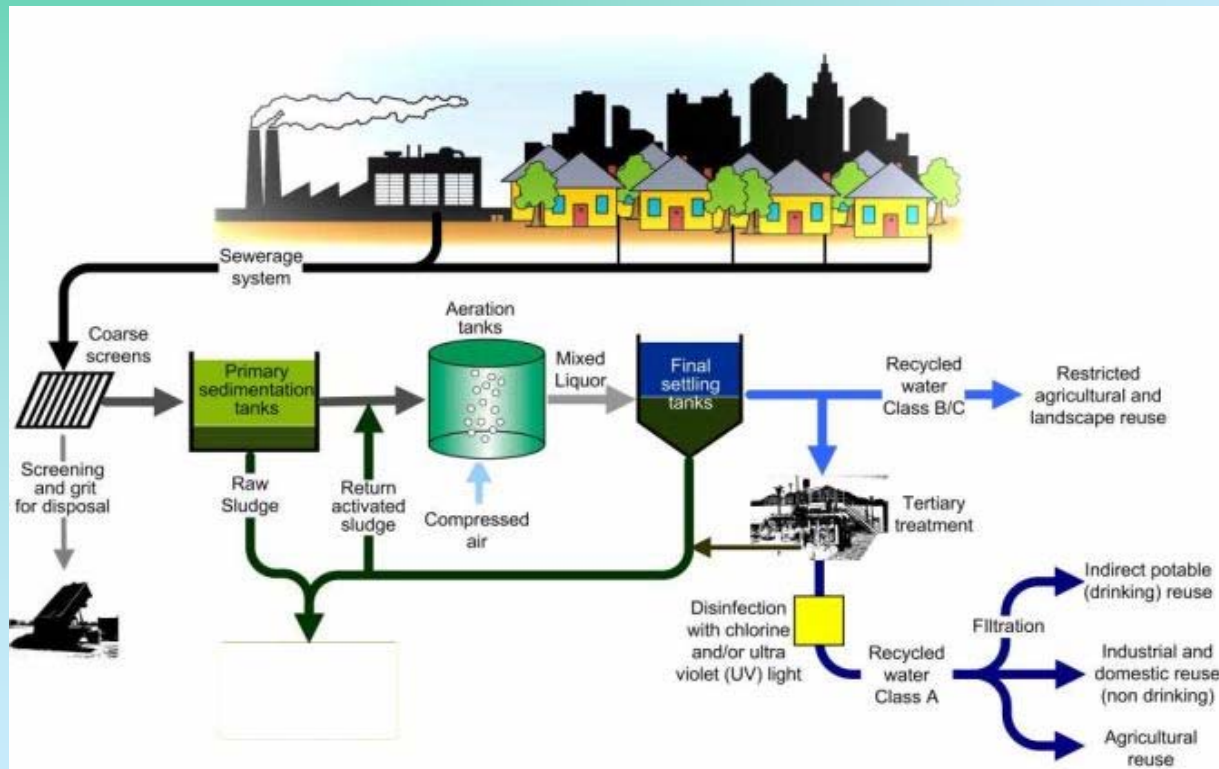
Two Sudanese boys use pipe filters to protect themselves from contracting Guinea worm disease, a parasitic water-borne disease that breeds in stagnant pools of water. The water is strained through a nylon material attached to one end of the straw-like device.

Indicator Organisms

- Routine monitoring for all possible microbial constituents, especially viruses, is either impossible or impractical.
- Tests for surrogate microorganisms (indicator microorganisms) is more practical to estimate the presence of pathogens.
- Ideal indicator organism ;
 - Present when fecal contamination is present.
 - Indicator organism should be $\geq$ pathogenic organism
 - Exhibit the same or greater survival characteristics in treatment process and environment as the target pathogen
 - Cannot reproduce outside of the host organism
 - The isolation and quantification of the indicator organism must be faster than target pathogen
- Example : Total coliform bacteria, *E. Coli* and Enterococci.

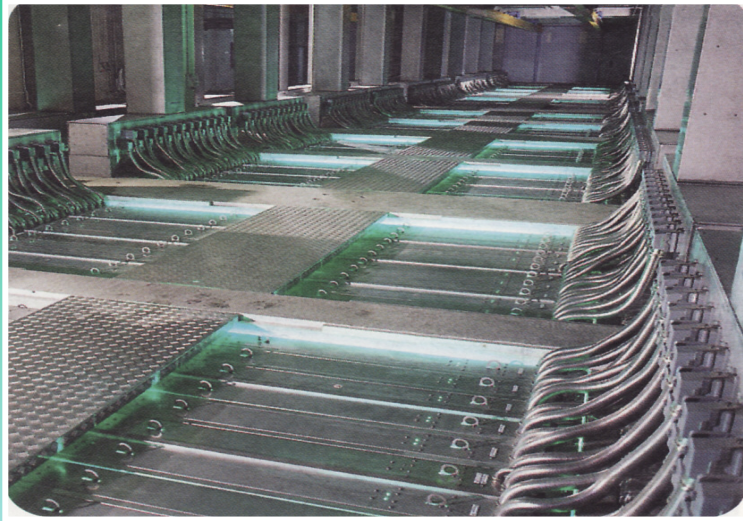
Treatment Levels and Technologies

- The treatment of wastewater typically consist of two methods ;
 - Unit operations : Physical treatment
 - Unit process : Chemical or biological reactions to remove contaminants



Typical wastewater treatment and it uses

Types of Advanced Treatment



**UV disinfection units at Manukau,
New Zealand**

**Europe's biggest membrane
ultrafiltration, at the Clay Lane
works, UK**



Pathogens in the Environment

- In receiving waters, natural process tend to reduce the concentrations of enteric microorganism due to dilution and die-off.
- Factors influence the inactivation rate ;
 - amount of particulate matter
 - oxygen
 - salinity
 - temperature
 - UV light the water is exposed to

Table 3. Survival of enteric pathogens and indicator bacteria in freshwaters

Microorganism	Time reported for 90% reduction in viable conditions	
	time (day)	temperature(°C)
Coliforms	0.83 – 4.8	10 – 20
E.Coli	3.7	15
Salmonella	0.83 – 8.3	10 – 20
Yersinia	7	5 – 8.5
Enteric viruses	1.7 – 5.8	4 – 30

Adapted from McFeters and Terzieva (1991)

Water-based Pathogens



E. Coli



Protozoa



Helminths

Chemical Constituents in Untreated and Treated Wastewater

- Classified into ;
 - organic : aggregate and individual
 - inorganic : nutrients, dissolved constituent, metal, gases
- Sources of the chemical constituents ;
 - present naturally in water supply course
 - present in treated water
 - added from residential, commercial and human activities
 - added from stormwater, infiltration from collection system
 - added in collection system for odor or corrosion control
- The required water quality for reclaimed water varies with each reuse applications.
- The constituents that remain after various treatment process can give long-term public health and environment impact.

REMOVAL OF WASTEWATER POLLUTANTS

Constituent	Raw	Primary Effluent		Secondary Effluent		Tertiary Effluent		Advanced Treatment		Overall
	Conc.	Conc.	Removal	Conc.	Removal	Conc.	Removal	Conc.	Removal	Removal
	(mg/l)	(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)	(%)
CBOD	185	149	19	13	74	4.3	5	NA		98
TSS	219	131	40	9.8	55	1.3	4	NA		99+
TOC	91	72	21	14	64	7.1	8	0.6	7	99+
TSS	1452	1322	9	1183	10	1090	6	43	72	97
Turbidity	100NTU	88NTU	12	14NTU	74	0.5NTU	14	0.27	0	99+
Ammonia	22	21	5	9.5	52	9.3	1	0.8	39	96
Nitrate	0.1	0.1	0	1.4	0	1.7	0	0.7	0	0
TKN	31.5	30.6	3	13.9	53	14.2	0	0.9	41	97
Phosphate	6.1	5.1	16	3.4	28	0.1	54	0.1	0	98
Arsenic	0.0032	0.0031	3	0.0025	19	0.0015	30	0.0003	40	92
Cadmium	0.0006	0.0005	17	0.0012	0	0.0001	67	0.0001	0	83

Adapted from Western Consortium for Public Health (1992)

REMOVAL OF WASTEWATER POLLUTANTS

Constituent	Raw	Primary Effluent		Secondary Effluent		Tertiary Effluent		Advanced Treatment		Overall Removal
	Conc.	Conc.	Removal	Conc.	Removal	Conc.	Removal	Conc.	Removal	
	(mg/l)	(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)	(mg/l)	(%)	
Calcium	74.4	72.2	3	66.7	7	70.1	0	1	88	99
Chloride	240	232	3	238	0	284	0	15	90	94
Iron	0.6	0.53	12	0.18	59	0.05	22	0.04	2	94
Magnesium	38.5	38.1	1	39.3	0	6.4	82	1.5	13	96
Manganese	0.065	0.062	5	0.0039	37	0.002	57	0.002	0	97
Mercury	0.0003	0.0002	33	0.0001	33	0.0001	0	0.0001	0	67
Nickel	0.007	0.01	0	0.004	33	0.004	11	0.001	45	89
Sodium	198	192	3	198	0	211	0	11.9	91	94
Sulfate	312	283	9	309	0	368	0	0.1	91	99+
Zinc	0.081	0.076	6	0.024	64	0.002	27	0.002	0	97

Adapted from Western Consortium for Public Health (1992)

Environmental Issues

Environmental impacts

- REUSE may alter land use
- conflict with any land use plans or policies
- wetlands will be adversely impacted
- endangered species or habitat
- displace populations or alter existing residential areas
- adversely affect a flood plain or important farmlands

3.0 WATER REUSE GUIDELINES

- to provide safe water supply and safe disposal of wastewater.

Factors affecting water reuse guidelines and regulations

Factor	Description
Public health protection	Microbiological and environmental concern for nonpotable water. For potable, concern on pathogenic and microorg.
Use area control	Safety precautions : warning sign, fencing, color coded pipe
Use requirements	The effect on crops, soil and groundwater.
Environmental	Flora and fauna around reclaimed water reuse areas.
Aesthetics	Urban irrigation, toilet flushing : odorless, colorless, clear. Recreational : should not promote algal growth.
Economics	Cost effective.
Politic realities	Influence by public policy, public acceptance, technical feasibility and financial considerations.

Signs Board



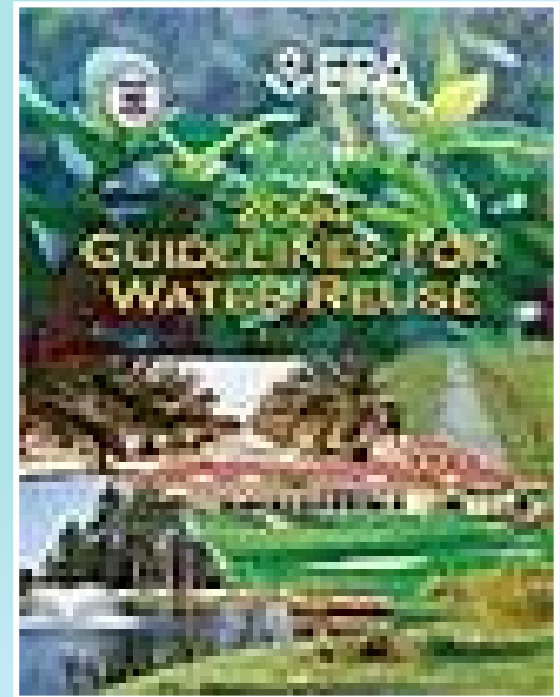
Water reuse sign in parks in New Jersey



Water Reclamation sign in Long Beach

U.S. EPA Guidelines for Water Reuse

- The U.S. EPA, in conjunction with the U.S. Agency for International Development (U.S. AID), published *Guidelines for Water Reuse* in 1992 and have been updated in 1994.
- Address various aspects ;
 - recommended treatment process
 - reclaimed water quality limits
 - monitoring frequencies
 - setback distances
 - other controls for water reuse applications



U.S. EPA suggested guidelines for reuse of municipal wastewater

Types of reuse	Reclaimed water quality	Reclaimed water monitoring	Setback distance
All types of landscape irrigation, vehicle washing, toilet flushing, fire protection systems and air conditioner	- pH = 6-9 - BOD = $\leq 10\text{mg/l}$ - Turbidity = $\leq 2\text{NTU}$ - No detectable fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - Turbidity : continuous - Coliform : daily - Cl_2 residual : continuous	- 15m to potable water supply wells
Surface or spray irrigation of any food crop	- pH = 6-9 - BOD = $\leq 10\text{mg/l}$ - Turbidity = $\leq 2\text{NTU}$ - No detectable fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - Turbidity : continuous - Coliform : daily - Cl_2 residual : continuous	- 15m to potable water supply wells
Surface irrigation of orchards and vineyards	- pH = 6-9 - BOD = $\leq 30\text{mg/l}$ - Turbidity = $\leq 2\text{NTU}$ - No detectable fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - TSS : daily - Coliform : daily - Cl_2 residual : continuous	- 90m to potable water supply well - 30m to public access (spray)

U.S. EPA suggested guidelines for reuse of municipal wastewater... cont'd

Types of reuse	Reclaimed water quality	Reclaimed water monitoring	Setback distance
Recreational - fishing, boating, incidental contact with reclaimed water allowed	- pH = 6-9 - BOD = $\leq 10\text{mg/l}$ - Turbidity = $\leq 2\text{NTU}$ - No detectable fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - Turbidity : continuous - Coliform : daily - Cl_2 residual : continuous	- 150m to potable water supply wells if bottom not sealed
Landscape - public contact with reclaimed water not allowed	- BOD = $\leq 30\text{mg/l}$ - TSS = $\leq 30\text{mg/l}$ - ≤ 200 fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - TSS : daily - Coliform : daily - Cl_2 residual : continuous	- 150m to potable water supply wells if bottom not sealed
Once through cooling	- pH = 6-9 - BOD = $\leq 30\text{mg/l}$ - TSS = $\leq 30\text{mg/l}$ - ≤ 200 fecal coli/100ml - $\geq 1\text{mg/l}$ Cl_2 residual	- pH : weekly - BOD : weekly - TSS : daily - Coliform : daily - Cl_2 residual : continuous	- 90m to areas accessible to public

U.S. EPA suggested guidelines for reuse of municipal wastewater...cont'd

Types of reuse	Reclaimed water quality	Reclaimed water monitoring	Setback distance
Wetlands, marshes, wildlife habitat, stream augmentation	- BOD = $\leq 30\text{mg/l}$ - TSS = $\leq 30\text{mg/l}$ - ≤ 200 fecal coli/100ml	- BOD : weekly - TSS : daily - Coliform : daily - Cl_2 residual : continuous	
Groundwater recharge by spreading into potable aquifers	- Meet drinking water standards after percolation through vadose zone	- Includes, but not to limited to the following; - pH : daily - coliform : daily - Cl_2 residual : continuous - BOD : weekly - Turbidity : continuous	- 150m to extraction wells. Vary depend on treatment and site conditions

Regulatory Considerations for Agricultural Irrigation

- The major health concern for agricultural irrigation is the potential contamination of food crops and resulting adverse effects to consumers of the crops.
- Important considerations ;

(a) Crop Contamination

Spray or surface irrigation of root crops such as carrots results in direct contact. While indirect contact occur by blowing dust or by workers, birds that convey organisms from irrigation water or soil to crop.

(b) Concern for pathogens

Many pathogens can survive for extended period on plants and in soil between irrigation and crop harvest period.



(c) Crop Processing

Transmission of infectious organisms may occur during handling crops that are contaminated and from selling or distributing the crops before processing.

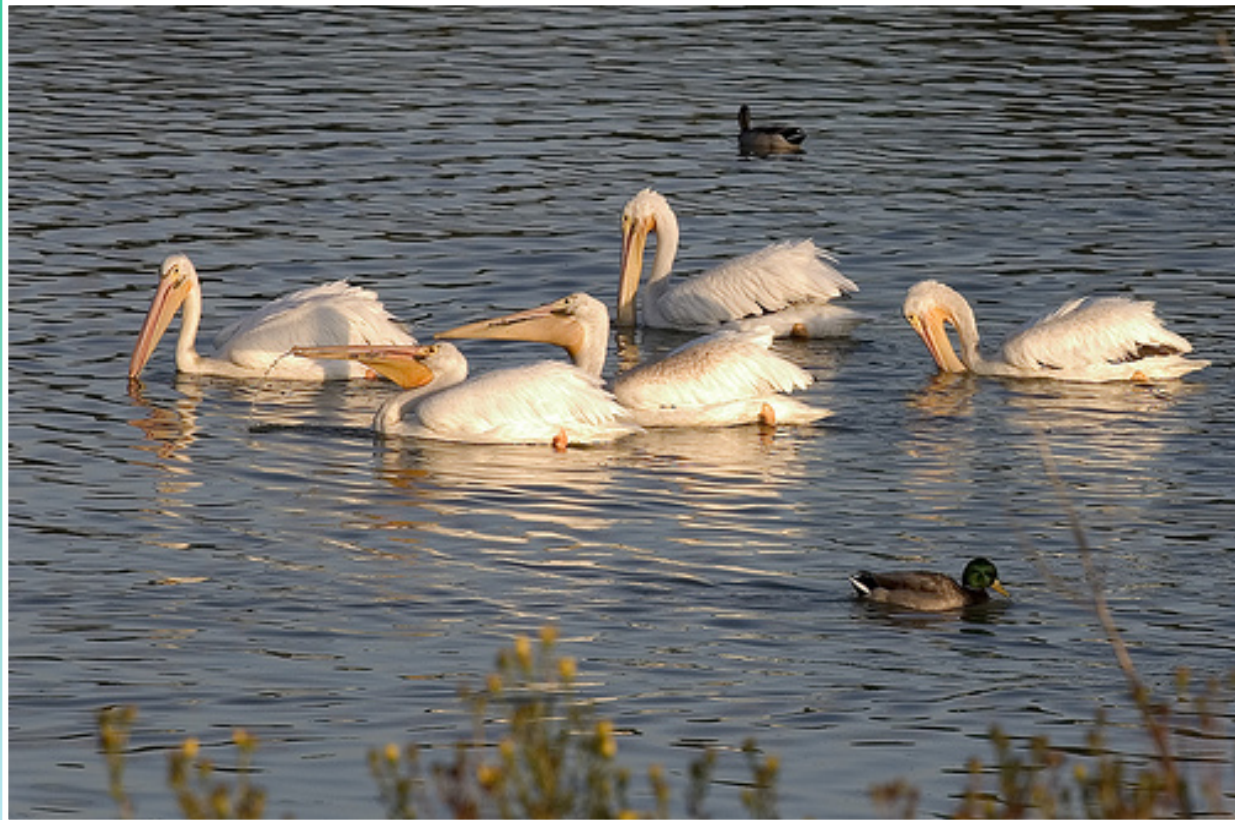
(d) Trace Constituents

Some can accumulate in particular crops, however most trace organic compounds are too large to pass through semipermeable membrane of plant roots (US EPA, 1981).



(e) Level of Treatment

Depends on water quality, type of crop irrigated, method of irrigation, and degree of contact between crop and reclaimed water.



White pelicans at the Las Gallinas Valley Sanitation District's Bird Habitat and Wastewater Reclamation Project, McInnis County Park, San Rafael, California.

Regulatory Considerations for Landscape Irrigation

- Considerations for landscape irrigation includes ;

- (a) Level of Public Access

- Usually takes place in urban areas where has closed contact with the public. So, the need to reduce the level of microbial pathogens in irrigation water becomes more important.

- (b) Trace Constituents

- EDCs maybe present and can migrate to groundwater used as drinking water supply sources or accumulated in turf or soil that can be ingested or contacted by children.

- (c) Use Area Controls

- Include signs warning, protect drinking water fountains from direct contact with irrigation water confine the reclaim water and irrigate during off-hours.

4.0 WATER REUSE APPLICATIONS

Water reuse categories and typical applications

Category	Typical application
Agricultural irrigation	Crop irrigation Commercial nurseries
Landscape irrigation	Parks School yards Golf courses
Industrial recycling and reuse	Cooling water Boiler feed
Recreational/environmental uses	Lakes and ponds Fisheries
Non-potable urban uses	Fire protection Air conditioning
Potable reuse	Blending in water supply reservoirs Direct pipe to pipe water supply

Agricultural Irrigation

- Evolved from the early practice of sewage farming when untreated sewage was directly applied to crops.
- The required treatment vary depends on the use of the crop (food or nonfood purposes) and how the irrigation water is to be applied.
- For example : for food crops, higher levels of treatment including disinfection is mandatory.
- Other considerations ;
 - type of crop
 - topography and soil characteristics
 - effect of water quality
 - runoff and drainage water management
 - infrastructure requirement





Operations of three agricultural projects in Aqaba, Wadi Mousa, and Irbid, for Jordan Water Reuse program.



Irrigation and mulching using reclaimed water & drip pipes



Planting activities

Landscape Irrigation

- The second largest user of reclaimed water in U.S.
- Comprise of various locations ;
 - Golf courses
 - Parks
 - Residential
 - Roadway medians
 - Roadside plantings
 - Cemeteries
- Other considerations include ;
 - limiting the formation and dispersion of aerosol
 - managing application rates to avoid ponding and runoff
 - controlling chlorine residuals to maintain proper disinfection





The Koele Golf Course has used recycled water for irrigation since 1994. The pond shown is recycled water, as is all the water used to irrigate this world-class golf course in the state of Hawaii.



In the Narragansett Bay, wastewater from the Field's Point WWTF that has been treated and cleaned flows into the Providence River, and wastewater from the Bucklin Point WWTF flows into the Seekonk River. Combined sewer from these rivers ultimately flow into Narragansett Bay.

Wetland in Nevada



Industrial Uses

- Major industrial users ;
 - power plants
 - oil refineries
 - manufacturing facilities where water is required for cooling purposes
- Specific concern : water quality (total dissolved solids, chlorides and DO) can cause potential scaling or corrosion in piping systems and heat exchangers.
- Residual organic matter : contribute to biological growths in heat exchangers and cooling towers.
- Other considerations ;
 - matching supply with demand
 - system reliability
 - disposal of cooling tower blowdown



The Palo Verde Nuclear Generating Station, located near Phoenix Arizona, uses recycled water for cooling purposes.

Urban Non-irrigation Uses

- Consist of ;
 - air conditioning
 - fire protection
 - toilet flushing
 - ornamental water features
 - road care and maintenance
 - car wash
 - laundries
- Limited to high-density development such as office and apartments to install a dual distribution system (one system for potable water and one for reclaimed water).
- Considerations ;
 - high cost infrastructure
 - prevention of cross-connection between two water supplies
 - high quality and disinfected reclaimed water



Water reuse reclamation laundry.

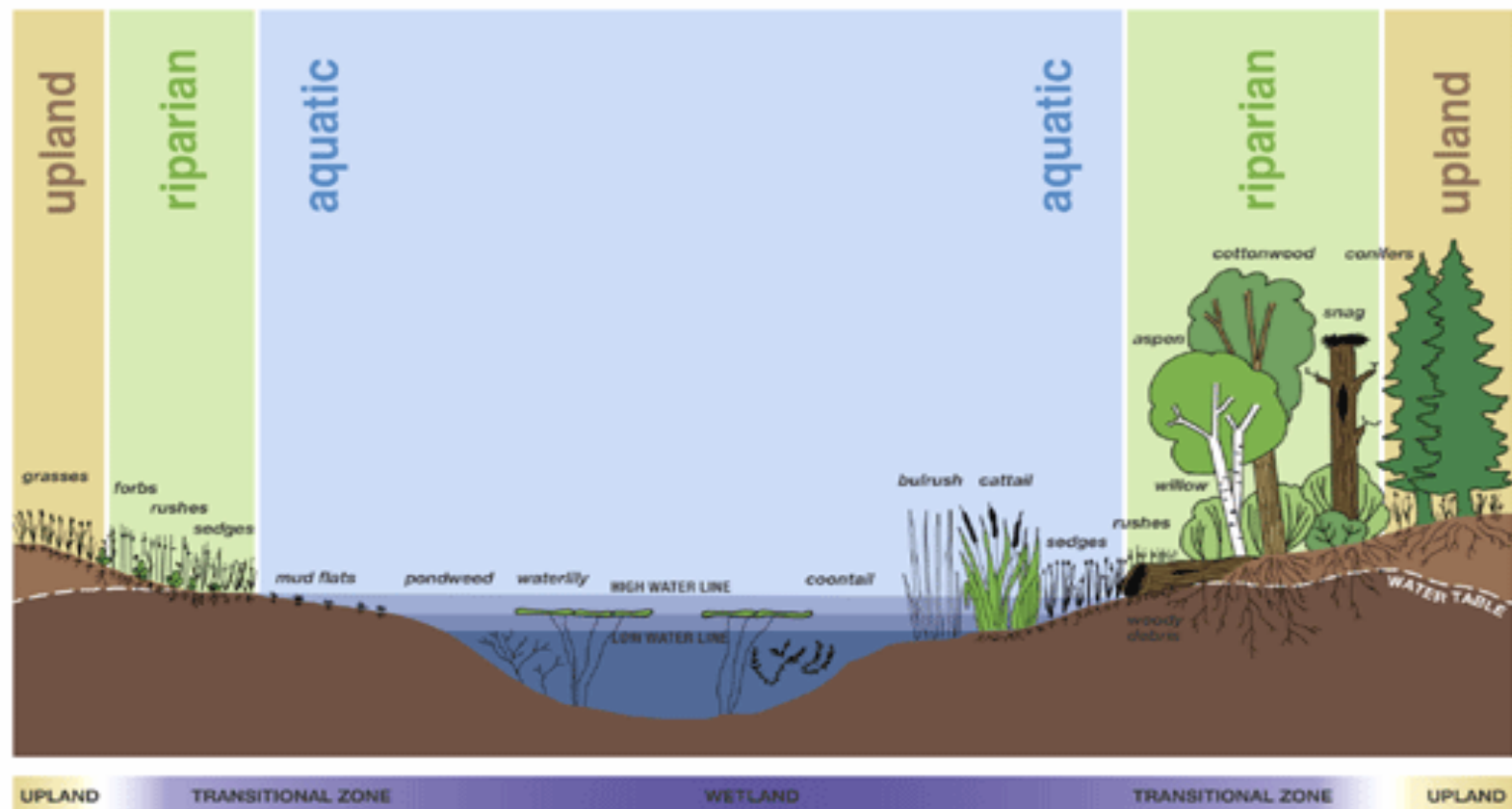


The Irvine Ranch Water District provides recycled water for toilet flushing in high rise buildings in Irvine, California.

Environmental and Recreational Uses

- Applied to ;
 - wildlife habitat maintenance
 - enhancement in wetlands
 - low flow augmentation in rivers
 - recreational lakes and ponds
- Considerations ;
 - type of waterbody
 - degree of public contact
 - need for nutrient
 - enhanced suspended solids removal
 - continuous versus intermittent use
 - matching supply with demand
- Plants, wildlife, and fish depend on sufficient water flows to their habitats to live and reproduce.

A Typical Wetland





The development of water recycling projects in Los Angeles has provided a way to partially offset the loss of Mono Basin water, and to allow the restoration of Mono Lake to move ahead.

Groundwater Recharge

- In ground water recharge projects, recycled water can be spread or injected into ground water aquifers to augment ground water supplies, and to prevent salt water intrusion in coastal areas.
- Has been used to ;
 - reduce, stop, or reverse declines of groundwater levels
 - protect underground freshwater in coastal aquifers against saltwater and brackish water intrusion
 - store surface water, including flood or other surplus water and reclaimed water for future use
- Water quality requirements include ;
 - nitrogen removal or reduction
 - control of organic and inorganic contaminants





For over 35 years, in the Montebello Forebay Ground Water Recharge Project, recycled water has been applied to the Rio Hondo spreading grounds to recharge a potable ground water aquifer in south-central Los Angeles County.

Indirect and Direct Potable Reuse Through Surface Water Augmentation

- A number of projects use recycled water indirectly for potable purposes.
- Include recharging ground water aquifers and augmenting surface water reservoirs with recycled water.
- Planned indirect potable use is careful and deliberate process to augment water resources while maintaining health and environmental safeguards.
- A potable water reclamation plant was completed in 1968 in Windhoek, Namibia to meet severe water shortages. The reclaimed water is blended with conventionally treated surface water.



Dual pipe distribution system, wastewater coming from bathtubs, showers, lavatories, and clothes washers are no longer required to discharge into sewer main. This gray water (blue pipe) is collectable for the use of flushing toilet and subsurface landscape irrigation if the proper procedure is followed.

Selection of Water Reuse Applications

- The selection is driven by several factors ;
 - (a) Water quality considerations
Extremely important especially where health and environmental issues are concern.
 - (b) Types of technology
Depth and surface filters, membrane filtration, carbon adsorption, reverse osmosis, disinfection with UV radiation and advanced oxidation are suitable treatment for most water reuse applications.
 - (c) Matching supply with demand
Characterization of water use requirements over time, can be used to analyze infrastructure needs.

(d) Infrastructure and economic requirements

Evaluate the feasibility of a water reuse project because it have a significant influence on the economic affordability.

(e) Environmental considerations

Identify probable environmental effects, provide alternative actions and involve public and environmental agencies participate in the decision process.



5.0 WATER RECLAIMED AND REUSE PROJECTS

(a) Australia (Kwinana Water Reclamation Plant)

The \$25-million plant will expand Perth 's water use options and help achieve the aims of the West Australian Government's State Water Strategy. An immediate benefit will see the amount of treated industrial wastewater discharged into Cockburn Sound reduced by about six million litres a day. There will be a reduction in the treated wastewater flow from the Woodman Point wastewater treatment plant through the Sepia Depression Ocean Outlet.



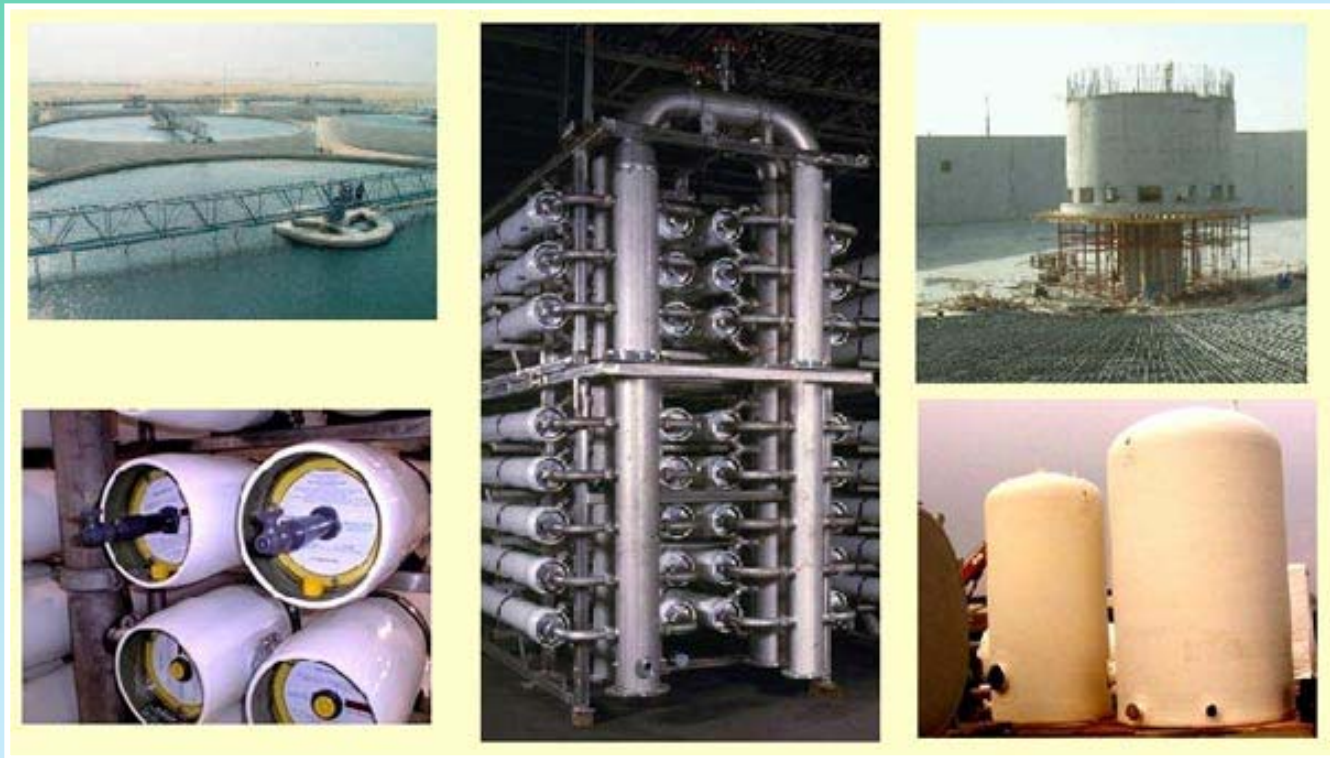


(b) Japan (Makuhari New Center Water Recycling Project, Tokyo)

Uses tertiary treated reclaimed water for toilet flushing, cleansing, and environmental water in a convention center, commercial buildings, hotels and parks. Operation began in 1989 and supply capacity is 4120m³/d.

(c) Kuwait (Sulaibiya Wastewater Treatment and Reclamation Plant)

Reclaimed water from Ardiya WTP with some treated effluent from Riqqa is directed to Data Monitoring Center storage reservoirs before transfer, for agricultural and landscape irrigation in Sulaibiya. The project also involved reforestation. The charge for treated effluent supplied to private farms are \$0.07/m³.

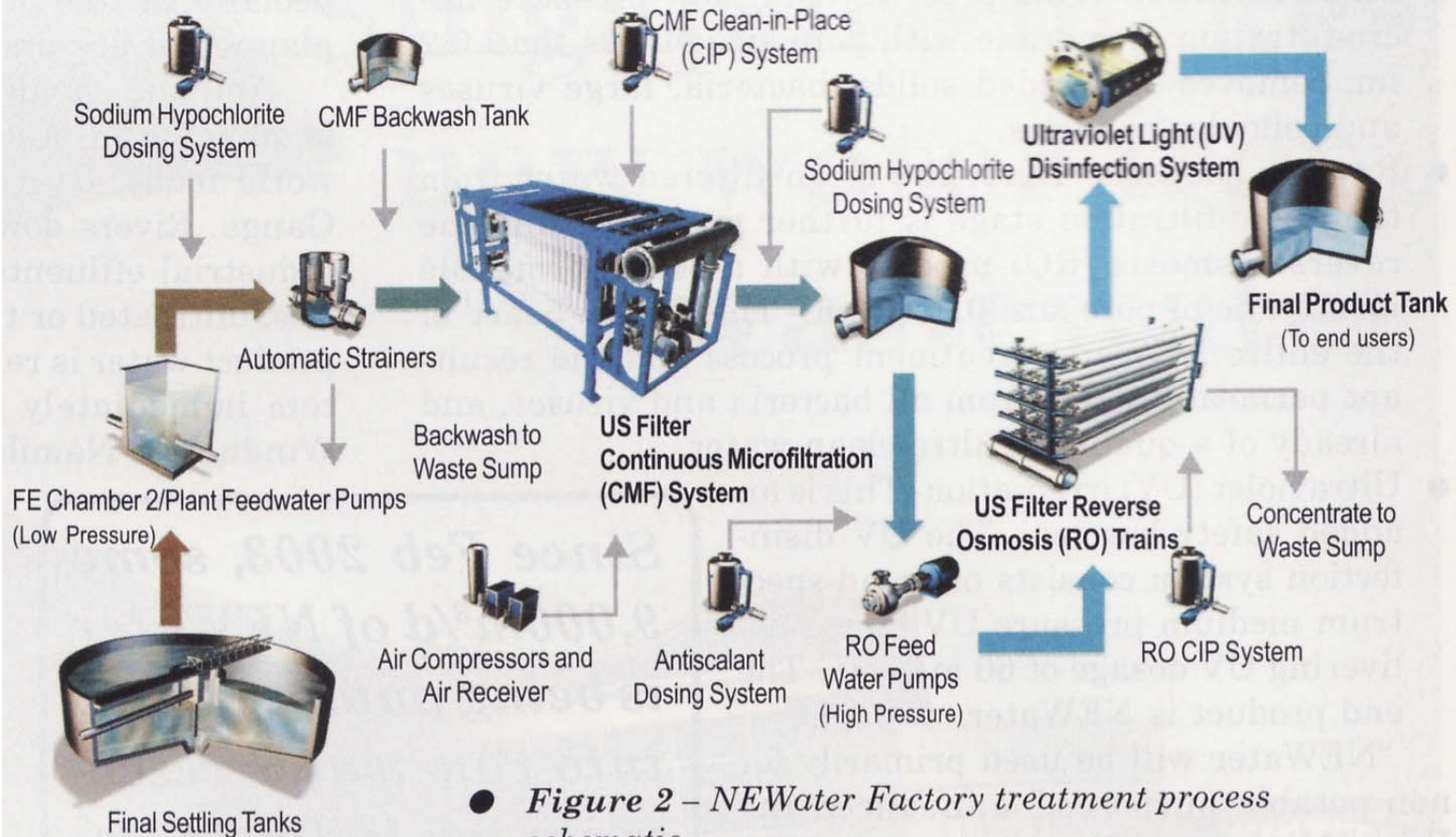


(d) Singapore (NEWater Study)

Reclaimed water that undergone stringent purification and treatment process using advanced dual- membrane and UV disinfection. In 2003, it supplied water to wafer fabrication plant at Woodlands. It also supply indirect potable use by pumping NEWater into reservoir and mixed with raw water. The mixed water undergoes naturalization process before being treated again to produce drinking water.



NEWater Factory - PROCESS FLOW SCHEMATIC



● *Figure 2 – NEWater Factory treatment process schematic.*

6.0 CONCLUSIONS

- As water demands and environmental needs grow, water recycling will play a greater role in our overall water supply.
- By working together to overcome obstacles, water recycling, along with water conservation, can help us to conserve and sustainably manage our vital water resources.

Thank You..