WATER MANAGEMENT SCHOOL

1° International Training Course

URBAN WATER RESOURCES MANAGEMENT for AFRICA

Rome, Link Campus University

22 January – 3 February 2018

Wastewater reuse

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Summary

- Why water reuse
- Benefits of wastewater reuse
- Health and environmental risks of water reuse
- Possible approaches to minimize the risks
- Italian regulation to water reuse to minimize the risks
- Case studies of water reuse
- Activities at EU level
- The WHO risk management approach

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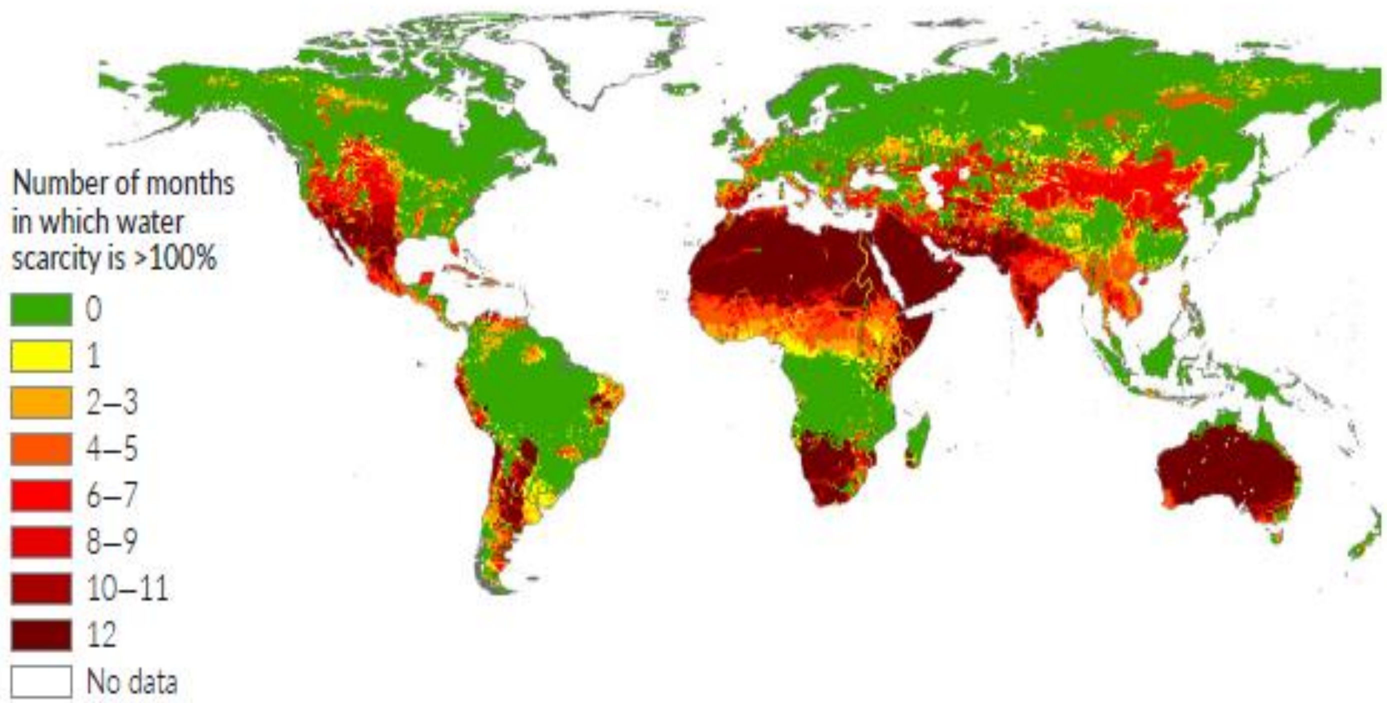
Water scarcity at global scale
Source: Unesco 2017

Figure 2 Number of months per year in which the volume of surface water and groundwater that is withdrawn and not returned exceeds 1.0 at 30 x 30 arc min resolution (1996–2005)*



*Quarterly averaged monthly blue water scarcity at 30 × 30 arc min resolution. Water scarcity at the grid cell level is defined as the ratio of the blue water footprint within the grid cell to the sum of the blue water generated within the cell and the blue water inflow from upstream cells. Period: 1996–2005.

Source: Mekonnen and Hoekstra (2016, Fig. 3, p. 3).

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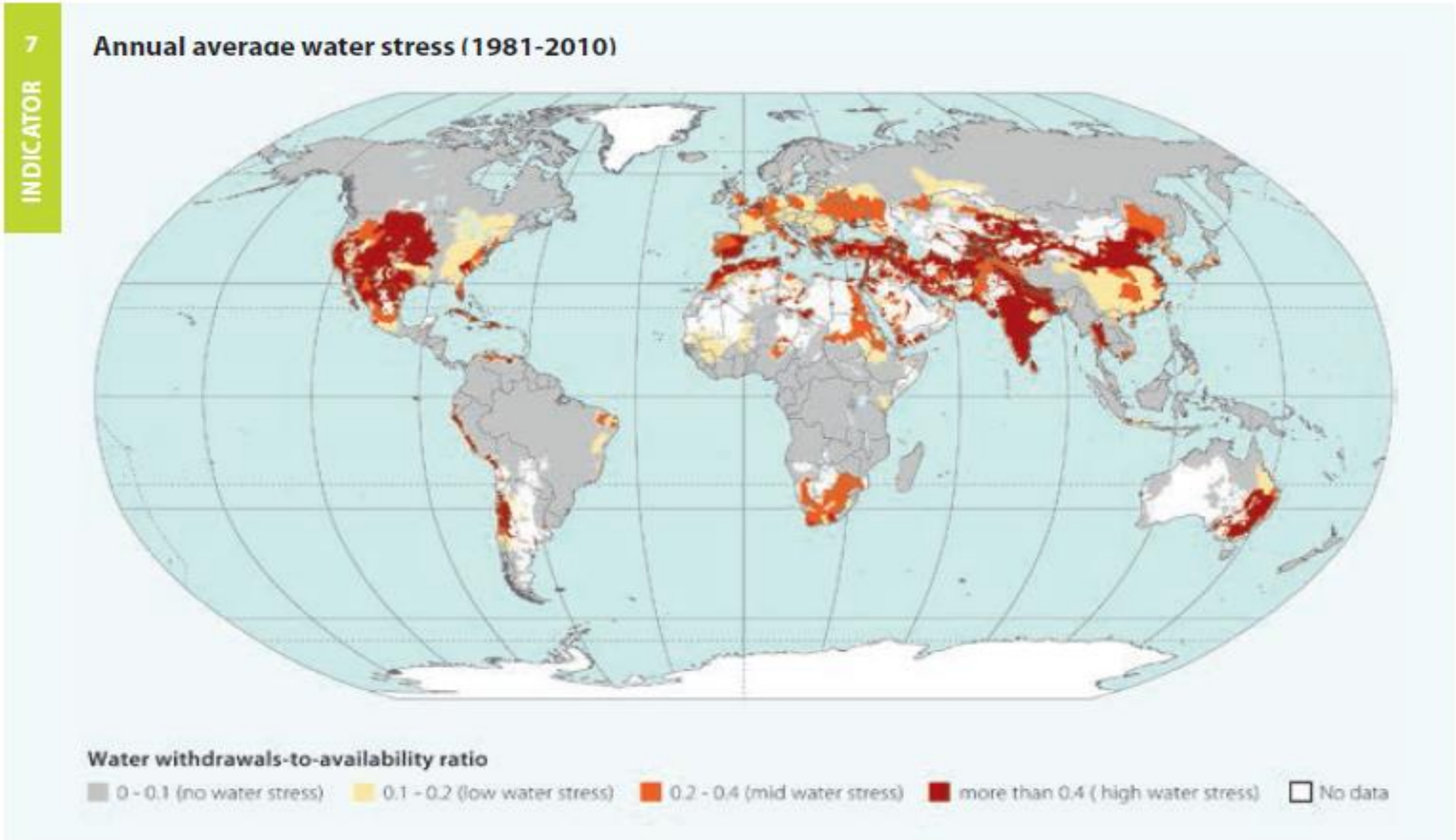
Water withdrawals to availability ratio
Source: WWAP, 2015



Note: Water stress measures the amount of pressure put on water resources and aquatic ecosystems by the users of these resources (households, industries, and agriculture) and can easily be compared across river basins. For calculating today's water stress, the withdrawals-to-availability ratio is used (w.t.a.). This indicator has the advantage of being transparent and computable for all river basins and has been used in several studies (e.g. Alcamo et al. 2007). The larger the volume of water withdrawn, used, and discharged back into a river, the more river flow is depleted and/or degraded for users downstream, and thus the higher the water stress. Water withdrawals and availability were computed by WaterGAP3 model on 5x5 arc minute grid cells and aggregated to river basin scale.

High water stress occurs in most of India, Northern China, Middle Asia, the Middle East, the Mediterranean rim countries, Eastern Australia (i.e. the Murray Darling basin), Western Latin America, large parts of the Western United States and Northern Mexico. Overall, river basins in these regions are at greater risk of seasonal or inter-annual variations in water flow. For a detailed description of the methodology, background work and findings: http://www.usf.uni-kassel.de/cesr/index.php?option=com_content&task=view&id=57&Itemid=86

Source: Center for Environmental Systems Research, University of Kassel (Generated in December 2014 using WaterGAP3 model).

Alcamo, J., Flörke, M. and Marker, M. 2007. Future long-term changes in global water resources driven by socio-economic and climatic changes. Hydrological Sciences Journal, 52(2): 247-275.

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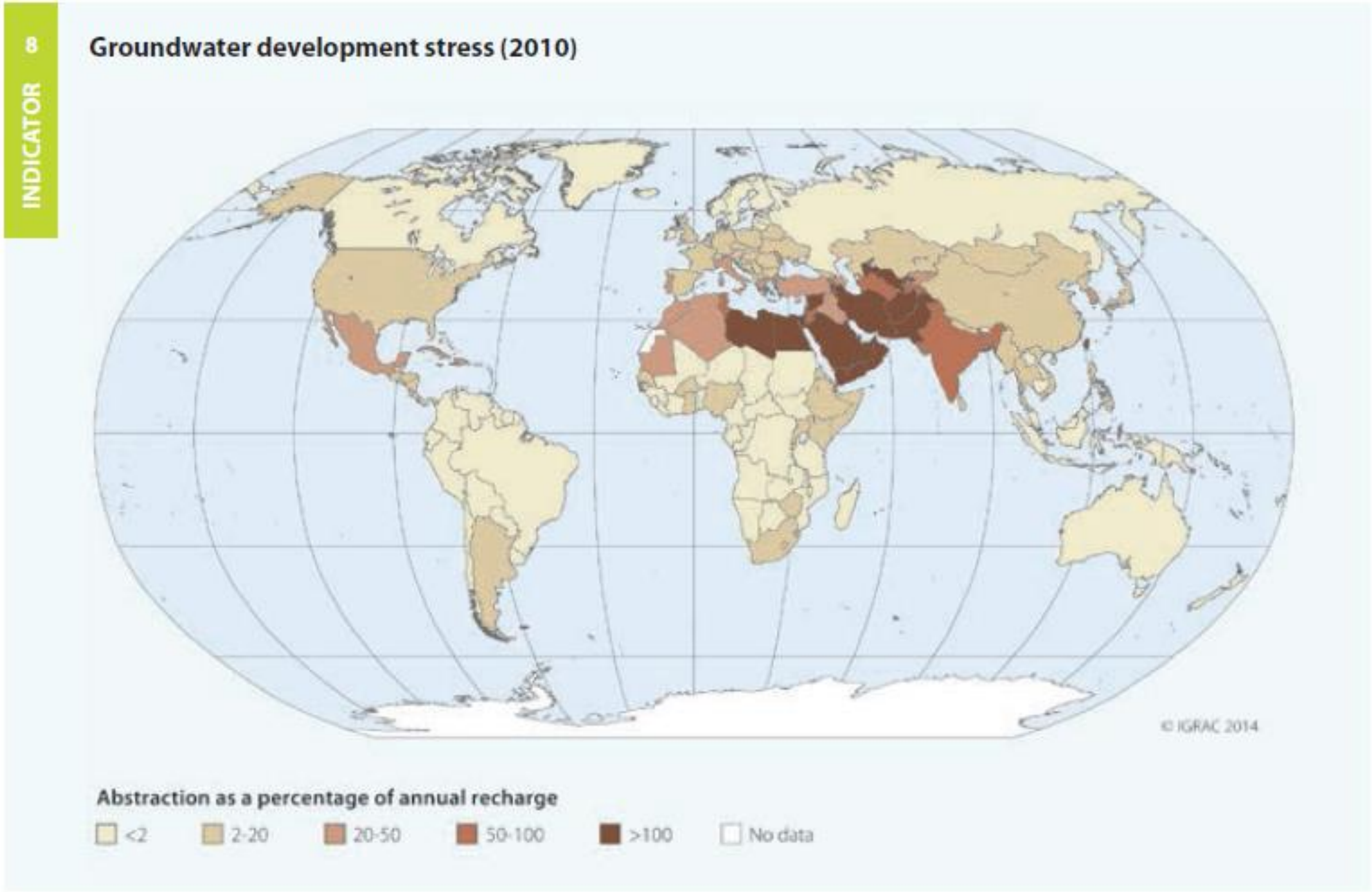
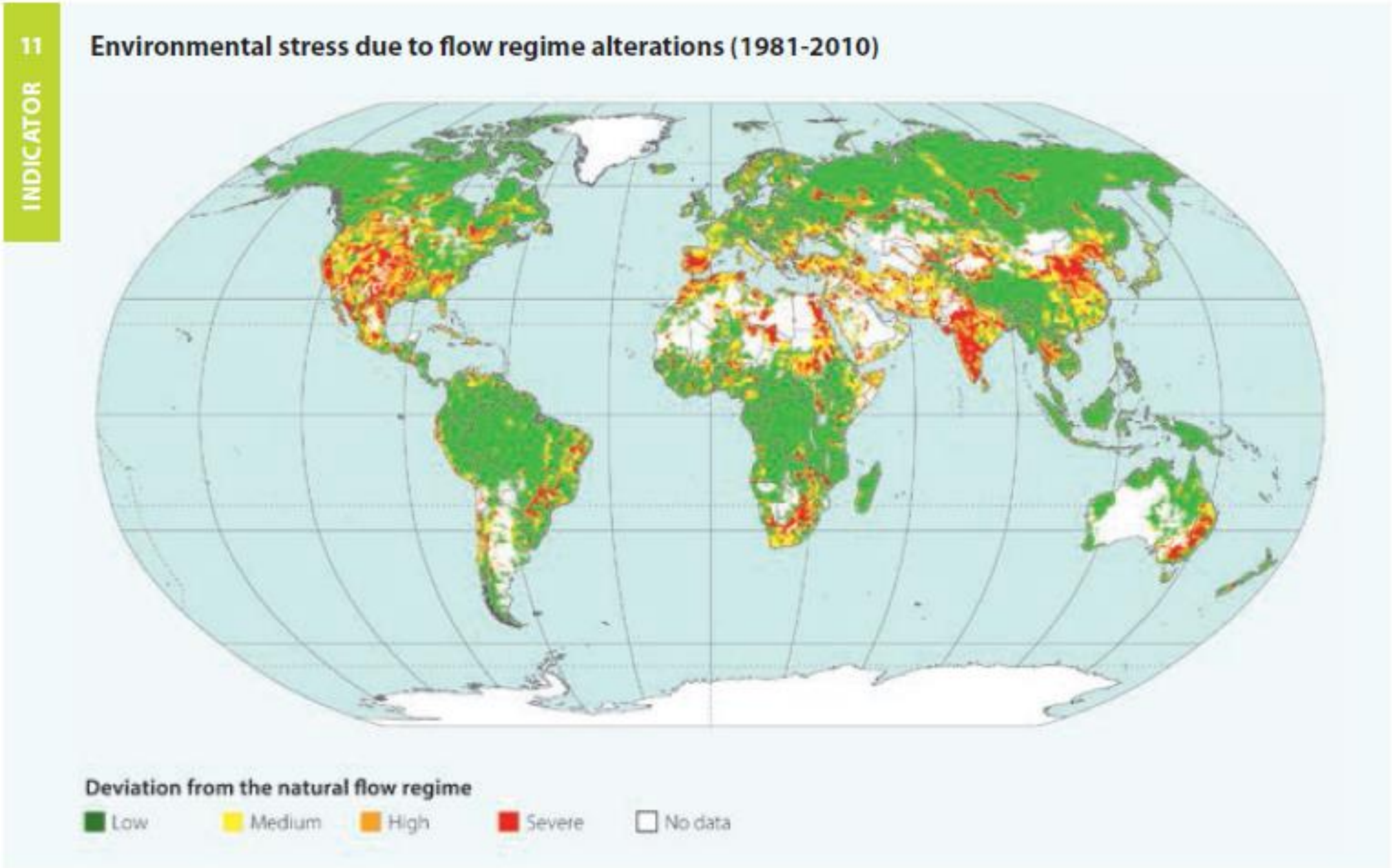
Groundwater development stress
Source: Unesco 2017

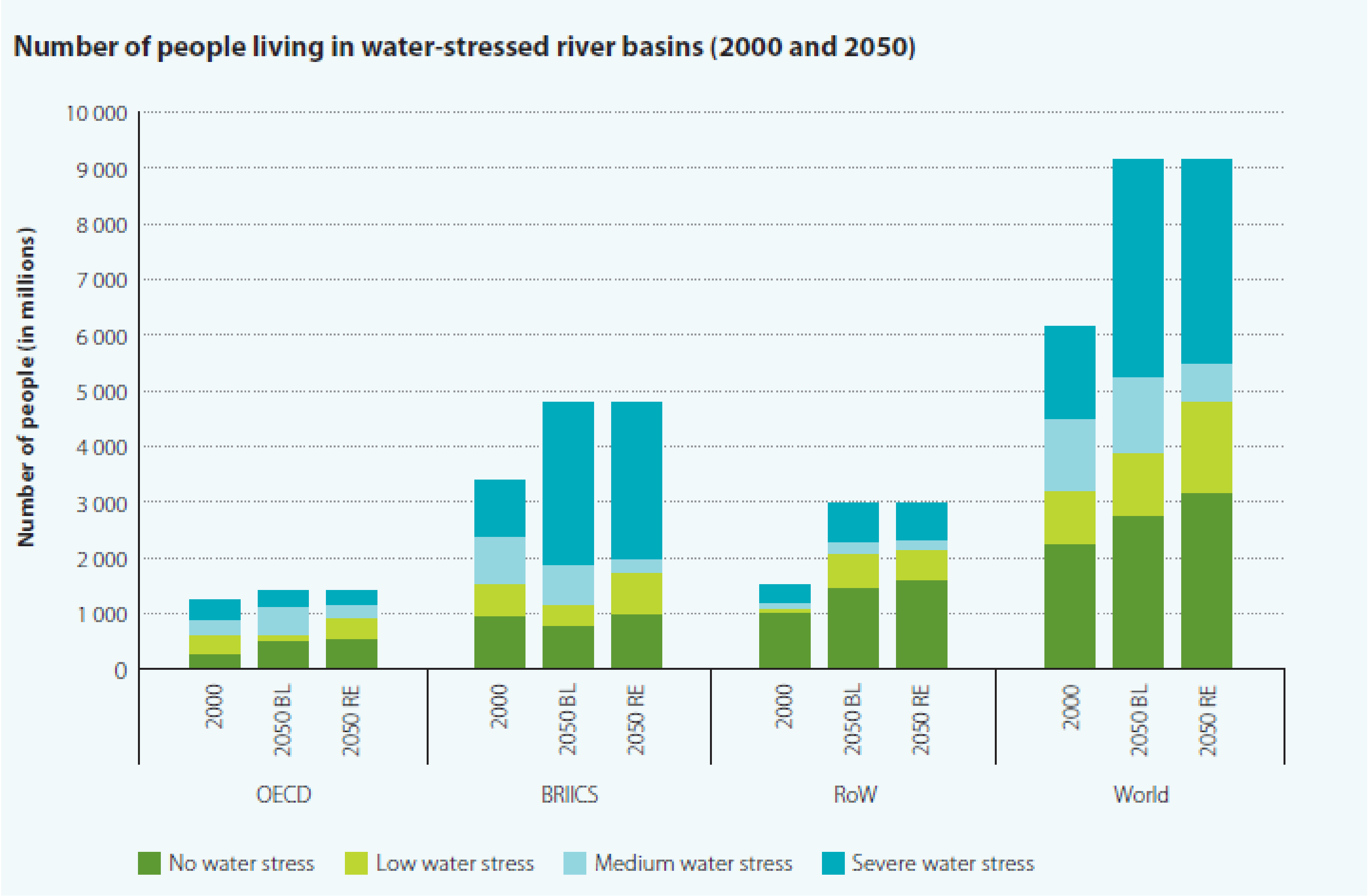


Source: IGRAC (2014).
IGRAC (International Groundwater Resources Assessment Centre). 2014. Information System. Global Overview application. Delft, the Netherlands, IGRAC. http://ggmn.e-id.nl/ggmn/GlobalOverview.html (Accessed December 2014). © IGRAC 2014.

Environmental stress due to flow regime alteration Source: WWAP, 2015

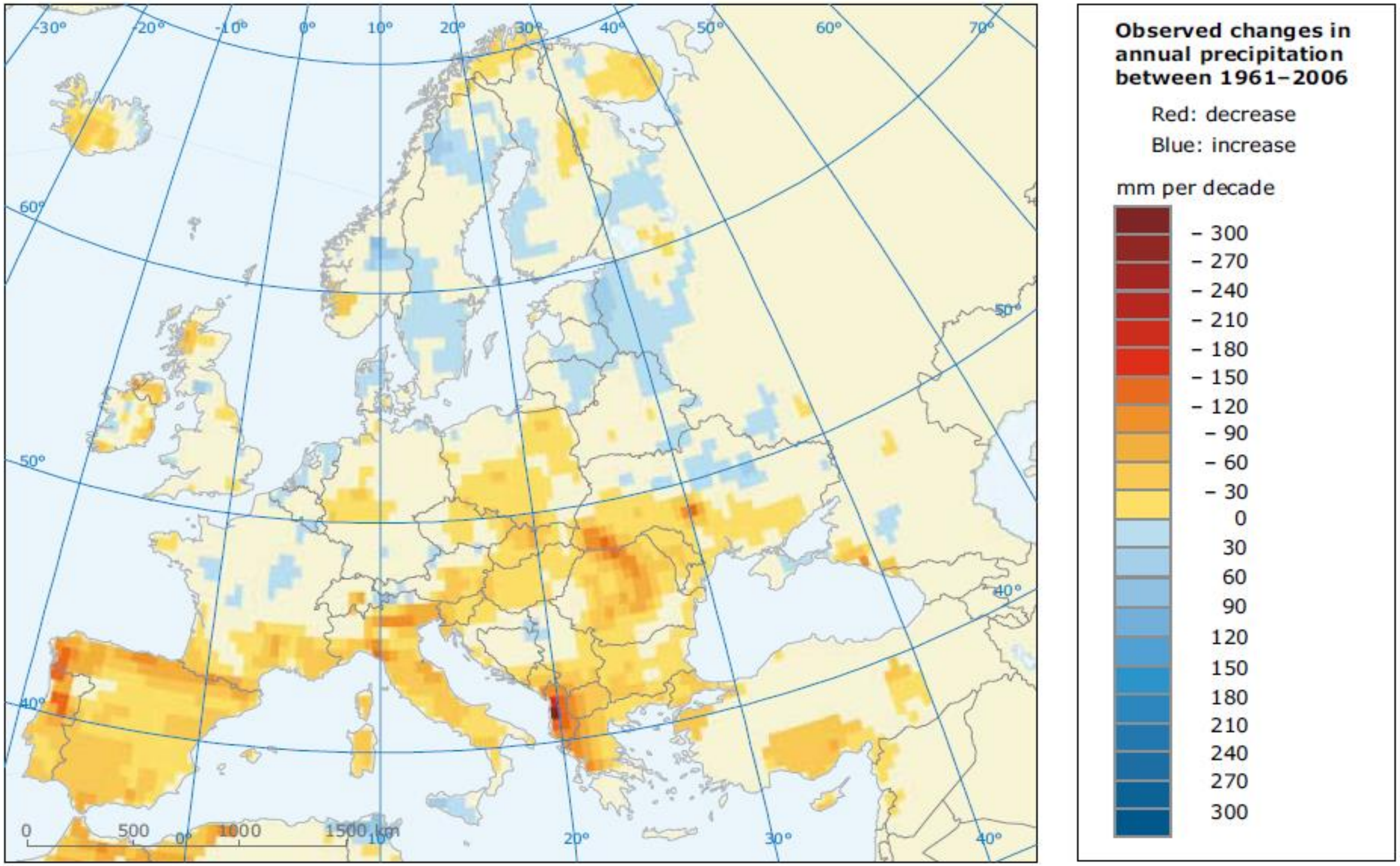


Number of people living in water-stressed rivers
Source: WWAP, 2015



Changes in Europe annual precipitation

European Environmental Agency 2/2009 Report



The impact of water resources scarcity have increased the profile of water reuse as one of the solution

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Wastewater reuse – why? (1/2)

- Alleviate water scarcity
- Reduce demand on potable water supplies and high quality sources
- Supplement conventional sources
- A valuable buffer against drought and water shortage especially for irrigation and industry
- Improve operational efficiency; reduce energy costs
- Reduce nutrient discharge to the environment
- Reduce water stress on specific sectors

Wastewater reuse – why? (2/2)

- 40% of world population is living in water stressed areas.
- At least 10% of the world population consumes wastewater irrigated food. Direct and unintentional use is increasing worldwide.
- Multiple benefits minimising contaminant flow and conserving water resources

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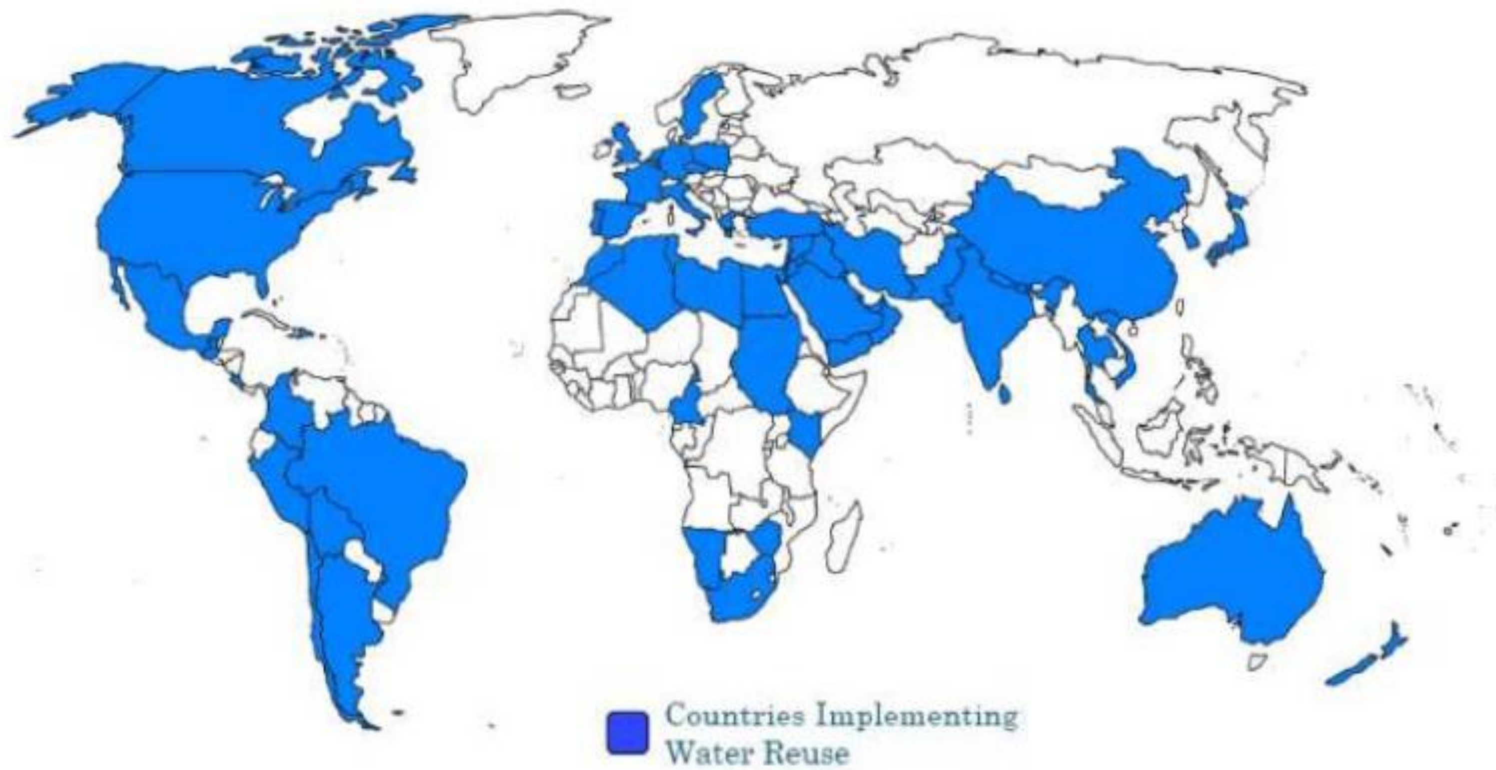
Views on wastewater reuse

- Wastewater reuse is already important in small communities in many countries, particularly to support agriculture

- Wastewater reuse is technically and practically feasible

- It should be an integral part of water management strategies now and for the future.

Water Reuse: a Global Trend towards Sustained Growth in All Continents



Jiminez, Blanca, and Takashi Asano, eds. 2008. *Water Reuse: An International Survey of current practice, issues and needs*. London, United Kingdom: IWA Publishing.

The State of Water Reuse

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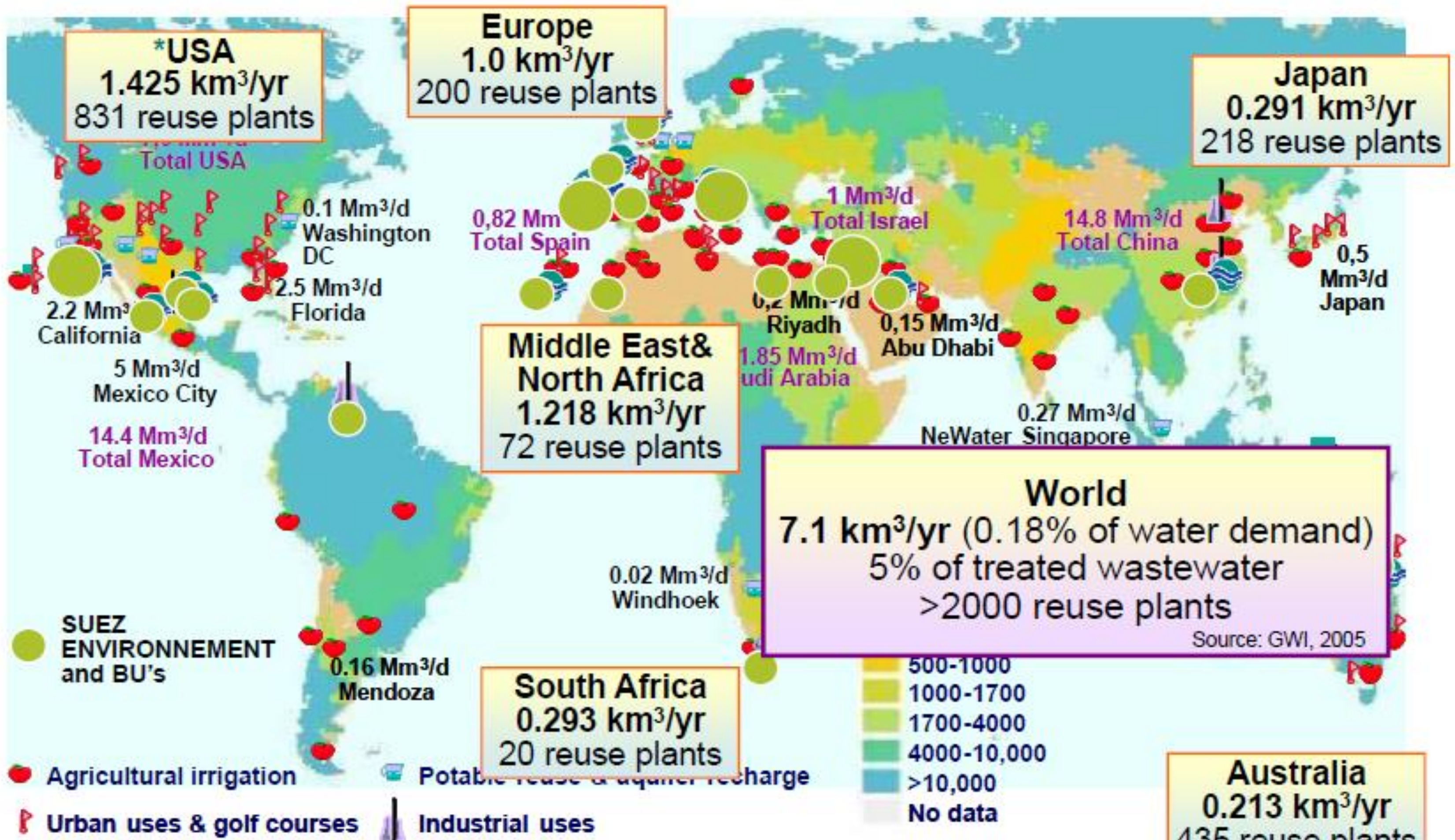
Water Reuse: a Global Trend towards Sustained Growth in All Continents

ReQpro



LIFE+ ReQpro Final Conference, 23 Feb 2017

suez

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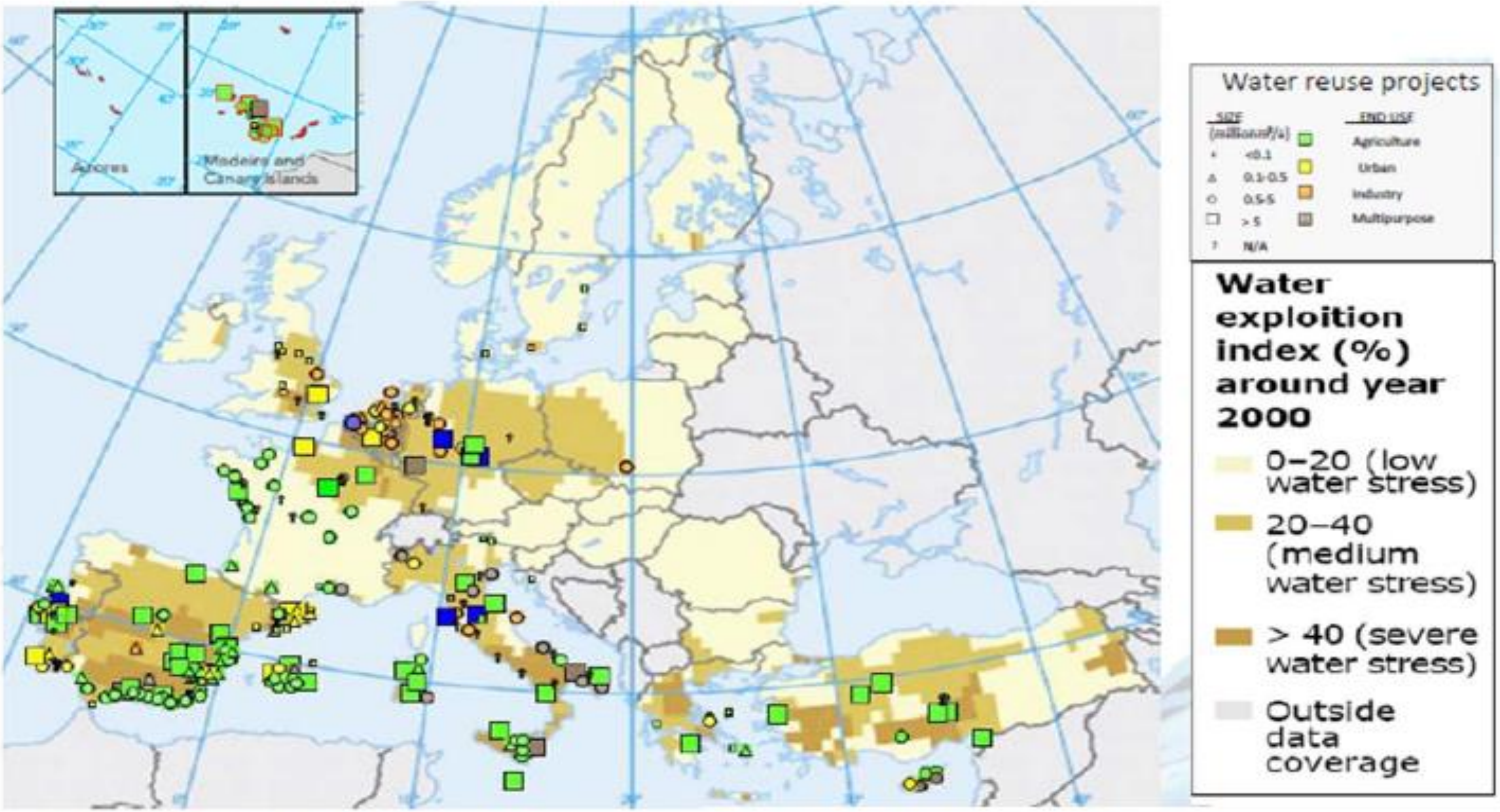
Water scarcity and water reuse



Source: Bixio et al., 2008, map EEA 2005

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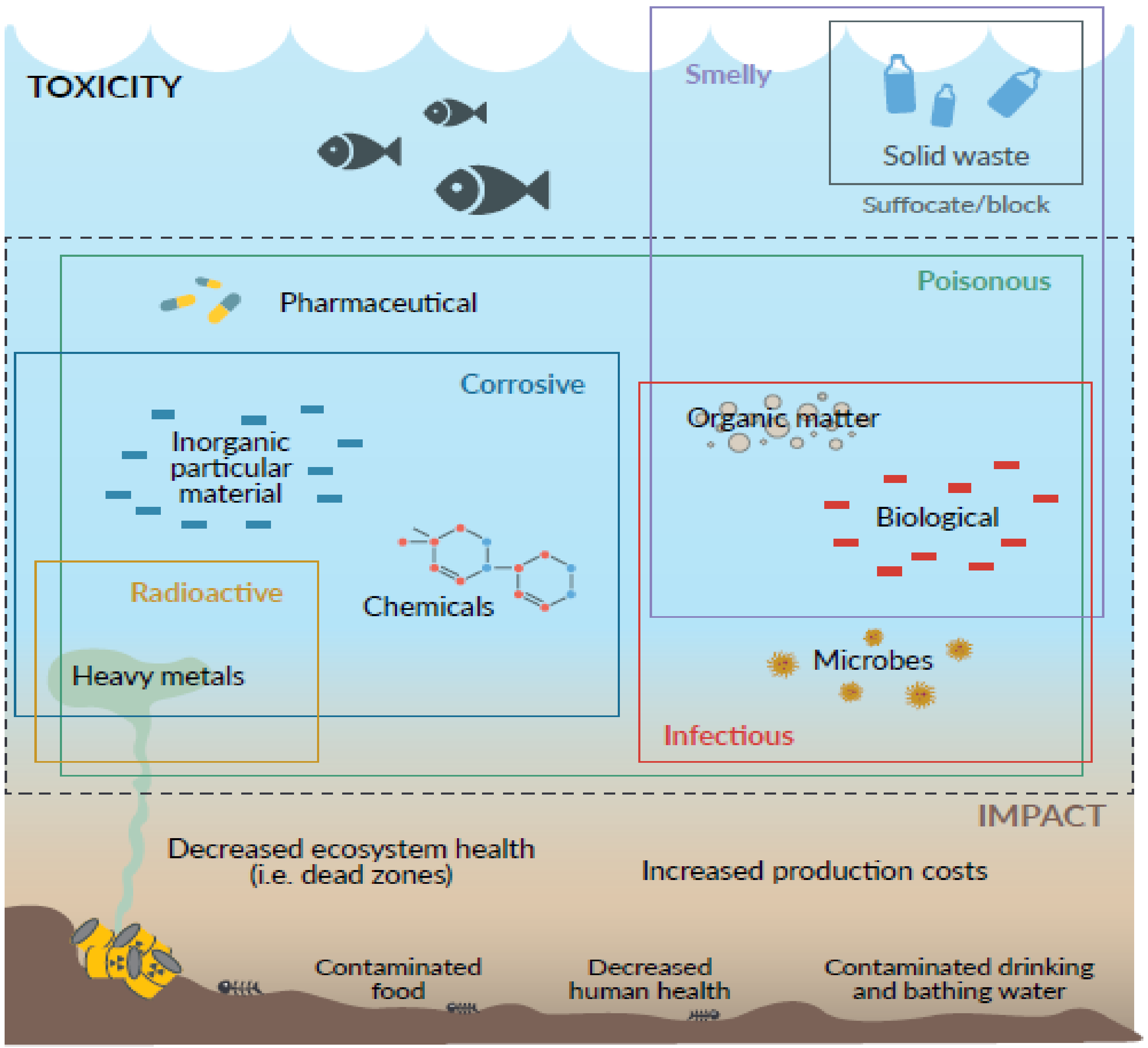
Framing Wastewater from a resource perspective

Resources in excreta and wastewater	Resource management options	Technical system options	Multiple potential benefits
Water Nutrients Energy content Organic matter Other	**Water reuse and recycling** Potable and non-potable water / industrial use / recharge of water bodies **Combined water and nutrient reuse** Agricultural irrigation / forestry irrigation / aquaculture **Nutrient reuse or combined organic matter/nutrient reuse** Solid and liquid fertilizer and soil conditioner for agriculture and forestry **Energy generation** Biogas generation / incineration / Biomas production **Ecosystem services** i.e. constructed wetland **Other outputs** i.e. protein feed for livestock / building material	Centralized vs decentralized Waterborne vs non-waterborne excreta management Separate greywater management Sludge management Off-site vs on-site treatment Wastewater treatment Excreta and sludge treatment	Health protection Environmental protection Livelihoods Gender equity Water security Food security Energy security Climate mitigation and adaptation

Source: Andersson et al. (2016, Fig. 3.1, p. 27).

Wastewater components and potential hazards



Source: Adapted from Corcoran et al. (2010, Fig. 5, p. 21).

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Wastewater: potential hazards

Source: WHO, 2016- Sanitation safety planning manual for safe use and disposal of wastewater, greywater and excreta

	WASTE COMPONENTS									
	POTENTIAL BIOLOGICAL HAZARDS					POTENTIAL CHEMICAL HAZARDS		POTENTIAL PHYSICAL HAZARDS		
	Viruses	Bacteria	Protozoa	Helminths	Vector-related diseases	Toxic chemicals	Heavy metals	Sharp objects	Inorganic material	Malodours
Liquid waste fractions										
Diluted excreta (human or animal)	▯	▯	▯	▯						▯
Urine (human or animal)	▯	▯	▯	▯						▯
Domestic waste water	▯	▯	▯	▯	▯			▯	▯	▯
Stormwater	▯	▯	▯	▯	▯	▯	▯	▯		
River water	▯	▯	▯	▯	▯	▯	▯			
Industrial wastewater (Note 1)						▯	▯			

Health risks (1/2)

Biological risk (patogens)

- **Viruses**

include highly contagious enteroviruses (polio, echo, coxsackie), hepatitis A and E, and a range of viruses causing diarrhea and gastoenteritis. Due to their small size, they are able to pass filtration devices and can be detected in drinking water, even after disinfection

- **Bacteria**

including harmless and pathogenic coliforms, salmonella, shigella, and enterococci.
They cause classical waterborne diseases like typhoid, dysentery, cholera and other gastroinintestinal illnesses

Health risks (2/2)

Biological risk (patogens)

- **Protozoan pathogens** single-celled eukaryotic parasites, which survive as cysts outside their host, the most common being Giardia lamblia and Cryptosporidium parvum. inactivated using UV-radiation but are fairly resistant to Chlorination
  - Helmints
- Chemical risk
  - heavy metals
  - organic compounds
  - emerging pollutants (i.e pharmaceuticals)

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RECOMMENDED MICROBIOLOGICAL QUALITY GUIDELINES FOR WASTEWATER USE IN AGRICULTURE[a]

Source, WHO 1989

Category	Reuse condition	Exposed group	Intestinal nematodes[b] (arithmetic mean no. of eggs per litre)[c]	Faecal coliforms (geometric mean no. per 100 ml[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parksd[d]	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

a In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and the guidelines modified accordingly.

b *Ascaris* and *Trichuris* species and hookworms.

c During the irrigation period.

d A more stringent guideline (<200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

e In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

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Environmental risks

- Water
  - nutrients (eutrophication)
  - heavy metals
  - organic compounds
  - emerging pollutants (i.e pharmaceuticals, endocrine disruptors)

- Soil (irrigation, landscape uses)
  - salinity (sodium absorption ratio index)
  - heavy metals
  - organic compounds
  - emerging pollutants
  - crop toxicity (yield reduction) and crop contamination

GUIDELINES FOR INTERPRETATION OF WASTEWATER QUALITY FOR IRRIGATION

Source: FAO 1985

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
or				
TDS	mg/l	< 450	450 - 2000	> 2000
Infiltration				
SAR and ECw				
0 - 3		> 0.7	0.7 - 0.2	< 0.2
3-6		> 1.2	1.2 - 0.3	< 0.3
6-12		> 1.9	1.9 - 0.5	< 0.5
12-20		> 2.9	2.9 - 1.3	< 1.3
20-40		> 5.0	5.0 - 2.9	< 2.9

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GUIDELINES FOR INTERPRETATION OF WASTEWATER QUALITY FOR IRRIGATION

Source: FAO 1985

Potential irrigation problem		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Specific ion toxicity					
Sodium (Na)					
	Surface irrigation	SAR	< 3	3-9	> 9
	Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)					
	Surface irrigation	me/l	< 4	4-10	> 10
	Sprinkler irrigation	me/l	< 3	> 3	
Boron (B)		mg/l	< 0.7	0.7 - 3.0	> 3.0
Miscellaneous effects					
Nitrogen (NO_3-N)[3]		mg/l	< 5	5-30	> 30
Bicarbonate (HCO_3)		me/l	< 1.5	1.5 - 8.5	> 8.5
pH		Normal range 6.5-8			

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Threshold levels of trace elements for crop production
Source: FAO 1985

Element		Recommended maximum concentration (mg/l)	Remarks
Al	(aluminium)	5.00	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As	(arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be	(beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	(cadmium)	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.
Co	(cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	(chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	(copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F	(fluoride)	1.00	Inactivated by neutral and alkaline soils.
Fe	(iron)	5.00	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum.

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Threshold levels of trace elements for crop production
Source: FAO 1985

Element		Recommended maximum concentration (mg/l)	Remarks
Li	(lithium)	2.05	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn	(manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo	(molybdenu m)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	(nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd	(lead)	5.00	Can inhibit plant cell growth at very high concentrations.
Se	(selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. As essential element to animals but in very low concentrations.
Sn	(tin)		
Ti	(titanium)	-	Effectively excluded by plants; specific tolerance unknown.
W	(tungsten)		
C	(vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn	(zinc)	2.00	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

Regulation on water reuse in Italy

Ministerial Decree n. 185/2003
Regolamento recante norme tecniche per
il riutilizzo delle acque reflue

Official Journal n. 169 of 23 July 2003

Water scarcity and drought in Italy

- In **Southern Italy** water scarcity is an issue in several areas (due to climatic conditions, infrastructural deficit, management problems)

  i.e.: Calabria, Campania, Basilicata, Puglia, Sicilia

- In **Northern Italy** the extreme events are increasing (i.e.. Drought in 2003)…!

Water ecosystem quality

To meet RBMP objectives on 2015
(chemical and ecological good/high status for all water bodies)

Review of current water uses

→ Conservation, saving, recycling, interconnection, flexibility, optimization

National food market competitiveness

EU consumers: Food quality and safety are fundamental
Env. sustainability is a topic

Farmers: concerns in reusing treated wastewater when other sources are available

→ **Irrigation water quality standard are currently not issued at EU27 level**

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Regulatory Framework
Legislative Decree 3 April 2006 n. 152 (implementing the Water Framework Directive 2000/60/CE)

art. 99 Riutilizzo dell'acqua (Water reuse)

1.Il Ministro dell'ambiente e della tutela del territorio con proprio decreto, sentiti i Ministri delle politiche agricole e forestali, della salute e delle attività produttive, detta le norme tecniche per il riutilizzo delle acque reflue

2.Le regioni, nel rispetto dei principi della legislazione statale, e sentita l'Autorità di vigilanza sulle risorse idriche e sui rifiuti, adottano norme e misure volte a favorire il riciclo dell'acqua e il riutilizzo delle acque reflue depurate

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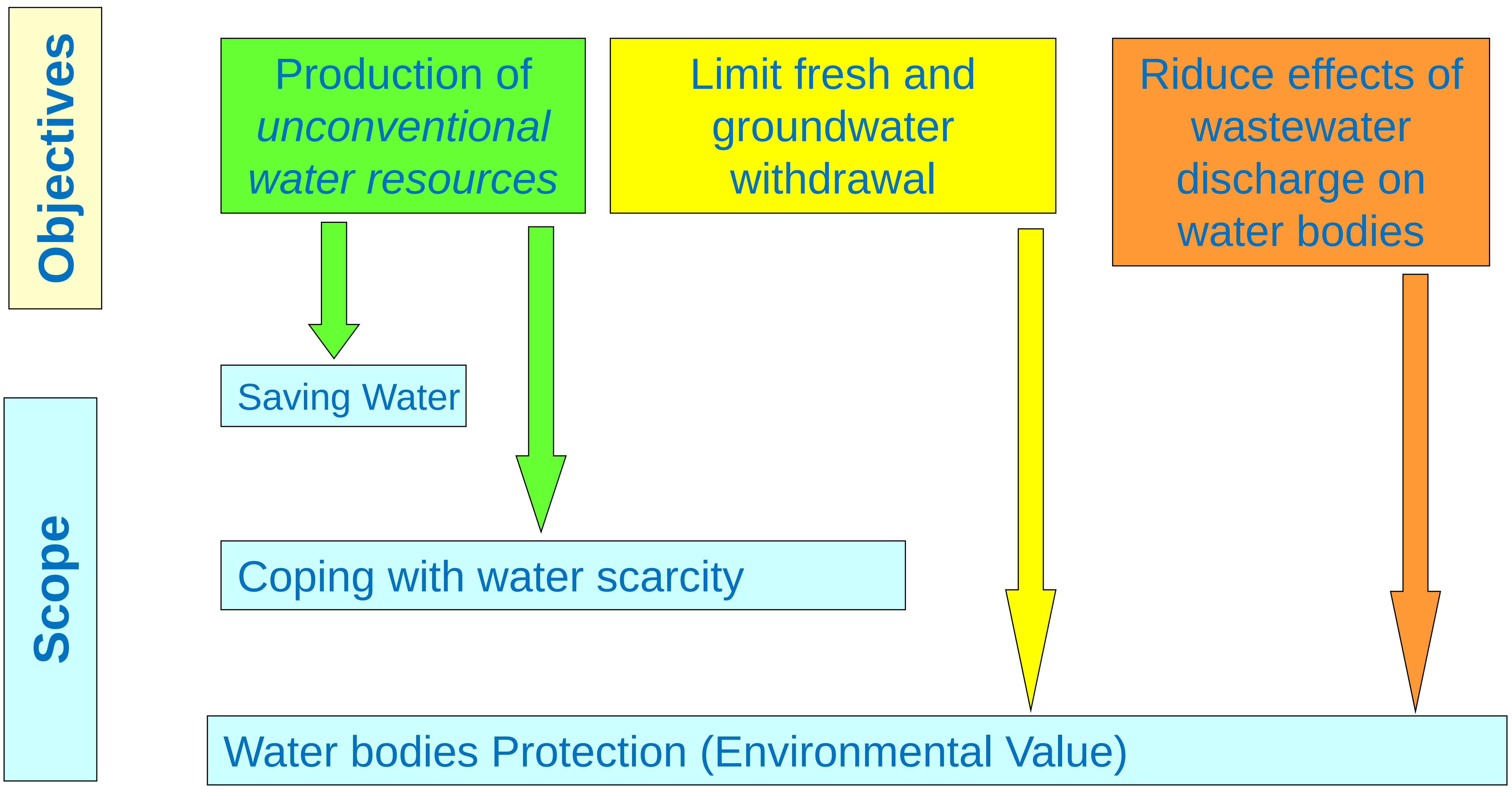
Treated Waste Water Reuse Regulation
Ministerial Decree 185/2003 (1)



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Italian regulation on water reuse

Means for achieving environment and health protection

- Strict quality standards for wastewater reuse for microbiological and chemical parameters
- Identified wastewater uses
- Obligations on water monitoring
- Provisions on controls

Provisions on permits for the specific activity of water reuse in the main regulation

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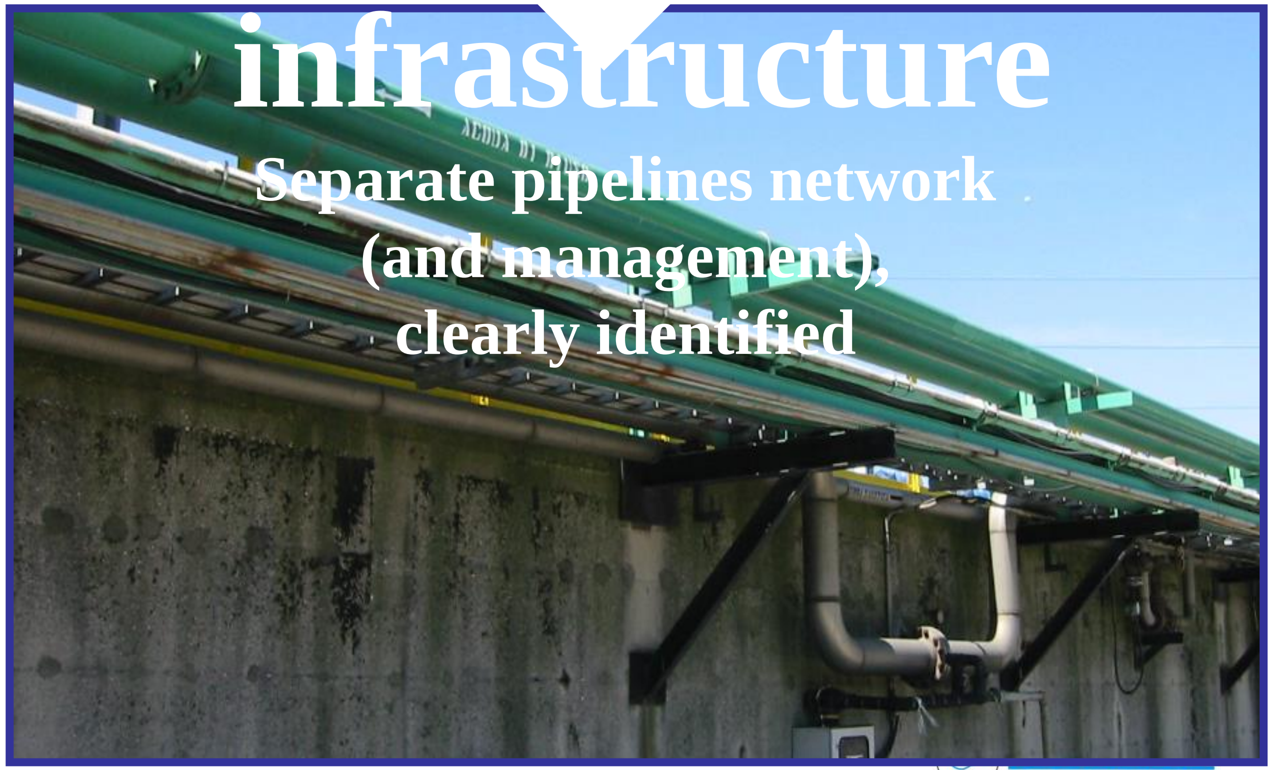
Ministerial Decree 185/2003 (2)
Types of Uses Allowed for TWW reuse

Irrigation	• all crops • public green areas
Urban use	• street cleaning; • WC NOTE: only in separate pipelines
Industry	• all types of industrial use (cooling, production, cleaning, fire control) • not allowed for certain productions (food, cosmetics……)

Ministerial Decree 185/2003
Definitions



Standards for water reuse(1/3)

Ministerial Decree 185/2003

Parametri	Unità di misura	Valore limite
pH		6-9.5
SAR		10
Materiali grossolani		Assenti
Solidi sospesi totali	mg/L	10
BOD5	mg O2/L	20
COD	mg O2/L	100
Fosforo totale	mg P/L	2
Azoto totale	mg N/L	15
Azoto ammoniacale	mg NH4/L	2
Conducibilità elettrica	μS/cm	3000

Notes

- Limit Values at the output of the treatment plant referred to annual average (for irrigation referred to single irrigation practice)
- In case of irrigation use: P=10mg/l; n=35mg/l. Ntot load contribute to the total Nitrate permitted amount in NVZs.
- Guidance values for pH, N ammonium, SAR, Al, Fe, Mn, chlorides, sulphites: Regions may define different values, not exceeding limit values for wastewater discharge

Standards for water reuse(2/3)

Ministerial Decree 185/2003

Alluminio	mg/L	1
Arsenico	mg/L	0,02
Bario	mg/L	10
Berillio	mg/L	0,1
Boro	mg/L	1,0
Cadmio	mg/L	0,005
Cobalto	mg/L	0,05
Cromo totale	mg/L	0,1
Cromo VI	mg/L	0,005
Ferro	mg/L	2
Manganese	mg/L	0,2
Mercurio	mg/L	0,001
Nichel	mg/L	0,2
Piombo	mg/L	0,1
Rame	mg/L	1
Selenio	mg/L	0,01
Stagno	mg/L	3
Tallio	mg/L	0,001
Vanadio	mg/L	0,1

Zinco	mg/L	0,5
Cianuri totali (come CN)	mg/L	0,05
Solfuri	mg H2S/L	0,5
Solfiti	mg SO3/L	0,5
Solfati	mg SO/L	500
Cloro attivo	mg/L	0,2
Cloruri	mg Cl/L	250
Fluoruri	mg F/L	1,5
Grassi e oli animali vegetali	mg/L	10
Oli minerali	mg/L	0,05
Fenoli totali	mg/L	0,1
Pentaclorofenolo	mg/L	0,003
Aldeidi totali	mg/L	0,5
Tetracloroetilene	mg/L	0,01
Solventi clorurati totali	mg/L	0,04
Trialometani	mg/L	0,03

Standards for water reuse(3/3)

Ministerial Decree 185/2003

Solventi organici aromatici totali	mg/L	0,01
Benzene	mg/L	0,001
Benzopirene	mg/L	0,00001
Solventi organici azotati totali	mg/L	0,01
Tensioattivi totali	mg/L	0,5
Pesticidi clorurati	mg/L	0,0001
Pesticidi fosforiti	mg/L	0,0001
Altri pesticidi totali	mg/L	0,05
Escherichia coli	UFC/100ml	10 (80%dei campioni). 100 valore massimo puntuale
Salmonella		Assente

Notes

- In case of phytoremediation plan Escherichia coli Std=50UFC/100ml (80% of samples) and 200UFC/100ml (max single value)

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Ministerial Decree 185/2003

Control and monitoring of Wastewater treatment plant

A Control & Monitoring programme is set out in the discharge permit

Monitoring for assessment of compliance with limit values established for water reuse

(Competent authorities and wastewater treatment plant)

Monitoring of reuse activities

- Water monitoring and monitoring of environmental and agronomic effects

(manager of the network for distribution of treated wastewater)

- Monitoring of effects on human health

Decreto n. 185/2003

Control and monitoring system

Treatment Plant Control

The wastewater plant is subject to supervision by the competent authority. The control upon order of the competent authority and on the basis of a monitoring program may be performed by the plant manager

Monitoring

The water supplier performs the monitoring plan to assess chemical and microbiological quality of the treated wastewater and to assess environmental,
agronomic and soil effects.

The authorities responsible for health issues
assess possible effects related to the use
of treated waste water.

Planning framework in Italy
National Irrigation Plan

Promoted by Ministry of Agriculture
to finance
irrigation facilities
including
treated waste water distribution
systems

Waste Water Reuse

Regional examples

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Sardegna (1/3)

34 Treatment Plants suitable for reuse

→ 1.5 10 ^{8} m^{3}/year

→ 1.14 10 ^{8} m^{3}/y already available

Gennargentu National park in winter (lake of Gusana) [WIKIPEDIA]

i.e. Treatment Plant:
Cagliari Is Arenas (557.000 PE),
Cagliari Macchiareddu (297.000 PE),
Serramanna (200.000 PE) e Sassari (180.000 PE)

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Sardegna (2/3)
EXAMPLES

Villasimius Municipality
Volume: 1.075 10^3 m^3/year of treated wastewater are reused for irrigation (on crops and green areas).
Note: local regulation for reuse

Alghero Treatment Plant
Volume: 2,2 10^6 m^3 since October 2011 of treated waste water are reused for irrigation

Agreement signed between the treatment plant manager and the local Irrigation Authority

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Sardegna (3/3)

WW reuse Management Plan

Site Specific: for each treatment plant (even group of plants)

Effective involvement of all the stakeholders (waste water management and end users) by creating a Consortium

Stakeholders and local Authorities consultation

Contents: stakeholders involved; end users; water quality and control protocol; volumes of TWW; monitoring program for soil, agriculture and environment; financial plan; cost - effectiveness analysis; contingency plans.

EMILIA_ROMAGNA REGION (1/2)

Codigoro, Po di Volano [WIKIPEDIA]

Overall water withdrawal

Agriculture: 1.385*$10^6$$m^3$/years (64%)

Civil: 489*$10^6$$m^3$/years (23%)

Industry: **278*$10^6$$m^3$/years (13%)**

Treatment Plants

100% agglomerations treated at least with a secondary treatment

24 WWTP for reusing of treated wastewater

→ **560.000 m^3/d and 2.000.000 PE**

(Regional Water Protection Plan, 2006)

http://www.arpa.emr.it/documenti/arparivista/pdf2008n3/Berr%C3%A8AR3_08.pdf

EMILIA ROMAGNA REGION (2/2)

- Urbanisation index is very high in the plains
- 22.000 km irrigation and drainage canals
- 220.000 hectars irrigated by collettive infrastrutture
- Po river water is the main water source
- Most of the WWTP discharge into water bodies already used for irrigation supply

Feasible conditions

for TWW reuse

TWW REUSE ACTION PLANS
AT LOCAL SCALE
are required by the Regional Water Protection Plan

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An example of implementation of Wastewater reuse ReQpro demonstration Project

Source: final Conference of the project (cofunded LIFE project)

http://reqpro.crpa.it/nqcontent.cfm?a_id=15397&tt=t_law_market_www

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EMILIA_ROMAGNA REGION (1/2)

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→ **560.000 m3/d and 2.000.000 PE**

(Regional Water Protection Plan, 2006)

http://www.arpa.emr.it/documenti/arparivista/pdf2008n3/Berr%C3%A8AR3_08.pdf

Emilia-Romagna – wastewater reuse in the regional Water Protection Plan

- The regional Water Protection Plan identifies wastewater reuse as a priority measure for quantitative and qualitative protection of water resources

- The regional Water Protection Plan identifies the priority list of wastewater treatment plants for reuse (including Mancasale WWTP, in Reggio Emilia province)

- Article 71 of the Norms established by the regional Water Protection Plan sets out the option to establish Programme agreements among involved stakeholders in order to support and promote water reuse

Wastewater treatment and reuse in Mancasale treatment plant

Pilot plant to test the technical options for finishing treatment

Carried out in 2009

Objective: identification of the most suitable solution in the specific conditions (technical and economic features were evaluated on a pilot scale)

.

Technical solution: **multi-layer rapid filtration followed by H2O2 /UV treatment**

Post treatment installation

June 2014

December 2014

February 2015

February 2015

May 2015

July 2015

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Wastewater reuse: irrigation

The irrigation catchment

Approximately **2000 hectares** **(**1 hectar 10.000 square meters)

Crops:

•Grassland and Alfa alfa

•Maize

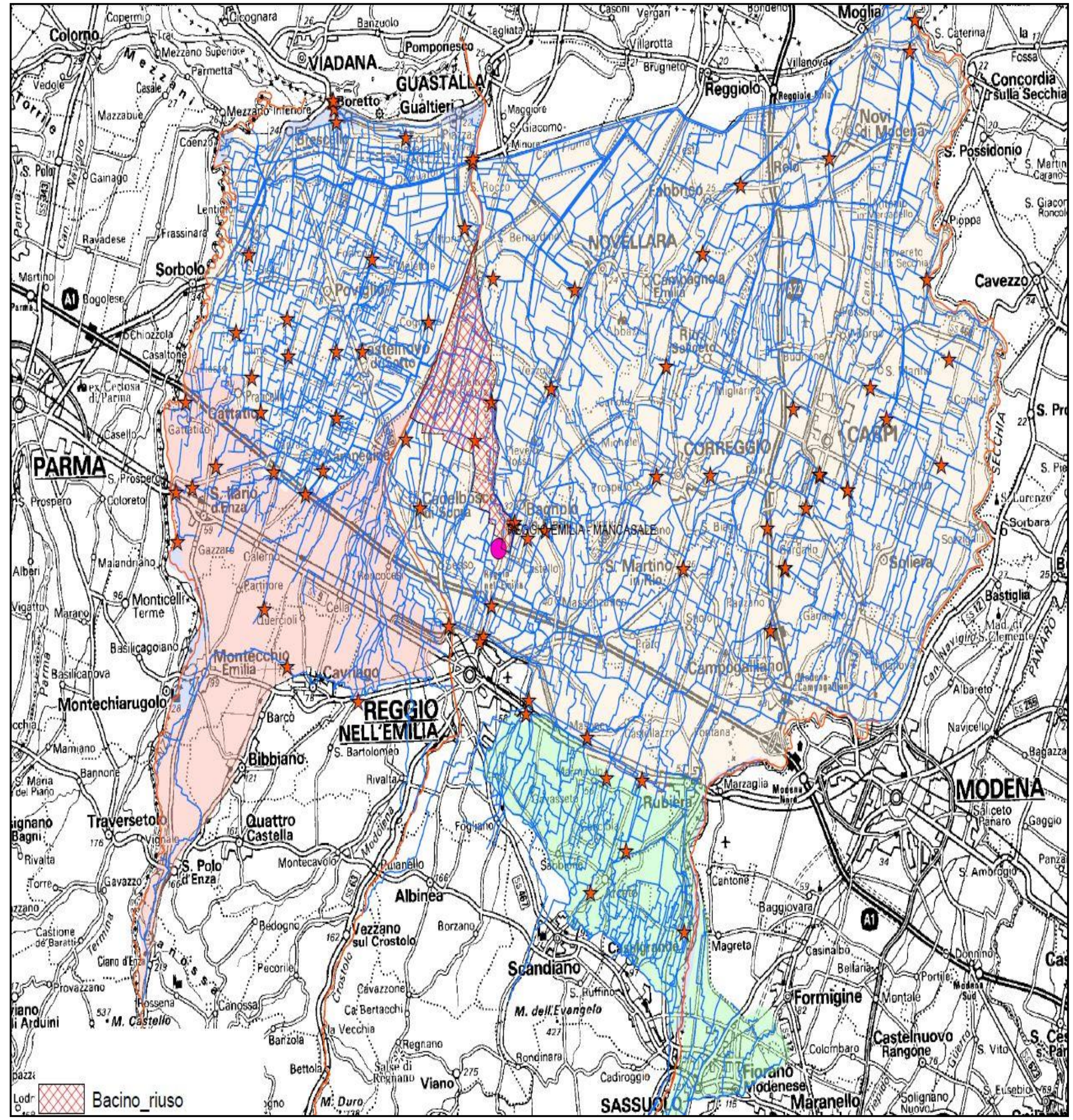
•Sugar beet

•Sorgum

•Tomatoes

•Melon

•Vineyard



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Procedures for the start up

- Programme agreement among all concerned Parties involved in wastewater reuse activities Regional Deliberation n. 966 il 20 July 2015.
- Signataires: Regione Emilia-Romagna, Provincia di Reggio Emilia, ATERSIR, IREN Emilia e Consorzio di Bonifica dell'Emilia Centrale.
- The programme agreement set out the committments of the Parties, the parameters for controls (sampling and analysis) and the frequency of sampling and analysis and the procedures for management of the possible critical issues

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Parameter for control in treated wastewater(n. 60)

Aldeidi (mg/l)	Cobalto (mg/l)	Mercurio (mg/l)	Selenio (mg/l)
Alluminio (mg/l)	Conducibilità a 25°C (µS/cm)	Molibdeno (mg/l)	Sodio (mg/l)
Arsenico (mg/l)	Cromo esavalente (mg/l)	Nichel (mg/l)	Solfati (mg/l)
Azoto ammoniacale (mg/l)	Cromo (mg/l)	Pentaclorofenolo (mg/l)	Solfiti (mg/l)
Azoto totale (mg/l)	Escherichia coli (MPN/100 ml)	Pesticidi azotati (mg/l)	Solventi clorurati (mg/l)
Bario (mg/l)	Fenoli (mg/l)	Pesticidi fosforati (mg/l)	Solventi organici aromatici (mg/l)
Benzene (mg/l)	Ferro (mg/l)	Pesticidi organoclorurati (mg/l)	Solventi organici azotati (mg/l)
Benzo(a)pirene (mg/l)	Fluoruri (mg/l)	pH (Unità pH)	Stagno (mg/l)
Berillio (mg/l)	Fosforo totale (mg/l)	Piombo (mg/l)	Tallio (mg/l)
Bicarbonati (mg/l)	Grassi e olii animali e vegetali (mg/l)	Portata (m3/gg)	Tensioattivi totali (mg/l)
Boro (mg/l)	Indice SAR su estratto acquoso (calc.)	Potassio (mg/l)	Tetracloroetilene - Tricloroetilene (mg/l)
Cadmio (mg/l)	Litio (mg/l)	Rame (mg/l)	Vanadio (mg/l)
Calcio (mg/l)	Magnesio (mg/l)	Ricerca di salmonella in 100 ml	Zinco (mg/l)
Cianuri (mg/l)	Manganese (mg/l)	Richiesta biochimica di O_2 (BOD) (mg/l)	Solfuri (mg/l)
Cloruri (mg/l)	Materiali grossolani	Richiesta chimica di O_2 (COD) (mg/l)	Solidi sospesi totali (SST) (mg/l)

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Treatment performance

PARAMETRI	U.M.	VALORE MEDIO INGRESSO	VALORE MEDIO USCITA	Limite Accordo di Programma
pH	u. pH	7,7	7,8	6-9,5
SST	mg/l	3	0,8	35
BOD	mg/l	2,4	1,5	20
COD	mg/l	22,7	20,6	100
NH_4	mg/l	0,77	0,42	5
N tot	mg/l	6,3	6,2	35
P	mg/l	0,95	0,91	10

Monitoring period 29 March – 19 October 2016, n. 55 samples

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Treatment performance

PARAMETRI	U.M.	VALORE MEDIO	VALORE MINIMO	VALORE MASSIMO	Limite Accordo di Programma
Tensioattivi IN	mg/l	0,32	0,1	1,5	-
Tensioattivi OUT	mg/l	0,31	0,1	0,9	1,0
Oli minerali IN	mg/l	<0,01	<0,01	0,06	-
Oli minerali OUT	mg/l	<0,01	<0,01	<0,01	0,05

Monitoring period 29 March – 19 October 2016, n. 55 samples

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Treatment performance

PARAMETRI	U.M.	VALORE MEDIO	VALORE MINIMO	VALORE MASSIMO	Limite Accordo di Programma
E-coli IN	MPN/100 ml	44.167	4.568	240.030	-
E-coli OUT Pistarina	MPN/100 ml	2	0	34	1000

E-coli removal 99,98%

Salmonella in 17/55, out: absent

Treatment performance

PARAMETRI	U.M.	VALORE MEDIO INGRESSO	VALORE MEDIO USCITA	Limite Accordo di Programma
Conducibilità	uS/cm	1471	1476	3000
Boro	mg/l	0,22	0,21	1,0
Cloruri	mg/l	205	219	500
Bicarbonati	mg/l	402,8	401,5	500
Solfati	mg/l	95,8	95,3	500
Indice di SAR	-	3,22	3,26	10
Sodio	mg/l	146,3	150,3	200
Calcio	mg/l	118,4	118,4	-
Magnesio	mg/l	21,9	21,7	-

Monitoring period 29 March – 19 October 2016, n. 55 samples

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Treatment performance

- Sand filtration followed by UV/H_2O_2 treatment performed the required reduction of suspended solids and microbial loading (i.e. Salmonella, Total coliforms, *Escherichia coli*)
- Also pollutants such as mineral oils and detergents are removed
- Overall it was concluded concluded that the finishing treatment showed good applicability in full scale

Wastewater reuse, optimization of use and treaceability

Achieved objectives:

1. **Mapping of individual parcels** e rand collection of information concerning crops, irrigation methods, landowner, derivation channel for irrigation

2. **Identification** of channels used for the distribution of treated wastewater

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Wastewater reuse, optimization of use and treaceability

Treaceability. Implementation of a communication system for irrigation water management ensuring:

- **Identification in real time** of the irrigation water sources delivered into the irrigation catchment;

- **Registration of the pertinent data for individual water distribution** to each plot/parcel (date and time of irrigation, volume applied, type of water (surface water and/or trated wastewater) and release to the farmer in real time of a **“receipt of irrigation”** including all the recorded available data

Wastewater reuse in agricolture

Wastewater reuse in agriculture

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Wastewater reuse

DATA RICHIESTA IRRIGUA: 13/07/2016   DATA PRENOTAZIONE RICHIESTA: 12/07/2016

APPEZZAMENTO

CODICE	16889
SUPERFICIE (ha)	5,2500
COLTURA	PRATO STABILE
PRESA	
POZZO	
IRRIGAZIONE	Scorrimento
CANALE	Canale-ARGINE
CANALE SECONDARIO	A7016-Cavo-PISTARINA
AREA IRRIGUA	DM-DEPURATORE MANCASALE
SOTTOZONA	42 - Dallara-Palladini

DOTAZIONE

Portata (l/s)	min (ore)	max reg. (ore)	IrriNET (ore)	eff. (ore)
35,00 consorziale	33	83	N.P.	0
20	58	146	N.P.	0
25	47	117	N.P.	0
30	39	97	N.P.	0
40	29	73	N.P.	0
50	23	58	N.P.	0
60	19	49	N.P.	0
70	17	42	N.P.	0
80	15	36	N.P.	0
90	13	32	N.P.	0
100	12	29	N.P.	0
110	11	27	N.P.	0

IRRIGAZIONI EFFETTUATE

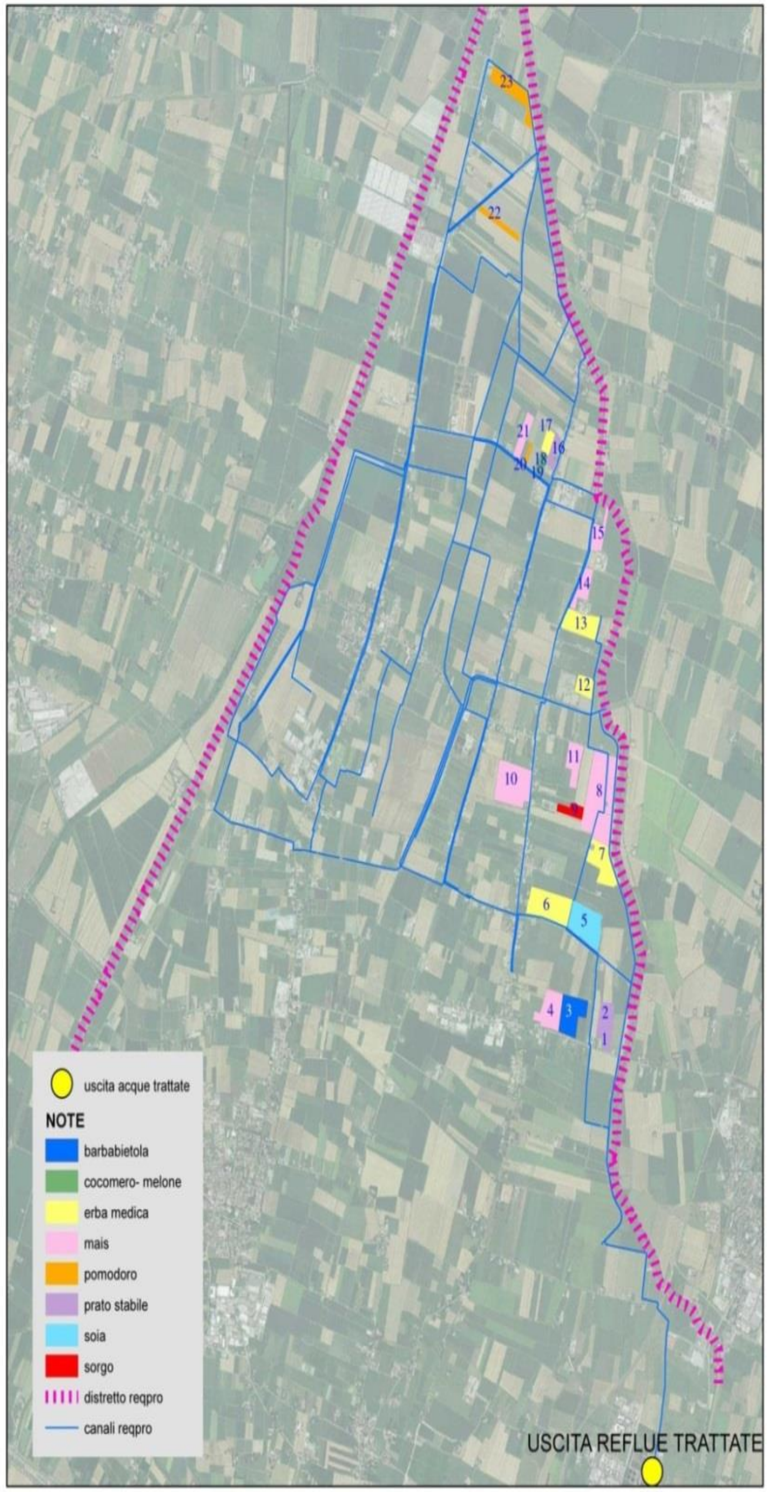
Non ci sono irrigazioni effettuate

Apertura	Chiusura	Portata	Superficie(ha)	Durata	Mc erogati	In. Produttività	In. Momento	In. Servizio	In. Rivalità
12/07/2016	15/07/2016	35.00	5.2500	83:00	10458,00	1,2	1	1	1

Monitoring of environmental impact

In the period **2014-2015 ex-ante** monitoring

In **2016 (Wastewater utilization,** 3.5 million m^3 of reused wastewater over 150 days **)** : 10 farms , 23 parcels and 9 crops; Analisys on 40 samples of water, 80 samples of biomass and 75 soil samples



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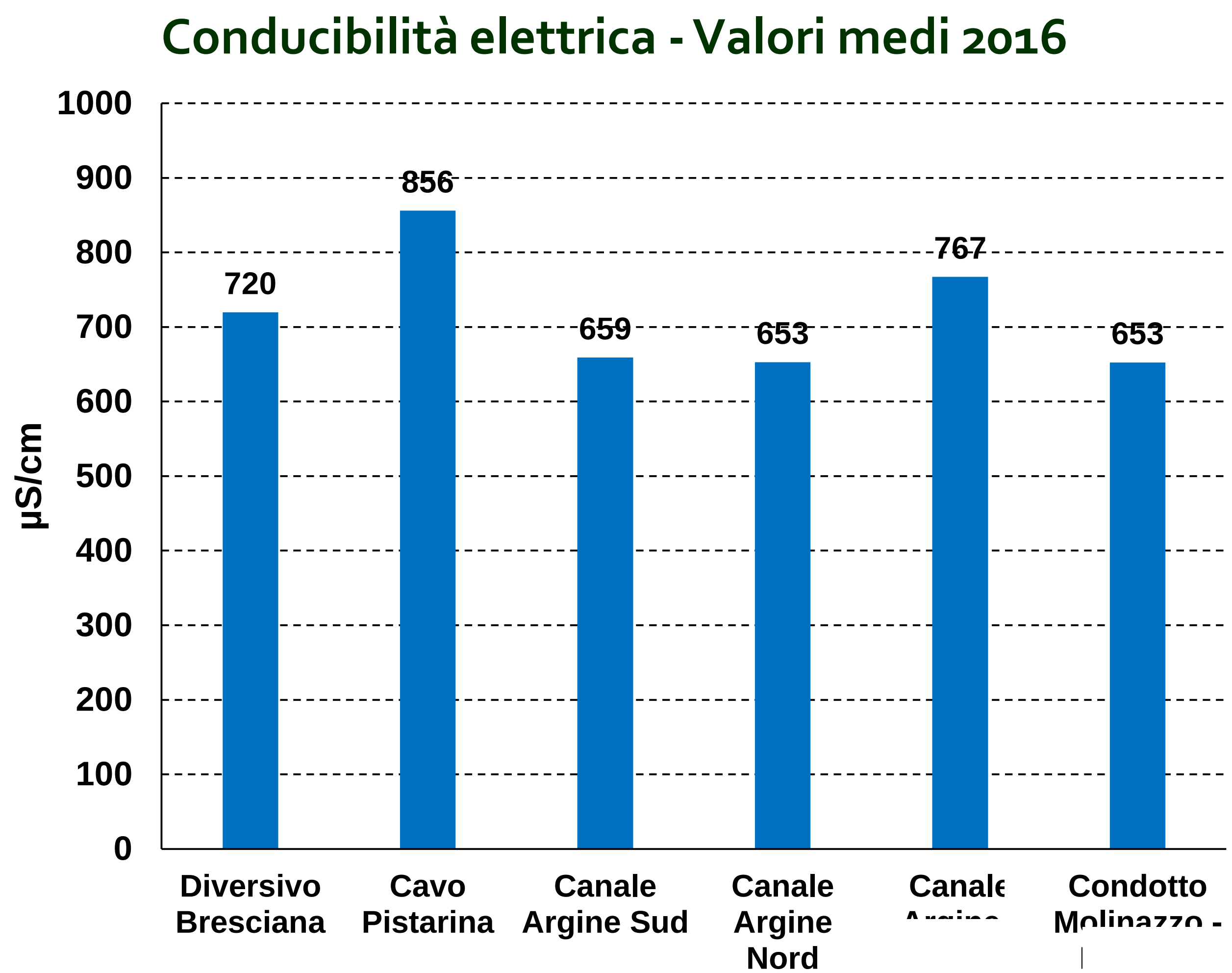
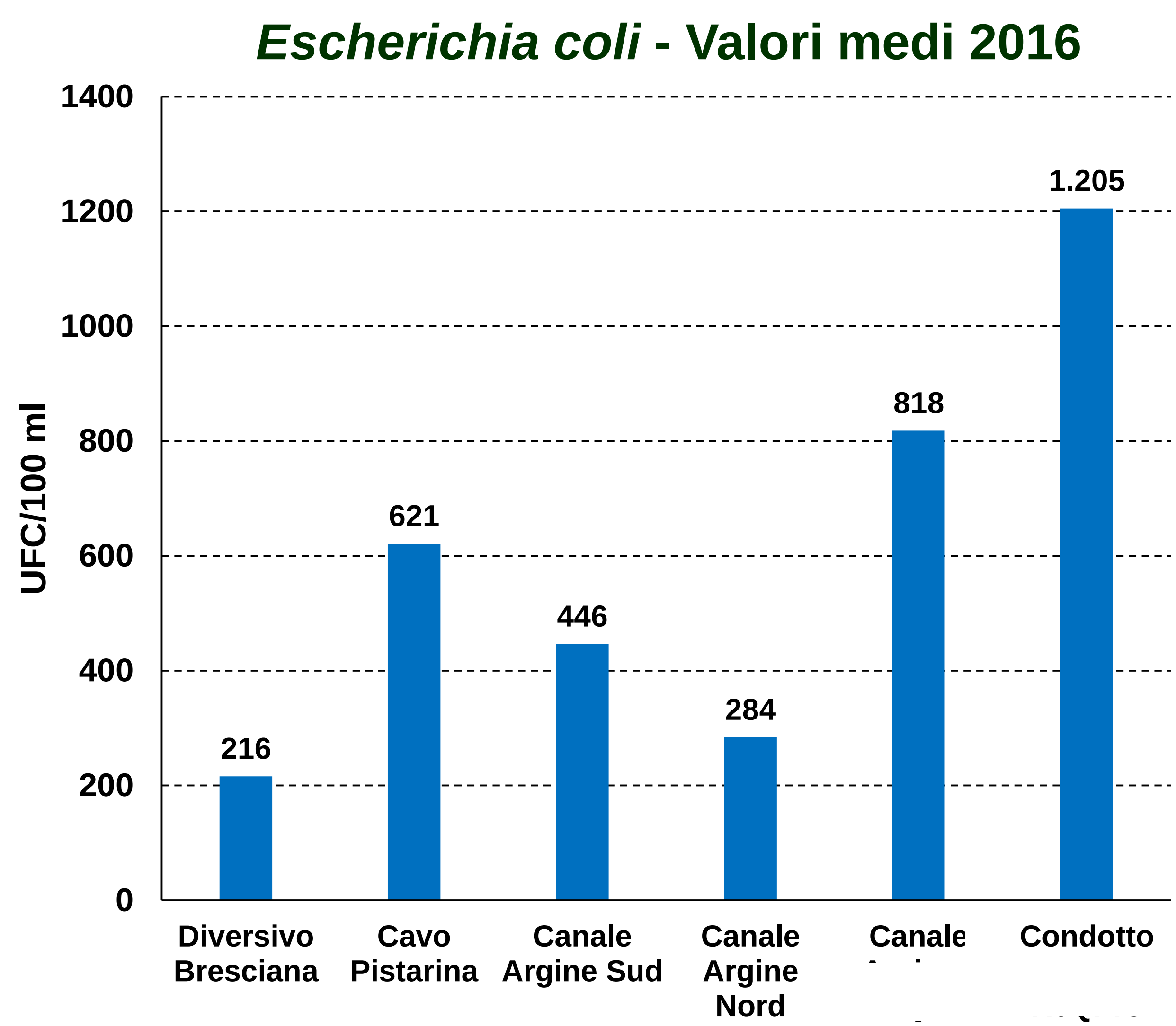
Water, soil and crop analysis

- Water: conductivity, Nitrates, total Nitrogen and Phosphorus, *Escherichia coli*
- Soil (strato superficiale): Nitrogen and Phosphorus, conductivity
- Crops (prodotti raccolti): Nitrates, *Escherichia coli*

Environmental monitoring-Water





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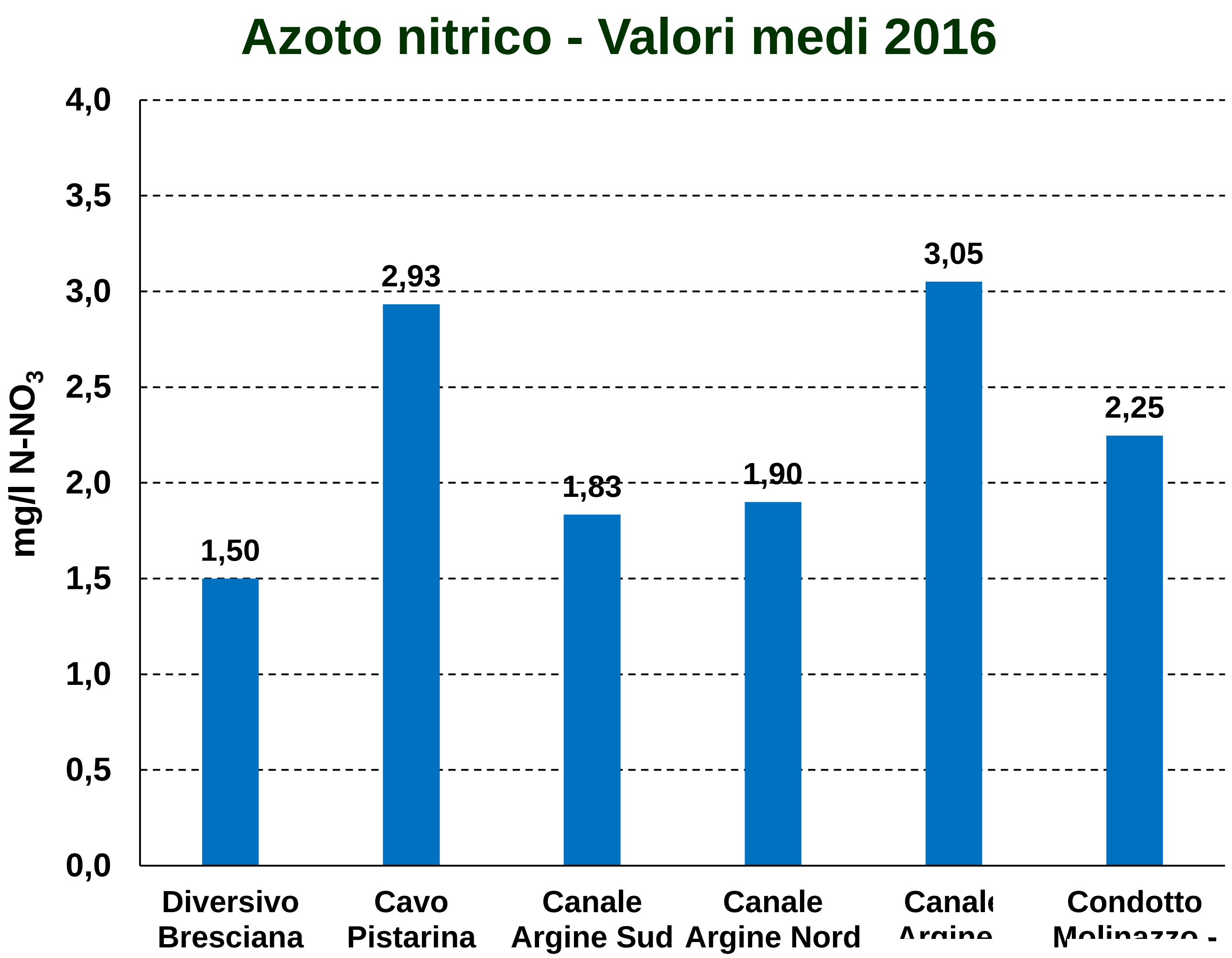
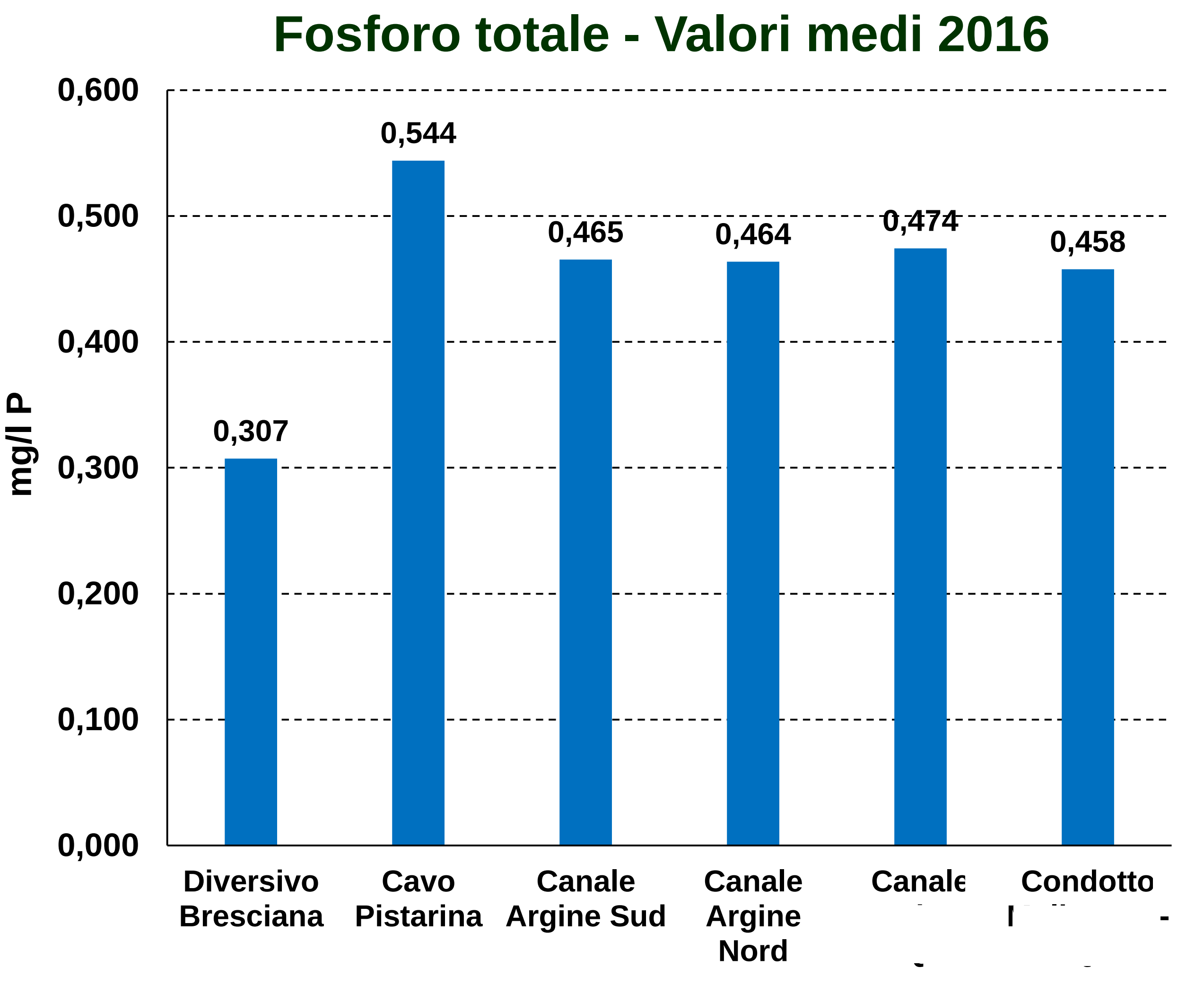
Environmental monitoring-Water





Environmental monitoring-Conclusions

- **Water**: no adverse effects on surface waters

- **Soil and crops**: no difference between ex ante situation (2014 and 2015- no application of treated wastewater and 2016 (treatment with irrigation water and treated wastewater)

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Socio-economic impact evaluation

Main costs

Finishing section of the wastewater treatment(~ 3M €)

Operational costs(0,069 €/m^3)

Main benefits:

Reduction of energy costs for pumping surface water (50-70% of the overall benefits)

Improved surface water quality

Summary of the project results

The project demonstrated the technical and economical applicability of the proposed model represented by the treatment plants and the irrigation catchment and its farms.

The project improved agricultural utilisation of treated wastewater reducing direct discharges into surface water and therefore:

- increased water availavility for irrigation
- reduced water withdrawals for irrigation needs from groundwater (high quality water)
- improved surface water status
- reduced energy costs for pumping irrigation water

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EU level perspectives
Wastewater Reuse

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EU level perspectives (1)
Wastewater Reuse

Objectives

1) Address water scarcity

2) Reduce vulnerability

Analysis

Reuse:

- **Significant alternative water source** (lower environmental impact compared to water transfers and desalinisation)
- **Limited explotation** (lack of common standards, potential limitations to free trade)

Proposal

Support water reuse:

- **EU level standards for water reuse**

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EU level perspectives on water reuse (2)

A. Guidance on planning and management of water reuse

- Integration in WFD planning and implementation

EU level perspectives (3)

B. EU quality standards for water reuse

Priority uses: agricultural irrigation and aquifer recharge

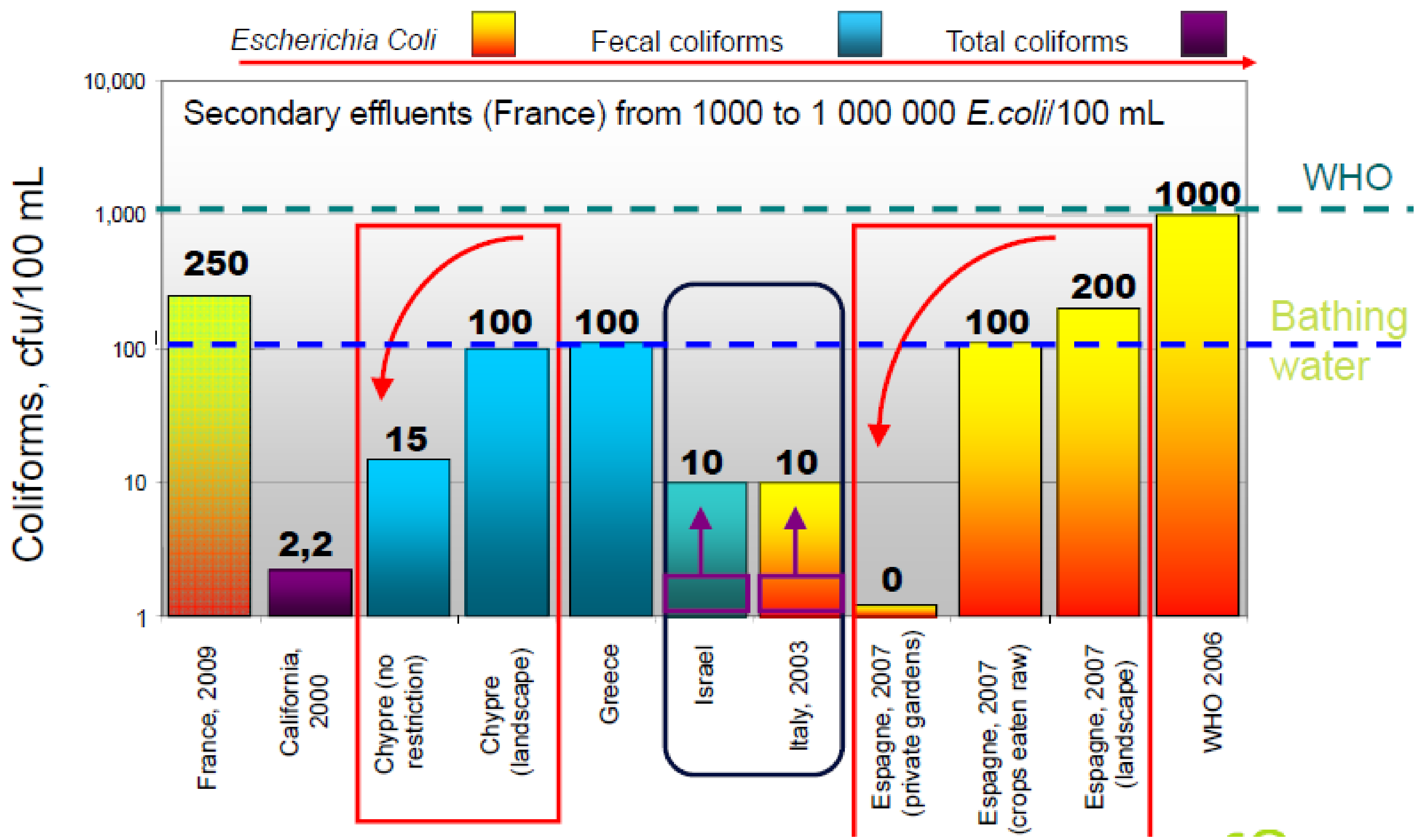
Comparison of wastewater uses in current Regulations of EU Member State

Intended use of reclaimed water	Cyprus	France	Greece	Italy	Portugal	Spain
Irrigation of private gardens						√
Supply to sanitary appliances						√
Landscape irrigation of urban areas (parks, sports grounds and similar)	√	√	√	√	√	√
Street cleaning			√	√		√
Soil compaction			√			
Fire hydrants			√			√
Industrial washing of vehicles				√		√
Irrigation of crops eaten raw	√	√	√	√	√	√
Irrigation of crops not eaten raw	√	√	√	√	√	√

Comparison of microbiological standards standards in EU Member States

Analytical parameters	Cyprus	France	Greece	Italy	Portugal	Spain
Microbiological parameters						
- *Escherichia coli* (cfu/100mL)	$5\text{-}10^3$	$250\text{-}10^5$	5-200	10		$0\text{-}10^4$
- Fecal coliforms (cfu/100mL)					$100\text{-}10^4$	
- Total coliforms (cfu/100mL)			2			
- Fecal enterococci (log reduction)		2-4				
- *Legionella* sp. (cfu/L)						$0\text{-}10^3$
- *Salmonella* sp.				absence		absence
- Sulphate-reducing bacteria (log reduction)		2-4				
- Helminths eggs (Intestinal nematodes) (eggs/L)	0				1	0.1
- F-specific bacteriophages (log removal)		2-4				

Comparison of microbiological standards



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WHO guidelines for wastewater reuse

WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater (Third edition, 2006)

- 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

WHO Guidelines background

- Wastewater use is extensive worldwide, and increasing
- Ten percent of the world's population is thought to consume wastewater irrigated foods
- Twenty million hectares in 50 countries are irrigated with raw or partially treated wastewater
- The use of excreta (faeces, urine) is important worldwide, but the extent has not been quantified
- The use of greywater is growing in both developed and less-developed countries – it is culturally more acceptable in some societies.

WHO Guidelines, policy and regulatory aspects Vol 1 http://apps.who.int/iris/bitstream/10665/78265/1/9241546824_eng.pdf

Policy formulation, a step by step process

- Establishment of a policy dialogue mechanism
- Defining objectives
- Situation analysis, policy appraisal and needs assessment
- Political endorsement, dialogue engagement and product legitimization
- Research

Institutional arrangements

- The concept of intersectoral collaboration
- Mechanisms to promote intersectoral collaboration

WHO Guidelines, lessons learned

- Overly strict standards borrowed from other countries often fail
- Guidelines are not just numbers; they are made up of good practice + microbial water quality standards
- Low-cost effective treatment technologies needed
- Risk reduction strategies necessary (and possible) where wastes receive no or inadequate treatment.

WHO Guidelines

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

- Target Audience: Policy makers, people who develop and enforce standards and regulations, environmental and public health scientists, educators, researchers and engineers.

WHO Guidelines general scope

The Guidelines cover:

- intentional use specifically but they may also be relevant to some unintentional uses e.g., irrigation or aquaculture with sewage contaminated surface waters
- municipal or domestic wastes without substantial industrial inputs
- detailed information only on matters related to health protection – only cursory reference to technical issues on good agriculture or aquaculture practices in text or annexes.

WHO Guidelines on the Safe Use of Wastewater, Excreta and Grey Water

Guidelines provide an integrated preventive management framework for maximizing public health and environmental benefits of waste use.

Health components:

- Define a level of health protection that is expressed as a health-based target for each hazard
- Identify health protection measures which used collectively can achieve the specified health-based target.

Implementation components:

- Establish monitoring and system assessment procedures
- Define institutional and oversight responsibilities.

Require:

- System documentation
- Confirmation by independent surveillance.

WHO guidelines Definition of a tolerable risk

- Based on local public health conditions
- Health priorities (hazards, types of diseases and relative importance)
- Capabilities (institutional, economic, social).

WHO guidelines. Definition of a tolerable risk

The desired level of protection can be reached through a combination of management control options such as:

- Wastewater treatment
- Crop restriction
- The method of irrigation
- Food preparation
  - Washing
  - Disinfection
  - Peeling
  - Cooking
- Hygiene practices at the marketplace
- Vaccines and other health sector preventive measures

WHO guidelines
Quantitative Microbial Risk Analysis (QMRA)

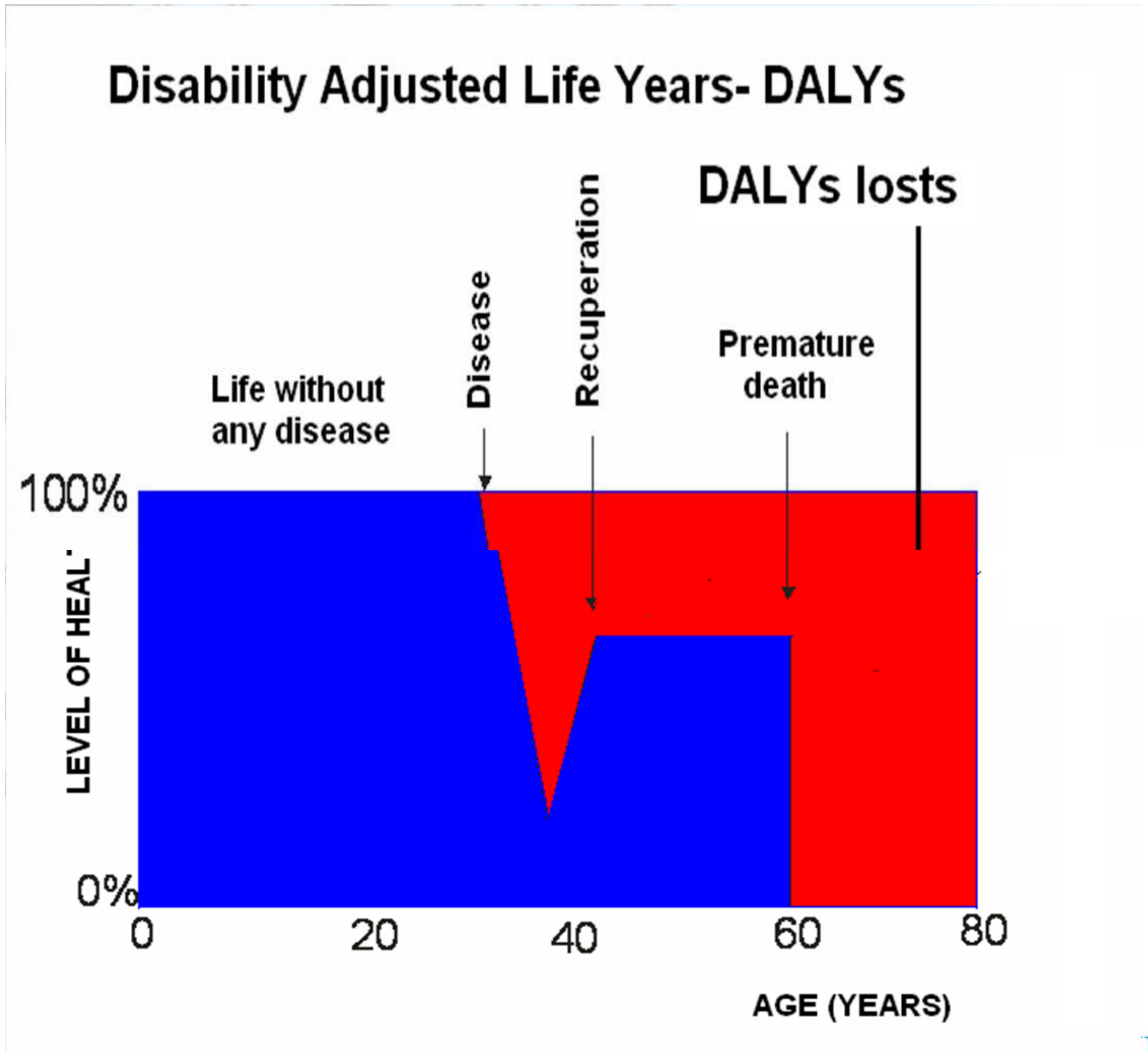
The amount of pathogens that can be ingested without exceeding a tolerable risk

- As result, limits to the number of microorganisms per L of wastewater that can be used to irrigate a certain type of crop are obtained
- The estimate is based on
  - A statistical analysis of the risk of being infected from a single dose (d) of a certain pathogen (P), i.e. an evaluation of P1(d) during several exposures.
  - Mathematical models are applied (exponential dose-response and the Bèta-Poisson model) but other models can be used

Definition of the tolerable risk

- The purpose is to standardize the acceptable risk caused by different agents in different norms (Drinking water a risk of 10^{-5} for cancer while in irrigation a risk of 10^{-3} for diarrhoeas)

- One DALY = One year of healthy life lost, as a measure of community health. The burden of disease, expressed in DALYs, represents the gap between a real community health status and an ideal situation where everyone lives into old age free of disease and disability .



WHO recommendation: ≤ 10^{-6} DALYs lost

Compatible with other public health safety standards

- ➢It is below the actual global incidence of diarrhoeal disease which is is estimated at 0.7, i.e. 10-1
- ➢ On a per person basis it is equal to losing 31.5 seconds of healthy life in a year.
- ➢ At the community level it signifies a collective loss of one year of healthy life per million people

Sanitation Safety Planning

- SSP is a step-by-step health risk based approach for managing monitoring and improving sanitation systems
- SSP also assists to implement the 2006 WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater

Thank you

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