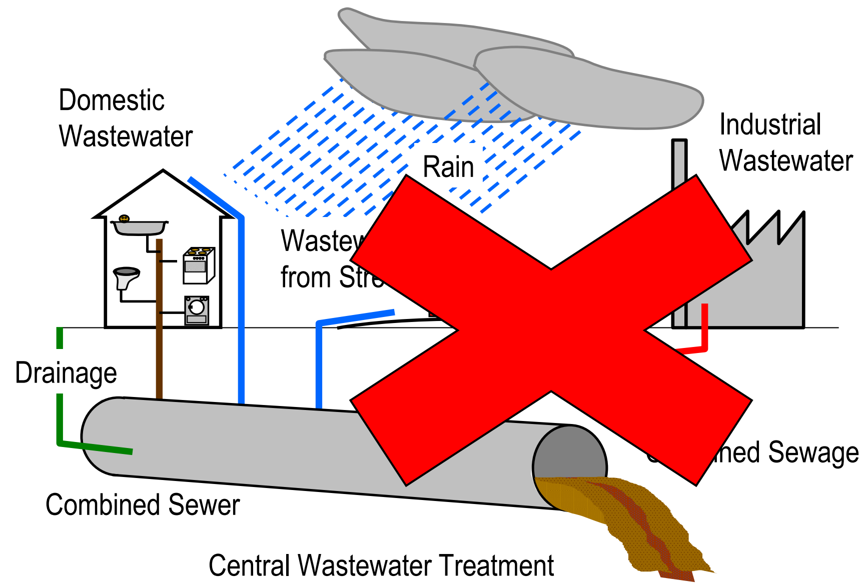
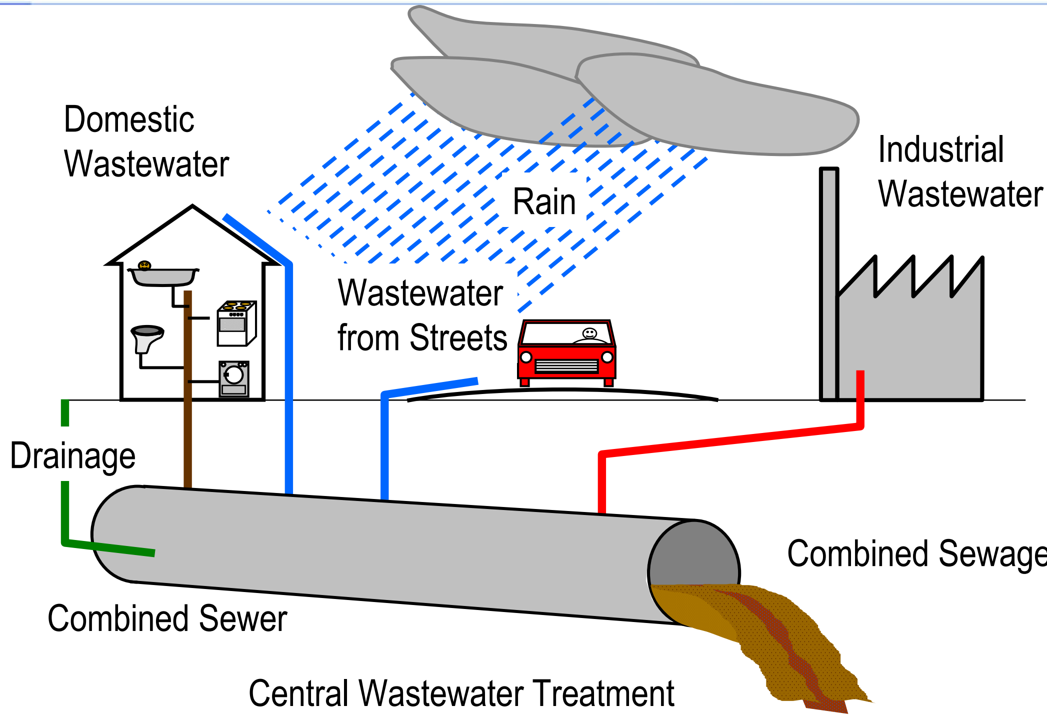
The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Reuse of Effluent

Re-use concepts, agricultural use of treated wastewater and cost effectiveness

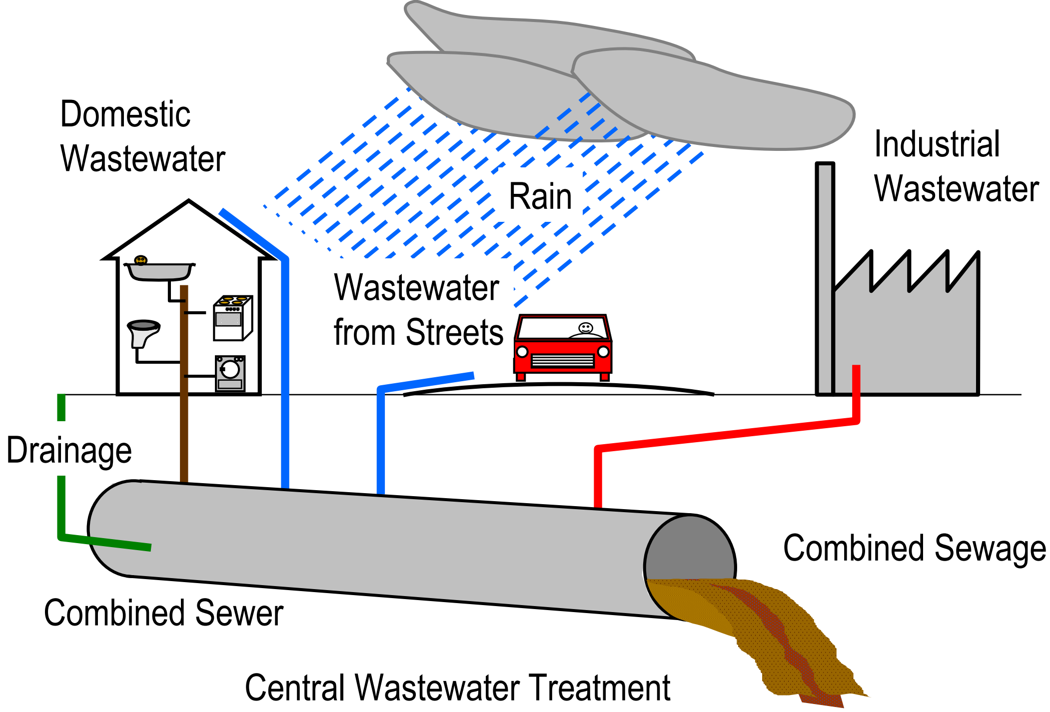


SWIM OLC
on
Natural Treatment Systems



Conventional Sanitation Systems

- Most important features
  - Collect all the wastes and wastewater in sewers
  - Build a central treatment plant
  - Discharge the treated effluent into a receiving stream



Conventional Sanitation Systems

- Most important features
  - Very costly to invest and operate
  - Continue pollute water even if comply the effluent standards
  - Discard nutrients in waterways

Wastewater is a resource

Irrigation water
Fertilizer
Energy

Wastewater reuse:

* improves financial and economic feasibility of wastewater treatment
* incentive for better operation and maintenance
* reduces environmental pollution

Sewage management

A Strategy

Pollution Prevention → Treat and re-use → Dispose 'self purification'

The 3 - Stage Approach

NH_4 to N_2

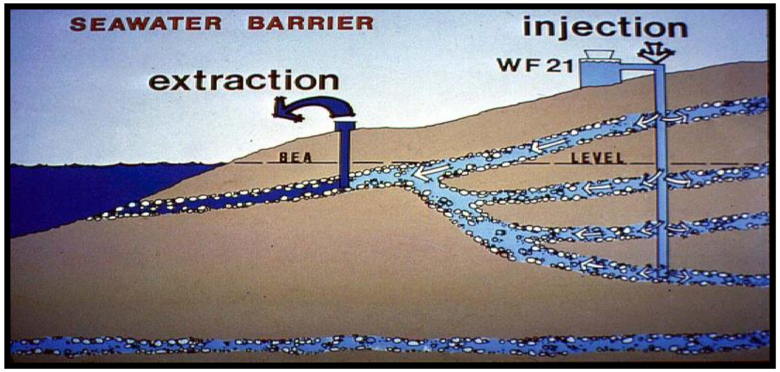
UNESCO-IHE
Institute for Water Education

NH4 to crops

Driving forces to increase reuse of treated wastewater

- Increasing water scarcity
- Degradation of fresh water resources resulting from improper disposal of wastewater
- Growing recognition of wastewater as a water and a nutrient source
- The millennium development goals (MDG) for ensuring environmental sustainability

Categories of reuse



- Planned/Intentional vs. Unplanned/Unintentional
- Potable vs. Non-potable
  - Agricultural irrigation
  - Urban irrigation
  - Industrial cooling and process water
  - Groundwater recharge
- Direct (Pipte-to-Pipe) vs Indirect (via groundwater/reservoir)

Categories of reuse

Category of reuse	Examples of applications
Urban	
Unrestricted	Landscape irrigation of parks, playgrounds,school yards, golf courses, cemeteries, residential green belts
Restricted	Irrigation of areas with infrequent and controlled access
Other	Fire protection, construction

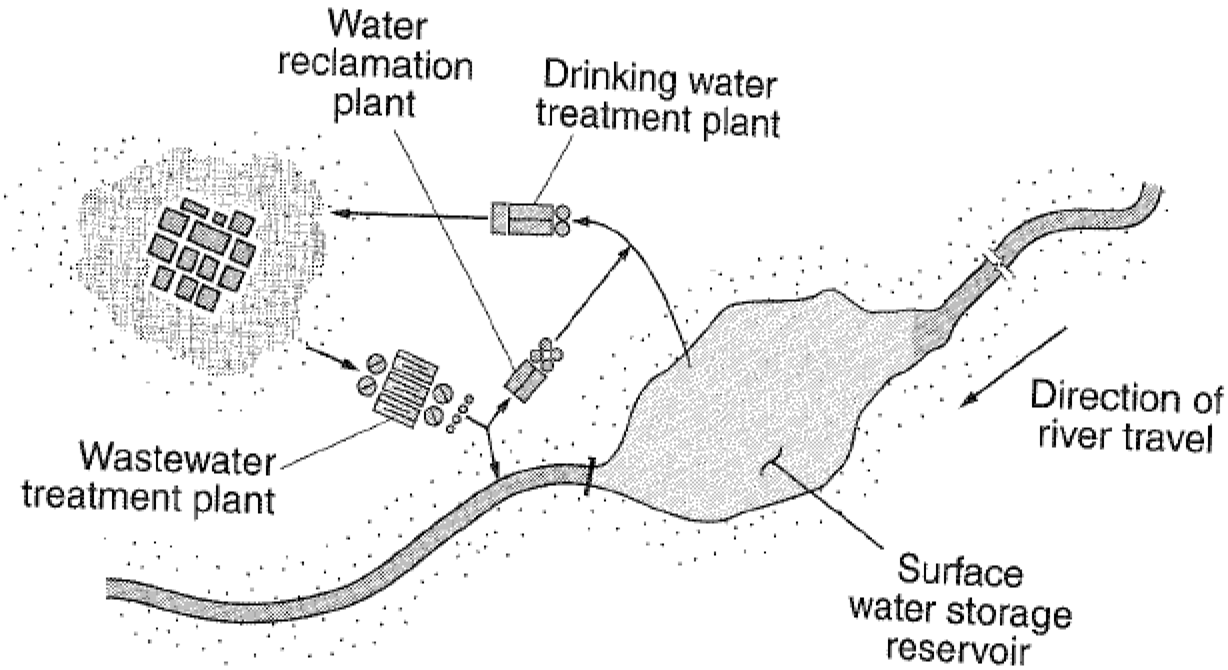
Categories of reuse

Category of reuse	Examples of applications
Agricultural	
Food crops	Irrigation for crops grown for human consumption
Non-food crops and crops consumed after processing	Irrigation for fodder, fibre, flowers, seed crops, pastures, commercial nurseries

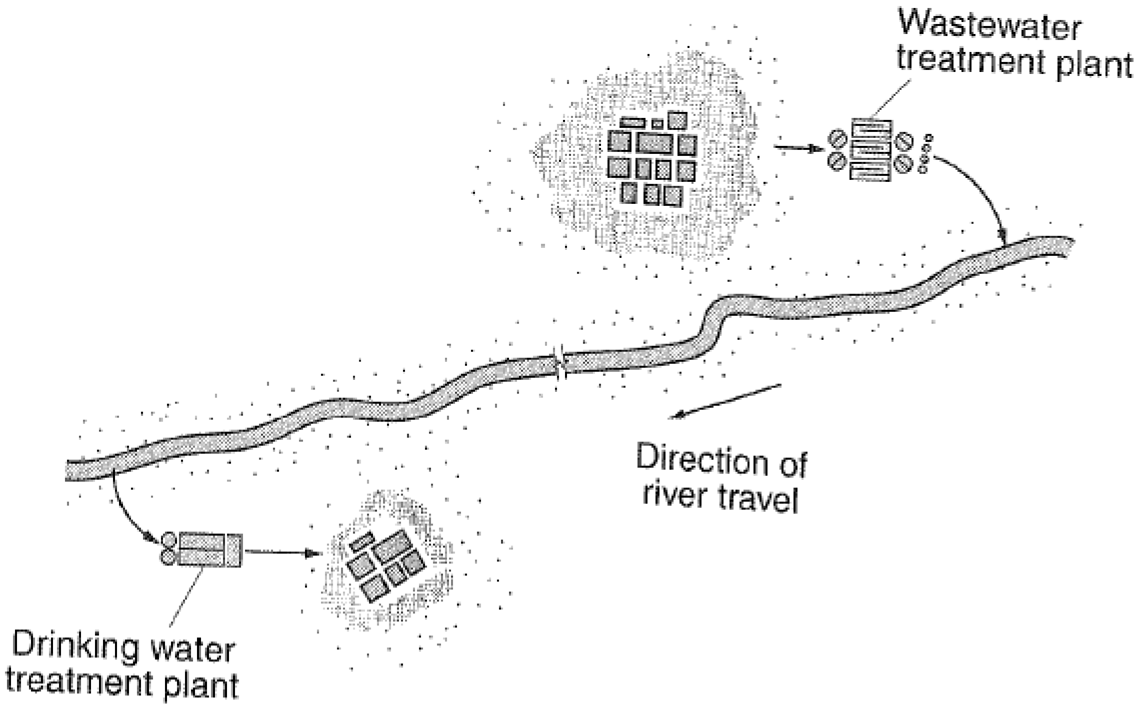
Categories of reuse

Category of reuse	Examples of applications
Recreational	Unrestricted – swimming Restricted – Fishing, boating
Environmental enhancement	Stream flow, artificial wetlands
Groundwater recharge	Replenishment, salt water intrusion control, subsidence control
Industrial	Cooling, process water, boiler feed
Residential use	Cleaning, laundry, toilet
Potable	

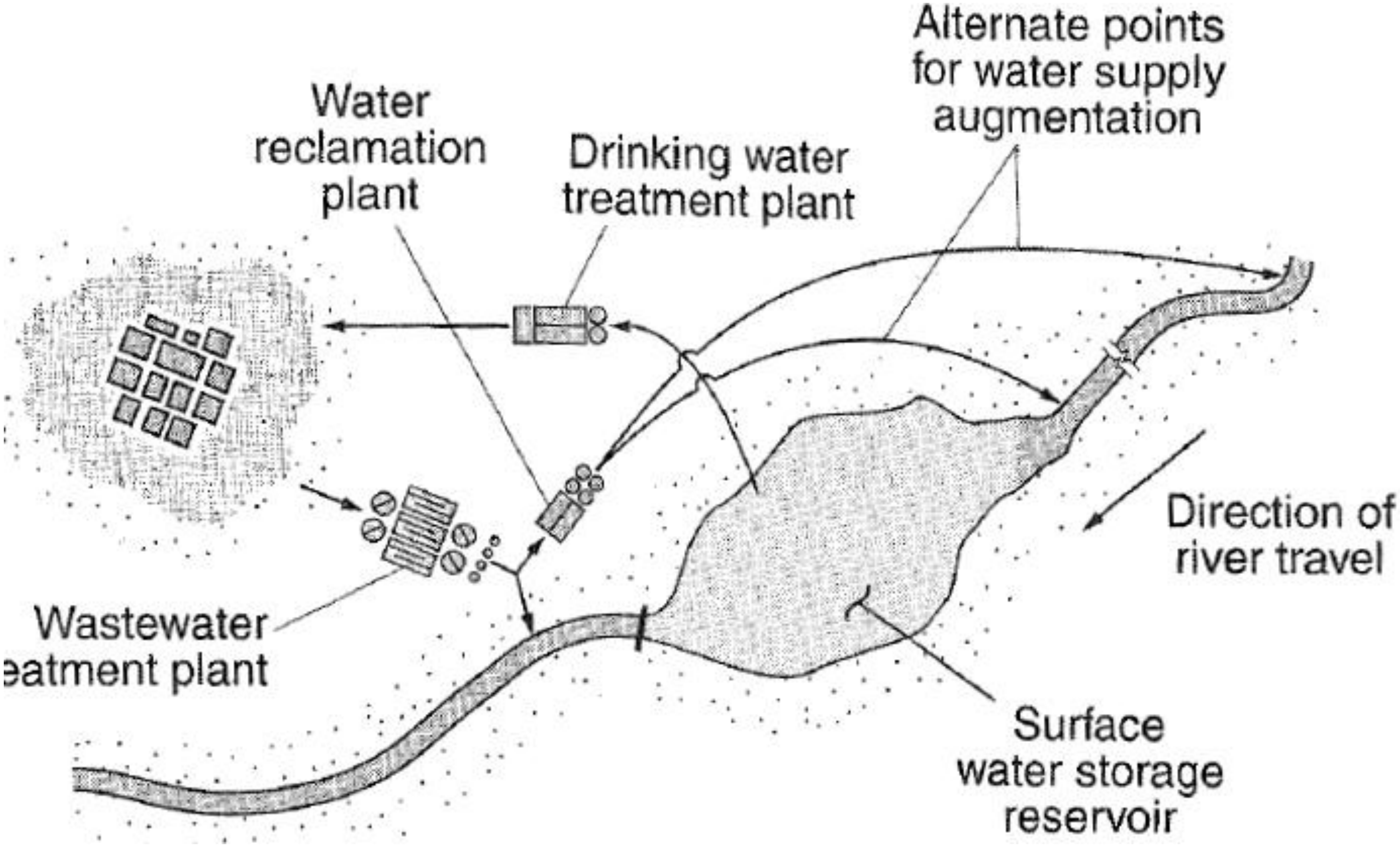
Direct potable use



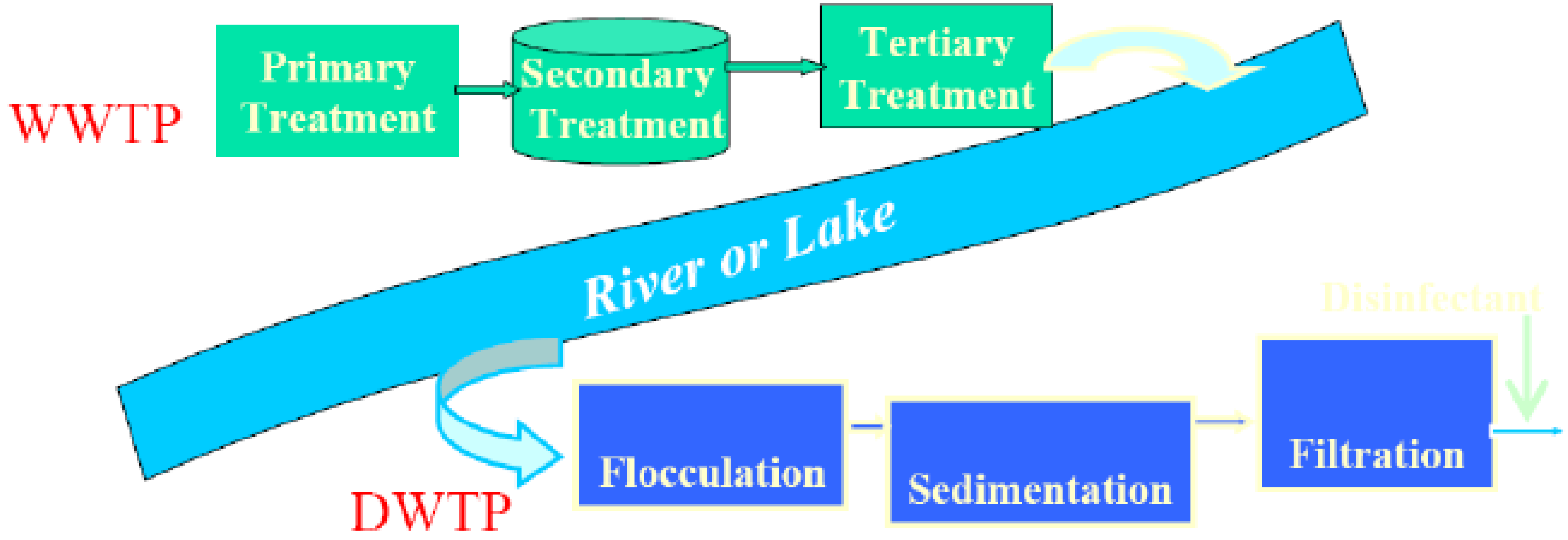
Unplanned indirect potable use



Planned indirect potable use



Is WW reuse being practised?

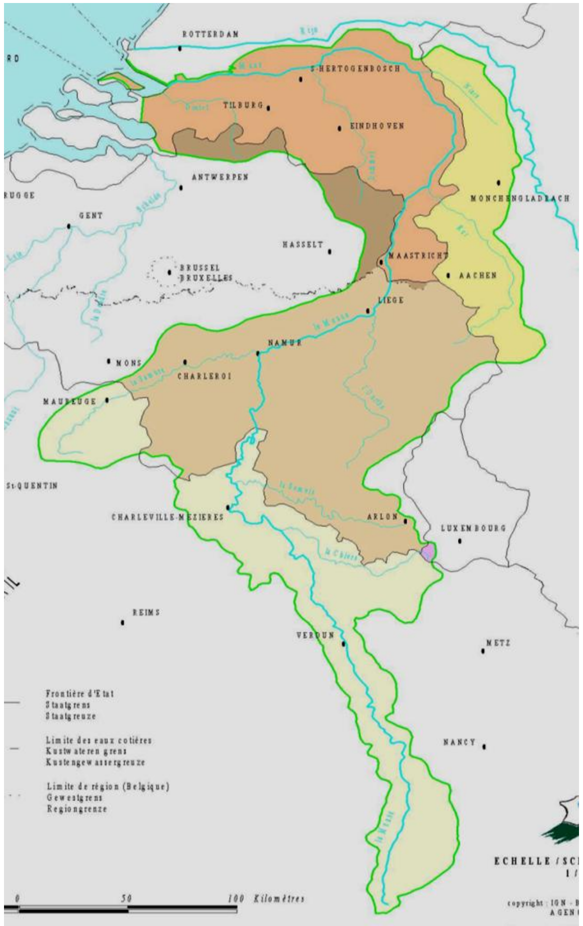


Unplanned indirect potable reuse: drinking water in Delft, The Netherlands

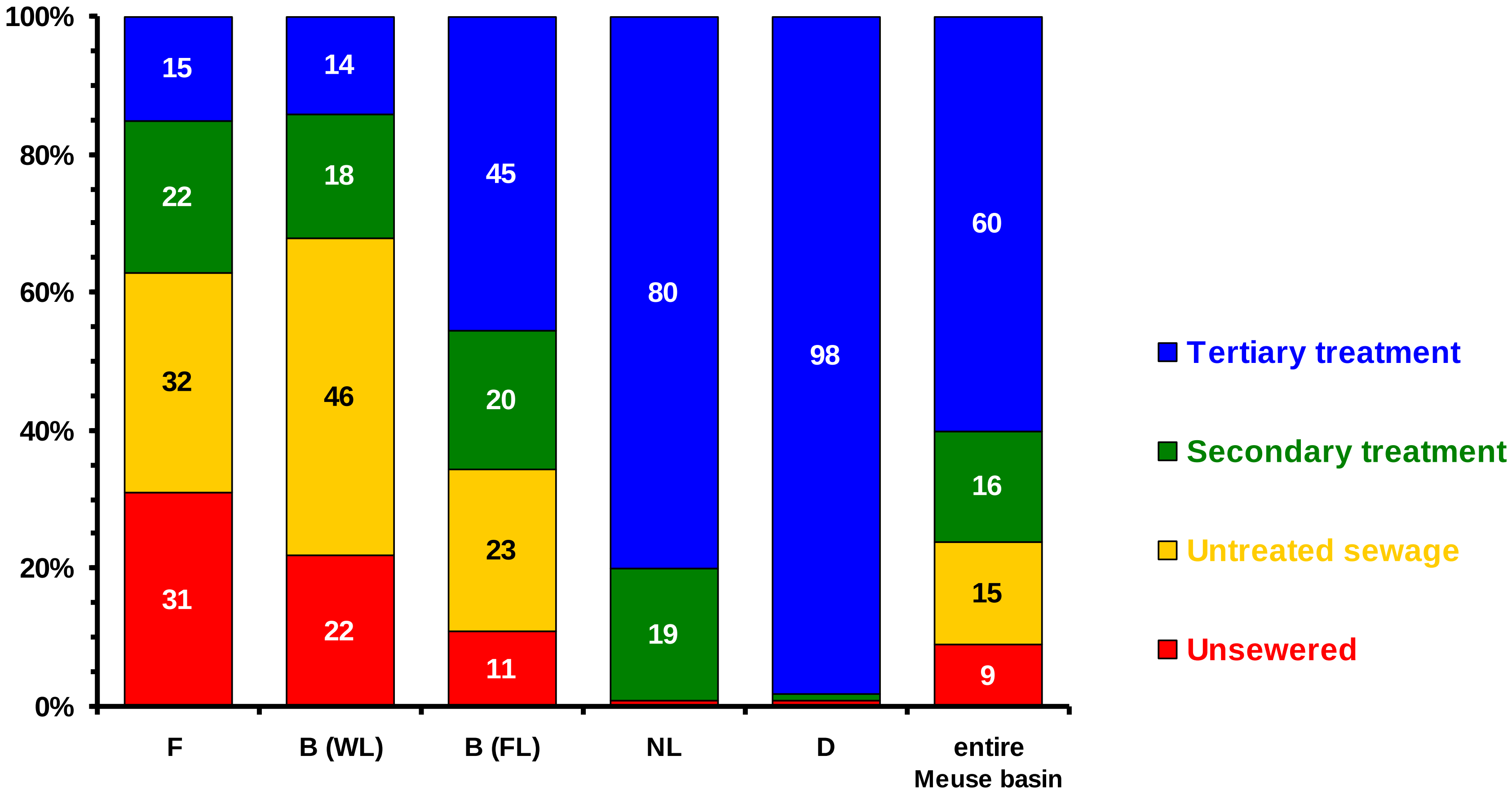
Meuse basin 33,000 km^2
Population 8 million

Mean river flow 325 m^3/s
Base river flow 35 m^3/s
Waste water load 20 m^3/s

Drinking water source for
6 million people (450 M m^3/year)
= 14 m^3/s



Sewage Disposal in the Meuse Basin



Planned direct potable reuse: Singapore

NEWATER = treated wastewater (including RO)

Unplanned non-potable reuse: Asmara, Eritrea

St. Petersburg – Florida US: planned non-potable reuse (for landscaping and garden irrigation) – dual distribution network

Constraints To Reuse

- Potable:
  - *Unknown* Health Effects
  - Microbial Risk (Viruses)
  - Chemical Risk (Trace Organic Chemicals)
  - Nitrogen (N) Species
- Agricultural:
  - TDS (Salt Toxicity)
  - Specific Ion Toxicity (e.g., Boron (B))
  - Attributes: Nutrients (N and P)
- Cooling Water:
  - TDS (Scaling Potential)

WHO realizes

- Reuse of wastewater, greywater and excreta in agriculture and aquaculture is practiced worldwide on a large scale, however often without sufficient health protection measures
- WHO recognizes the importance of reuse of wastewater, greywater and excreta for sustainable food production and improved livelihood
- WHO provides guidance on health protection measures for safe reuse
- WHO recognizes source-separation as a special and valid approach

Objective new targets: <u>maximize the protection of human health and the beneficial use of important resources</u>

New WHO publication in 2006 (3rd edition)

WHO guidelines for the safe use of wastewater, excreta and greywater:

- Volume 1: Policy and regulatory aspects (114 p.)
- Volume 2: Wastewater use in agriculture (222 p.)
- Volume 3: Wastewater and excreta use in aquaculture (162 p.)
- Volume 4: Excreta and greywater use in agriculture (204 p.)

www.who.int

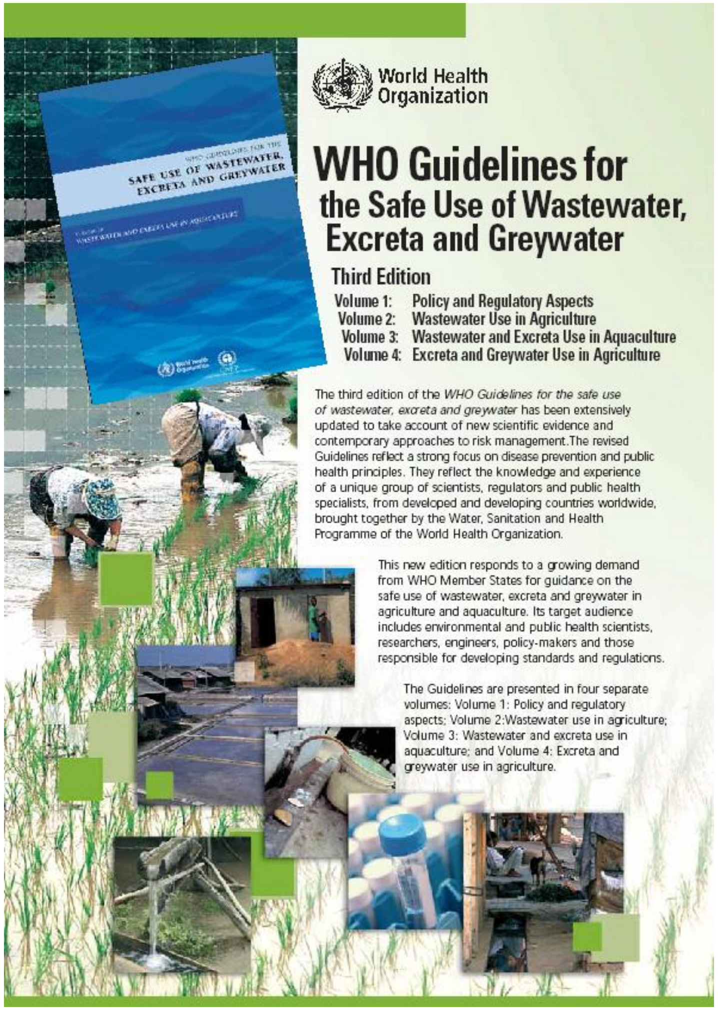
Update from the 1989 (and 1973) guidelines

Source: Werner (2005)

WHO 2006 guidelines

- The present 3rd ed. of the Guidelines has been based on radically different approach from the one taken in the 1973 and 1989
- 2006 Guidelines are based on a risk assessment (QMRA) and management approach
- QMRA estimates risks from a variety of different exposure and pathogens (difficult to measure using epidemiological studies: high costs, large populations)

WHO 2006 guidelines



World Health Organization

WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater

Third Edition

Volume 1: Policy and Regulatory Aspects
Volume 2: Wastewater Use in Agriculture
Volume 3: Wastewater and Excreta Use in Aquaculture
Volume 4: Excreta and Greywater Use in Agriculture

The third edition of the *WHO Guidelines for the safe use of wastewater, excreta and greywater* has been extensively updated to take account of new scientific evidence and contemporary approaches to risk management.The revised Guidelines reflect a strong focus on disease prevention and public health principles. They reflect the knowledge and experience of a unique group of scientists, regulators and public health specialists, from developed and developing countries worldwide, brought together by the Water, Sanitation and Health Programme of the World Health Organization.

This new edition responds to a growing demand from WHO Member States for guidance on the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Its target audience includes environmental and public health scientists, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The Guidelines are presented in four separate volumes: Volume 1: Policy and regulatory aspects; Volume 2:Wastewater use in agriculture; Volume 3: Wastewater and excreta use in aquaculture; and Volume 4: Excreta and greywater use in agriculture.

Volume 1 of the Guidelines presents policy issues and regulatory measures distilled from the technical detail found in volumes 2, 3 and 4. Those faced with the need to expedite the development of policies, procedures and regulatory frameworks, at national and local government levels, will find the essential information in this volume. It also includes summaries of the other volumes in the series and an index for all four volumes.

Volume 2 of the Guidelines explains requirements to promote safe use concepts and practices, including health-based targets and minimum procedures. It also covers a substantive revision of approaches to ensuring the microbial safety of wastewater used in agriculture. It distinguishes three vulnerable groups: agricultural workers, members of communities where wastewater-fed agriculture is practiced and consumers. It introduces health impact assessment of new wastewater projects.

Volume 3 of the Guidelines informs readers on the assessment of microbial hazards and toxic chemicals and the management of the associated risks when using wastewater and excreta in aquaculture. It explains requirements to promote safe use practices, including minimum procedures and specific health-based targets. It puts trade-offs between potential risks and nutritional benefits in a wider development context. Special reference is made to food-borne trematodes.

Volume 4 of the Guidelines focuses exclusively on the safe use of excreta and greywater in agriculture. Recent trends in sanitation, including ecological sanitation, are driven by rapid urbanization. The momentum created by the Millennium Development Goals is resulting in dramatic changes in human waste handling and processing. New opportunities enable the use of human waste as a resource for pro-poor agricultural development, particularly in periurban areas. Best practice to minimize associated health risks is at the heart of this volume.

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Reuse of treated wastewater in agriculture

Objective: Maximize the protection of human health and the beneficial use of important resources

protection of public health: ‘multiple barriers’ approach

- waste water treatment
- crop restriction
- irrigation technique
- human exposure control
- vaccination (curative)

Must be managed by Guidelines or standards

Good practices for risk reduction

WHO's *multiple barrier* approach from "Farm to Fork"

Wastewater generation
Wastewater treatment

Farmer/ Producer
Safe irrigation practices

Traders/ Retailers
Hygienic handling practices

Street food kitchens
Safe food washing and preparation

Consumer
Awareness creation to create demand for safe produce

Policy recognition, safer farm land, tenure security, market incentives, safe-food labelling,…

2006 WHO guidelines is intended to support

- Establishment of national standards and regulations

  (Each country should review its needs and capacities in developing a regulatory framework)
- Policy framework of incentives and sanctions to alter behaviour and monitor and improve situations
- Intersectoral coordination and cooperation at national and local levels and the development of suitable skills and expertise
- Ultimately, the regulatory framework should adopt the format of a <u>safe reuse of wastewater</u> plan

Multi-level pathogen reduction

Control measure	Pathogen reduction (log units)
Wastewater treatment	1−6
Localized (drip) irrigation (low-growing crops)	2
Localized (drip) irrigation (high-growing crops)	4
Spray drift control (spray irrigation)	1
Spray buffer zone (spray irrigation)	1
Pathogen die-off	0.5−2 per day
Produce washing with water	1
Produce disinfection	2
Produce peeling	2
Produce cooking	6−7

Pathogen removal

	Removal (log units)	
	Bacteria	H. eggs
Primary sedimentation	0-1	0-2
Activated sludge*	0-2	0-2
Trickling filter*	0-2	0-2
Chlorination/ozonation	2-6	0-1
WSPs	1-6	1-3

* Including settling pond/tank

WHO guidelines (2006) unrestricted reuse

	Worm eggs per liter	Faecal coli per 100ml
A crops: consumed Uncooked	≤ 0.1	$\leq 10^3$
B crops: fodder and industrial crops		
•workers, nearby communities		
* spray,sprinkler	≤ 1	$\leq 10^5$
* flood, furrow ≤ 1		$\leq 10^3$
• workers including children < 15 years ≤ 0.1		$\leq 10^3$

Wastewater irrigation – basic facts

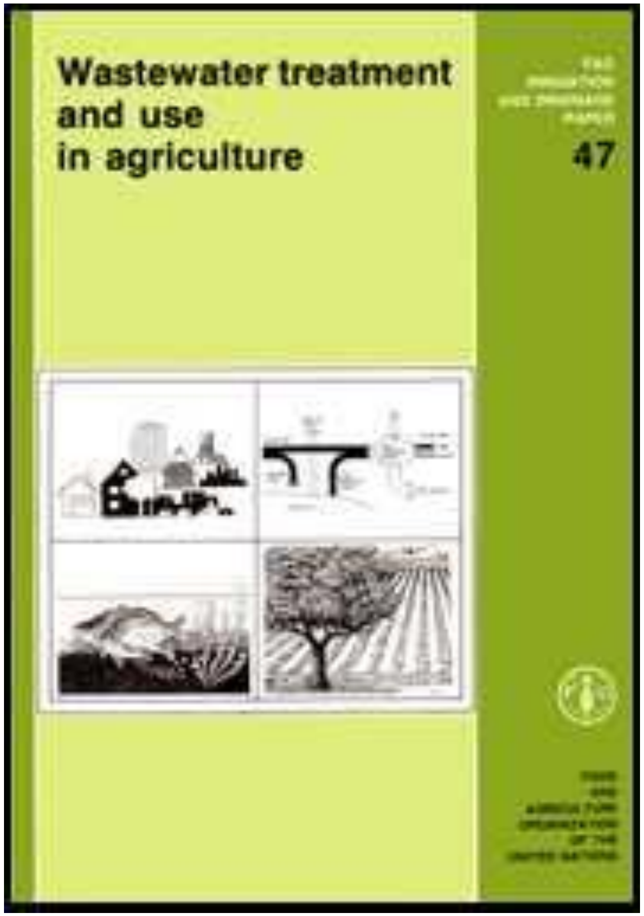
- WW is an increasingly important water source
- More reliable than fresh water during droughts
- Nutrients in wastewater (partly) replace fertilizers
- Also as polishing step for treatment

Successful projects require appropriate irrigation techniques and good irrigation water management to avoid health risks (farmer and consumer) and pollution (surface water, groundwater, soil profile)

WHO guidelines (2006) unrestricted reuse

	Worm eggs per liter	Faecal coli per 100ml
C drip irrigation without exposure of public/workers	-	-

FAO irrigation and drainage paper 47:
Wastewater treatment and use in agriculture



Covers health aspects and agronomic aspects of reuse of wastewater in agriculture

- Draws on the WHO Guidelines (1989) for health protection measures

FAO irrigation and drainage paper 47: Wastewater treatment and use in agriculture

- FAO guidelines define use restrictions with respect to salinity, trace elements, nitrogen, etc. in order to not produce negative effects on productivity and yields.
- Blending conventional water with treated effluent, or using the two sources in rotation is possible.
- This means that nutrients elimination in wastewater treatment is not necessary if reclaimed water can be blended with normal irrigation water.

source: GTZ

FAO irrigation and drainage paper 47: wastewater treatment and use in agriculture

- Water quality guidelines for maximum crop production (example)

Potential irrigation problem	units	Degree of restriction on use		
		none	Slight to moderate	severe
Salinity (Ec_w[1])	dS/m	< 0.7	0.7 - 3.0	> 3.0
Na, surface irrigation	me/l	< 4	4 - 10	> 10
Na, sprinkler irrigation	m^3/l	< 3	> 3	
Nitrogen (NO_3-N)[3]	mg/l	< 5	5 - 30	> 30
pH		Normal range 6.5-8		

FAO irrigation and drainage paper 47: wastewater treatment and use in agriculture

- **Threshold levels of trace elements for crop production (example)**

Element	Recommended maximum concentration (mg/l)	Remarks
Cd	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Cu	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
Zn	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.
Pd	5.0	Can inhibit plant cell growth at very high concentrations.

Aspects of design for wastewater Irrigation

- Design choices in sanitation and treatment
- Storage to solve mismatch between supply and demand
- Irrigation techniques, water and nutrient management
- Crop choice and crop handling
- Institutional aspects and stakeholders
- Long term environmental impacts

Conditions for succesful irrigation

1. Match supply and demand of water
2. Ensure proper water quality
   For crops (toxicity versus growth)
   For humans (workers and consumers)
3. Schedule water application
4. Crop selection and cropping pattern
5. Select appropriate irrigation method
6. Practice leaching in case of saline water use
7. Provide proper drainage if applicable
8. Manage nutrients to sustain growth

Match water supply and water demand

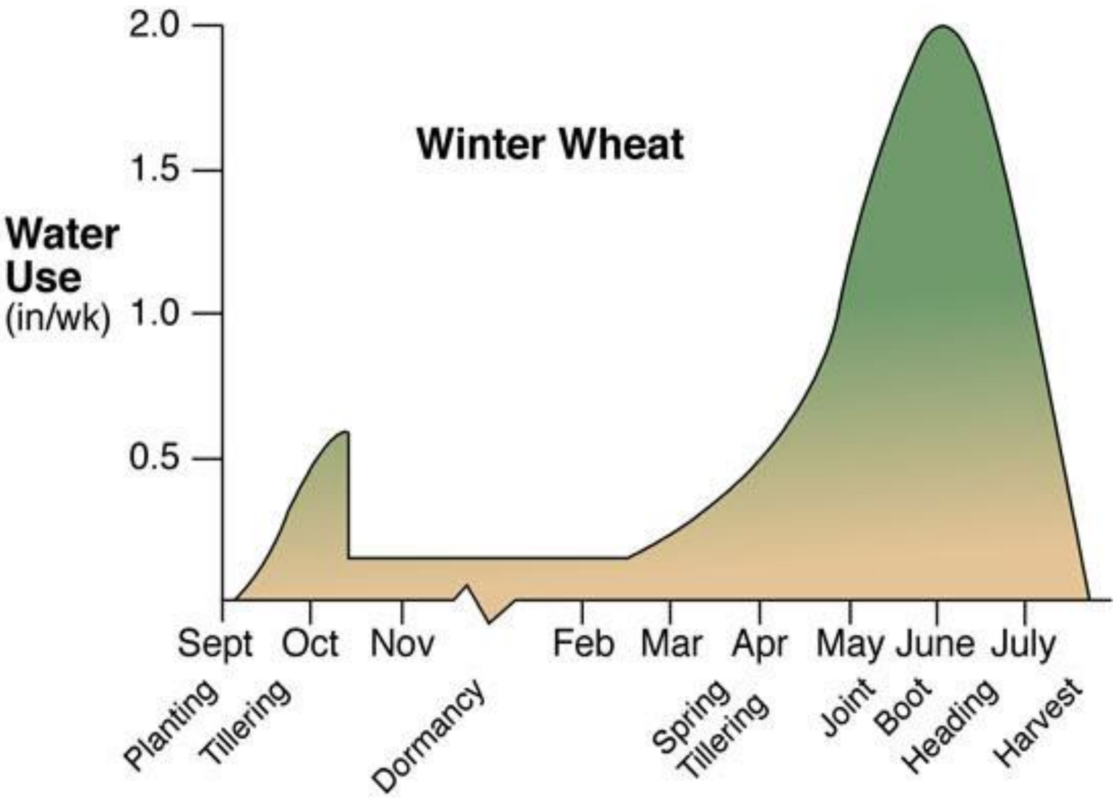
Wastewater is a more or less constant flow, but seasonal demand for water and nutrients varies.

Options

- Adjust cropping system to match water and nutrient supply
- Use multiple water resources to allow mixing or to meat peak water demands
- Adjust level of treatment as a function of nutrient demand

Crop water demand

- The supply of purified wastewater is rather constant through the year, but the demand of crop water is highly fluctuating with climate and crop stage.



Wastewater nutrients - effects

- Reduced need for fertilization
  - N and P are present in significant concentrations

- Nitrogen overdose and nutrient imbalance
  - Excessive N&P leads to micro nutrients deficiency (Cu, Zn, Fe)
  - Excessive N may affect crop quality (e.g. enhanced vegetative growth or delays in fruit ripening)

Wastewater nutrients - effects

- Induced algae bloom in storage ponds and tanks
  - May result in clogging problems

- Environmental, human and animal health hazards
  - Algae toxins, nitrate contamination of aquifers

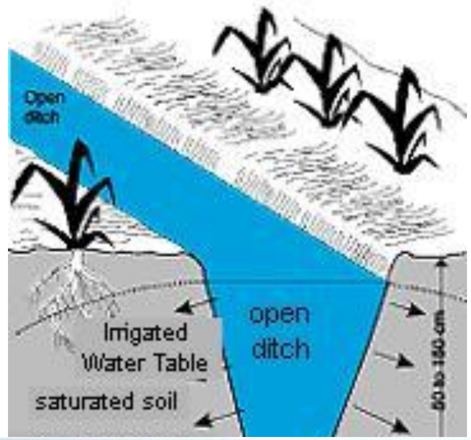
Wastewater: Available Nutrients

Location		Nutrient level		
		N mg/l	P mg/l	K mg/l
Haroonabad	Pakistan	78	6	20
Faisalabad	Pakistan	42	6	35
Amman	Jordan	88	47	44
FAO Guidelines		20 - 85	6 - 20	15 - 30

Irrigation methods

Surface irrigation

Pressurized irrigation
- Dripping
- Sprinklers



Method	Risks	Costs
Sprinkler	Cover the vegetables even for trees. Generate aerosols.	Controllable water consumption. Low labour cost. Low technological cost.
Dripping	Minimal.	Low water consumption. Low labour cost. High technological cost.
Flooding	Large area covered.	Large water consumption. Low labour costs.

Wastewater reuse in agriculture

Source: Jimenez & Asano (2008)

Table 1.7. Ranking of countries reusing wastewater, using three different criteria.

Rank	Country	Total reuse m^3/d	Country	Reuse, m^3/d per million capita	Country	Reuse/ Extraction, %
1	China	14,817,000	Qatar	170,323	Kuwait	35.2
2	Mexico	14,400,000	Israel	166,230	Israel	18.1
3	USA	7,600,000	Kuwait	163,330	Singapore	14.4
4	Egypt	1,920,000	Mexico	136,235	Qatar	13.3
5	Saudi Arabia	1,847,000	UAE	126,713	Cyprus	10.4
6	Syria	1,014,000	Cyprus	88,952	Jordan	8.1
7	Israel	1,014,000	Saudi Arabia	75,081	UAE	8.0
8	Chile	840,600	Bahrain	56,301	Malta	7.8
9	Spain	821,920	Syria	55,109	Tunisia	7.1
10	Japan	573,800	Chile	52,211	Mexico	6.7
11	Tunisia	512,328	Tunisia	51,233	Saudi Arabia	5.5
12	UAE	506,850	Jordan	40,179	Namibia	4.3
13	Peru	505,100	Malta	27,400	Bahrain	4.2
14	Australia	456,100	Oman	27,385	Chile	2.4
15	Iran	455,700	Egypt	26,301	Oman	1.9
16	Korea, Rep	430,000	US	25,486	Syria	1.9
17	Kuwait	424,657	Australia	22,805	Bolivia	1.1
18	Iran	422,000	Spain	20,436	Egypt	1.0
19	Jordan	225,000	Namibia	19,733	Libya	0.9
20	Turkey	136,986	Libya	18,966	Peru	0.9
21	Argentina(1)	129,600	Peru	18,327	China	0.9

Wastewater reuse in agriculture

Source: Jimenez & Asano (2008)

Table 1.8. Rankings of countries reusing treated wastewater, using three different criteria.

Rank	Country	Treated waste-water reused m^3/d	Country	Treated wastewater reused m^3/million capita	Country	Treated wastewater reuse as % of the total water extraction
1	USA	7,600,000	Qatar	170,323	Kuwait	35.2
2	S. Arabia	1,847,000	Israel	166,230	Israel	18.1
3	Egypt	1,780,821	Kuwait	163,330	Singapore	14.4
4	Syria	1,014,000	UAE	126,713	Qatar	13.3
5	Israel	1,014,000	Cyprus	88,952	Cyprus	10.4
6	Spain	821,920	S. Arabia	75,081	Jordan	8.1
7	Mexico	767,280	Bahrain	56,301	UAE	8.0
8	China	670,000	Syria	55,109	Malta	7.8
9	Japan	573,800	Tunisia	51,233	Tunisia	7.1
10	Tunisia	512,328	Jordan	40,179	S. Arabia	5.5
11	UAE	506,850	Malta	27,400	Namibia	4.3
12	Australia	456,100	Oman	27,385	Bahrain	4.2
13	Korea, Rep	430,000	USA	25,486	Oman	1.9
14	Kuwait	424,657	Egypt	24,395	Syria	1.9
15	Iran	420,000	Australia	22,805	Bolivia	1.1
16	Chile	320,000	Spain	20,436	Egypt	1.0
17	Peru	280,100	Chile	19,876	Libya	0.9
18	Jordan	225,000	Namibia	19,733	Chile	0.9

Conclusions

•Increasing water scarcity makes wastewater reuse more and more feasible and a requirement

• Proper management of agricultural reuse schemes requires both good sanitary engineering and agricultural/engineering practices

• Integrated design and management of reuse schemes is therefore required