Chapter 8

Non-Conventional Water Resources
Main points

- Wastewater Use
- Wastewater and Effluent Characteristics
- Wastewaters Characteristics Relative to Agricultural Use
- Wastewater Treatment
- Minimizing Health Hazards in Wastewater Use in Irrigation
- Crop Restrictions and Irrigation Practices
- Monitoring and Control for Safe Wastewater Use in Irrigation
- Wastewater for Aquifer Recharge
- Non-agricultural Uses of Wastewater
- Use of Brackish, Saline, and Drainage Waters
- Characteristics and Impacts of Saline Waters
- Criteria and Standards for Assessing the Suitability of Water for Irrigation
- Crop Irrigation Management Using Saline Water
- Leaching Requirements and Control of Impacts on Soil Salinity
- Long-Term Impacts: Monitoring and Evaluation
- Non-agricultural Use of Saline Waters
- Desalinated Water
- General Aspects and Treatment Processes
- Extent of Use, Costs and Environmental Impacts of Desalination
- Fog-Capturing, Water Harvesting, Cloud Seeding, and Water Transfer
Inferior quality water

• Whenever good quality water is scarce, water of inferior quality will be considered for use in agriculture, irrigation of lawns and gardens, washing of pavements, and other uses not requiring high quality water.

• Nonconventional water is defined as water that possesses less-than-favorable characteristics which have the potential to cause problems.

• The use of non-conventional water requires adoption of more complex management practices and more stringent monitoring procedures.

• Non-conventional waters include saline water, brackish water, agricultural drainage water, water containing toxic elements and sediments, as well as treated or untreated wastewater effluents.

• Non-conventional waters also include desalinated water and water obtained by fog capturing, weather modification, and rainwater harvesting.
Wastewater use

- When used for irrigation, the nitrogen and phosphorus content of sewage might reduce the requirements for commercial fertilizers.

- Treated industrial effluents can be reused in the same industrial plant, treated municipal wastewater can be used in aquaculture (water farming for fish production), for the irrigation of lawns and recreational areas, and for low quality domestic water uses when separated (dual) municipal distribution systems are available.

- In arid and semi-arid areas, irrigation is the only reliable means of increasing agricultural production on a sustainable basis. Water produced from saline aquifers or resulting from field drainage has to be used/reused for irrigation of agricultural crops along with wastewaters.

- In case of reuse of drainage waters, agriculture acts both as a user of the water and as a disposal site, so contributing temporarily to control of potential environmental impacts from salts carried by those waters.
Unconventional water sources

- **Desalinated waters** are commonly added to the fresh waters for domestic uses. They are free from toxic substances or pathogens and can be used for most human requirements. Because of its low level of salts and the high costs associated with treatment, desalinized water is less appropriate for agricultural uses.

- **Fog capturing** is used in isolated arid areas in mountains and islands where the occurrence of fog is common but rainfall is rare.

- **Cloud seeding** is a process of augmenting rainfall by adding substances to the cold clouds that act as nucleii for the formation of large water drops that otherwise would not fall to the ground.

- **Water importation** mainly consists of transferring water from a basin where it may be in excess to the demand into another basin where water demand is greater than the natural supply.
Wastewater treatment & reuse

Pre-treatment
- Separation of solids, coarse screening

Primary treatment
- Primary sedimentation for organic & inorganic solids, skimming of oils & greases
- Secondary sedimentation, removal of suspended solids

Secondary treatment
- Biological aerobic treatment, removal of residual organics, soluble BOD\(_5\) and suspended solids
- Clarification and removal of micro-organisms

Tertiary treatment
- Chemical coagulation, sedimentation & filtration for removal of suspended and colloidal solids

Quaternary treatment
- Chemical coagulation, sedimentation & filtration for removal of suspended and colloidal solids

Advanced treatment
- Disinfection
- Reverse osmosis or distillation & remineralization

Water for irrigation of non-food crops, full health restrictions must apply
Water for irrigation of crops which are not eaten without cooking
Water for street and floor washing, water for irrigation of gardens, golf courses and crops which are not eaten without cooking
Water for unrestricted crop irrigation
Water for unrestricted uses
Levels of health risk

Public health risk from using wastewater in irrigation

- Crops not for human consumption
- Crops processed by heat or drying before human consumption.
- Vegetables and fruits grown exclusively for canning or processing
- Fodder crops/animal feed crops

- Pasture, green fodder crops
- Crops that do not come into direct contact with wastewater.
- Crops eaten only after cooking
- Crops the peel of which is not eaten
- Crops under sprinkling

- Crops eaten uncooked grown in close contact with wastewater
- Landscape irrigation with public access

Lowest risk to the consumer, but for the field worker protection is needed

Increased risk to consumer, field worker and handler

High risk to consumer, field worker and handler
Minimizing health hazard

• A potential for disease transmission exists when wastewater is used for irrigation because pathogens brought with the wastewater can survive for many days in the soil or on the crop.

• Factors influencing transmission of disease include the degree of wastewater treatment, the crops grown, the irrigation method used to apply the wastewater, and the cultural and harvesting practices used.

• The possible infection of field workers results from direct contact with the crop or soil in the area where wastewater is used.

• The only feasible means of dealing with the worker safety problem is to adopt preventive measures against infection. These include wearing protective clothing, including impermeable boots, maintenance of high levels of hygiene, and immunization against likely infections.

• International guidelines or standards for the microbiological quality of irrigation water used on a particular crop do not exist. Because there is a lack of direct epidemiological data, the standards and guidelines for the quality of wastewater used for irrigation are focused on effluent standards at the wastewater treatment plant, rather than at the point of use.
Uncontrolled & controlled wastewater reuse

Uncontrolled

Natural water bodies

Urban, domestic water use

Industry water use

Treatment

Agricultural & landscape water use

Controlled

Natural water bodies

Urban, domestic water use

Industry water use

Treatment

Agricultural & landscape water use
Onsite wastewater treatment

- An example from Brazil: a small plant consists of a collection system for home and roof waters, septic collection tanks, bioreactors, and solar radiation (UV) disinfection units. The resulting treated water is intended to be used for irrigation.
Brackish, saline & drainage waters

- Fresh water is considered to have a total dissolved solids (TDS) concentration of less than 500 mg/L. Saline and brackish water have 500-30,000 mg/L, while sea water has TDS averaging 35,000 mg/L.

- The major potential hazards associated with the use of saline water in agriculture are:
  1. Yield decrease of crops due to decrease of soil fertility.
  2. Soil degradation due to salinization and sodification (high sodium content).
  3. Negative environmental effects as nutrients in reused drainage effluents give rise to uncontrolled algal bloom.
  4. Public health risk: toxic ions such as heavy metals are potentially cancerous; and vectors of disease such as mosquitoes and snails develop better in saline water.
Crop irrigation management using saline water

- To **minimize the accumulation of salts** in the active root zone and to eliminate salt stress of plants:

1. Appropriate selection of irrigation methods.

2. Efficient leaching management, including volume and frequency, and respective drainage of the salty water away from the cropped land.

3. Proper irrigation scheduling compatible with irrigation system.

4. Crop rotations adapted to the prevailing conditions. Considerations must include irrigation water quality, soil salinity levels, chemical and physical properties of the soils, and climatic conditions.
Hazards related to agriculture

- The **selection of the irrigation method** must consider water quality and the potential for both water and irrigation method to produce negative agriculture impacts:

1. Soil salinity hazards due to salt accumulation in the root zone.

2. Toxicity hazards caused by direct contact of the salty water with the plant leaves and fruits.

3. Soil infiltration and permeability hazards caused by the modification of the soil physical properties, mainly due to sodium.

4. Yield hazards which may occur when the irrigation system does not allow adoption of appropriate irrigation management, i.e. frequency and volume of irrigation.
Strategies for irrigation with saline water

- The dual rotation management strategy in which sensitive crops (e.g. lettuce, alfalfa) in the rotation are irrigated with low salinity river water, and where salt-tolerant crops (e.g. cotton, sugarbeet, wheat, barley) are irrigated with saline drainage water.

- Blending which is a drainage reuse strategy where water supplies of different salinity levels are mixed in variable proportions before or during irrigation.

- Cyclic application of saline and fresh water: Salinity must not be above acceptable thresholds for the crops grown. Cycles of application of fresh water should coincide with the more sensitive growth stages, particularly for planting and seedling development, and for the leaching of the upper soil layers.
Non-agriculture use of saline water

- Low salinity brackish water is not appropriate for drinking or for animal consumption.

- **Conjunctive use** of saline water with high quality water, for example from roof-top collection, should be adopted.

- For large populations, when a separated municipal distribution system is available, brackish saline water may be used for low quality demanding uses such as **toilet flushing and washing**.

- Saline waters have an advantage over treated wastewaters in that they tend to be free of pathogens.

- The presence of salt and its **corrosive potential** may affect the **piping system and equipment**. The cyclic use of good quality water for flushing salts accumulated in the pipe systems is recommended.
Desalinated water

- Desalination is a water treatment process that removes salts from saline water to produce water that is low in total dissolved solids (TDS).

- Desalination processes include:
  1. **Distillation**: relies on boiling and condensing water.
  2. **Electrodialysis**: uses a current through the water.
  3. **Reverse osmosis**: pressures the water through a filtering membrane.
  4. **Solar desalination**: uses solar energy to cause humidification, distillation, or photovoltaic separation.

- The TDS of saline water may range from 500 to 50,000 mg/L. Treatment of saline water may include **physical filtration**, **chemical conditioning**, and other processes. The desalinated water may have TDS in the range of 50 to 500 mg/L.

- The source of energy input into desalination plants is usually **thermal**, **electrical**, or **mechanical**, and very often is a combination thereof.
Environmental impact of desalinated water

- It requires **significant land area** for the facilities, although this is not much larger than any other treatment facility, which may cause some impact on the landscape.

- It is **energy intensive** with energy consumption greater than that used in other water treatment process. This high consumption has implications regarding carbon dioxide (CO$_2$) production.

- It **may be noisy**, which impacts nearby populations.

- Brine disposal is a **serious problem** where it must be transported to the sea through brine pipelines, or for drying in evaporation ponds. Brine would need to be diluted before disposal into the sea.

- Possibility of **contamination of the brine by chemicals** used in the pre-treatment process, with by-products of membrane and tube cleaning, and/or by coagulants and aids in filters.
Fog capturing

- Fog capturing is achieved by means of appropriate screens that promote the coalescence of the small fog droplets to create larger drops with enough dimensions to flow down by gravity into collectors.

- The amount of water collected every day is small and depends on the properties of the air masses passing over the collection sites. The reliability of fog capturing is associated with the frequency of fog occurrence. When fog occurs nearly everyday, yield is about 3 L/day/m².

- Fog capturing is only feasible for human consumption for small populations living in water-scarce areas, and for drinking of animals.
Rainwater harvesting

- Roof-top rainwater harvesting plays a major role in making water available for **domestic uses and animal drinking in arid environments**.

- Care is required to keep stored water free from contamination by animals and sewage water. Drinking water should be boiled before consumption.

- To avoid contamination, appropriate drinking facilities should be used such as **drinking fountains connected to the reservoir by a pipe**.
Cloud seeding

- Cloud seeding is a method for **rainfall augmentation**.

- Wet air masses must be cold enough for water to form particles as ice crystals that coalescence to be large enough to create drops which can reach the ground as rain.

- In most low-lying arid areas, wet air masses are not as large, cold, or frequent as in mountainous areas. There, cloud seeding could be effective, but these are often unpopulated regions.

- During the 1980 drought in Morocco, cloud seeding over the Atlas mountains increased the rainfall by 10–15%.
Water transfer

- It is often a long distance transfer of water from basins in a humid or semi-humid zone to those in a semiarid environment.

- An example is the transfer of water from the Colorado River to irrigate the arid southern California, and to supply the Los Angeles and San Diego areas.

- Although water transfer is a rational way for increasing water availability in areas where demand exceeds supply, several factors contribute to a decline in interest in water transfer:
  
  1. It may contribute to an unbalanced regional development since the demand in the water importing area may exceed its overall ecological potential.
  2. Water exporting region may fall behind in development when compared with water importing regions.
Questions?