



Microbial health risks related to irrigation of fresh produce with wastewater

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Wastewater reuse in agriculture



Wastewater reuse in agriculture

Incentives

Source of water

Source of nutrients

Available all year

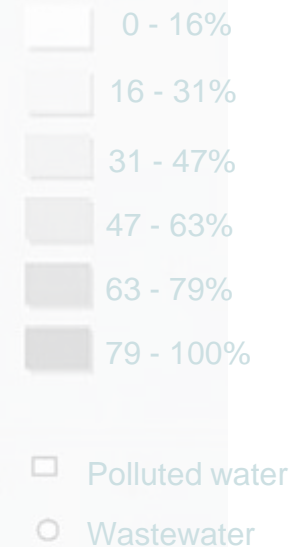
Available in vicinity of settlements

Economical value:

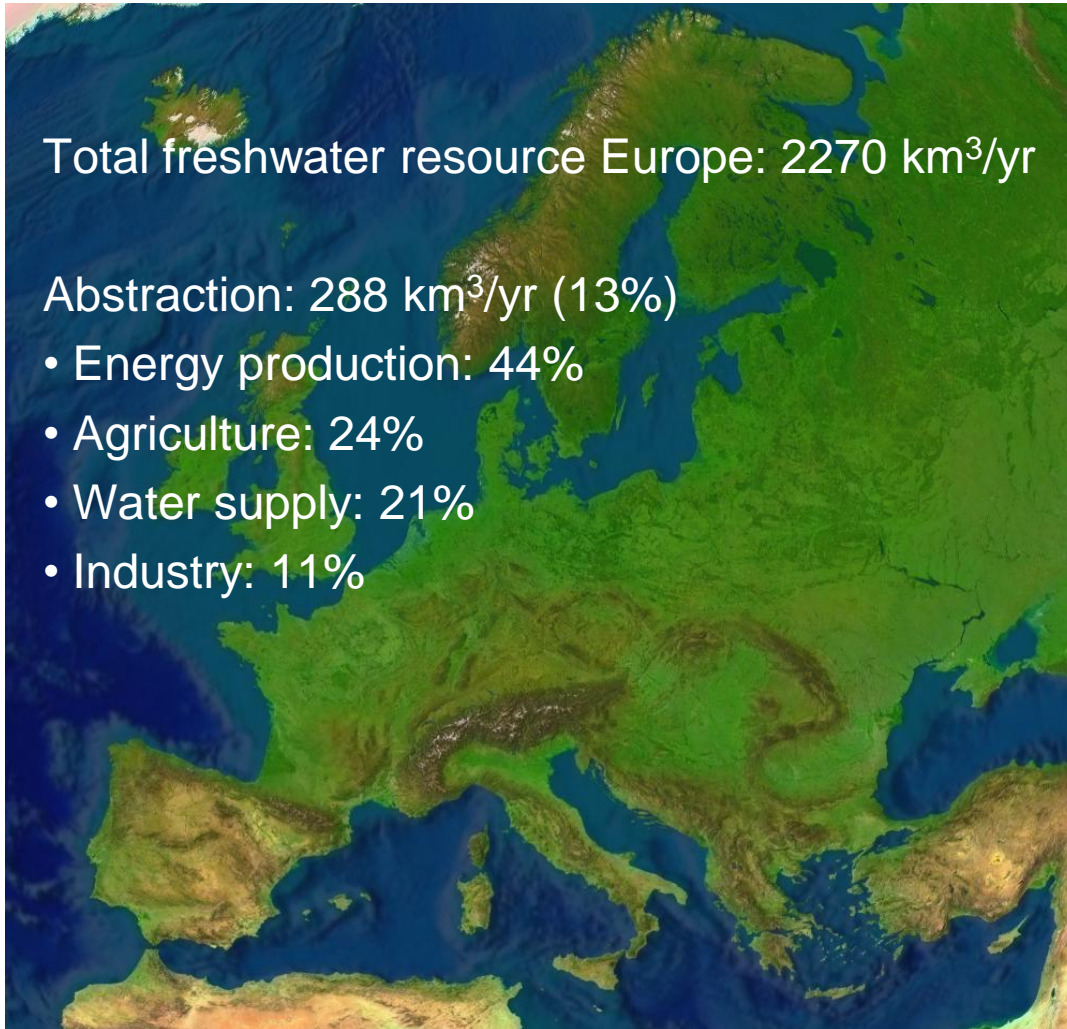
- Increased harvest
- Reduced cost for fertilizer
- Reduced cost for wastewater treatment

Ecological value:

- Less discharge of wastewater to surface water

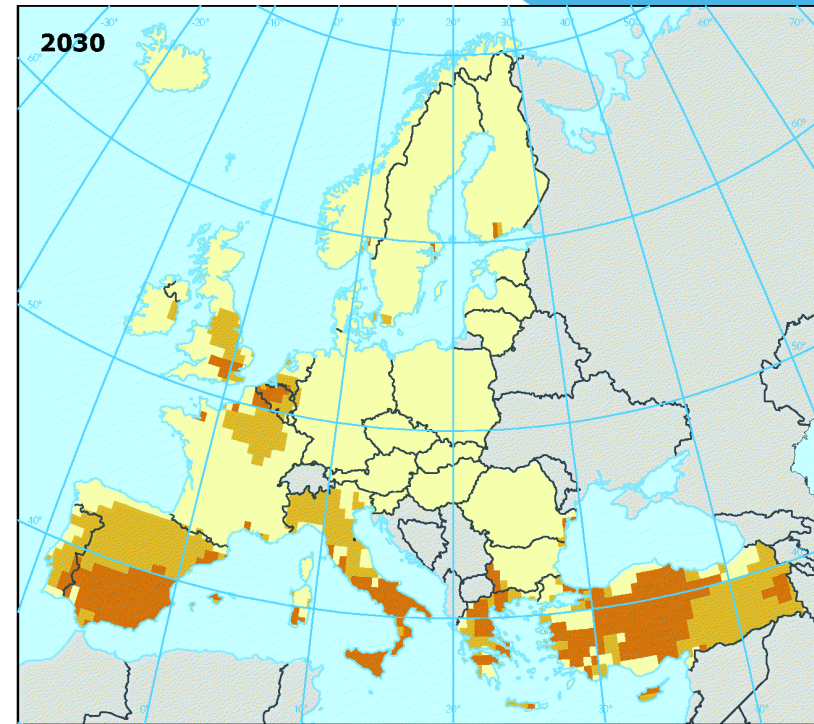
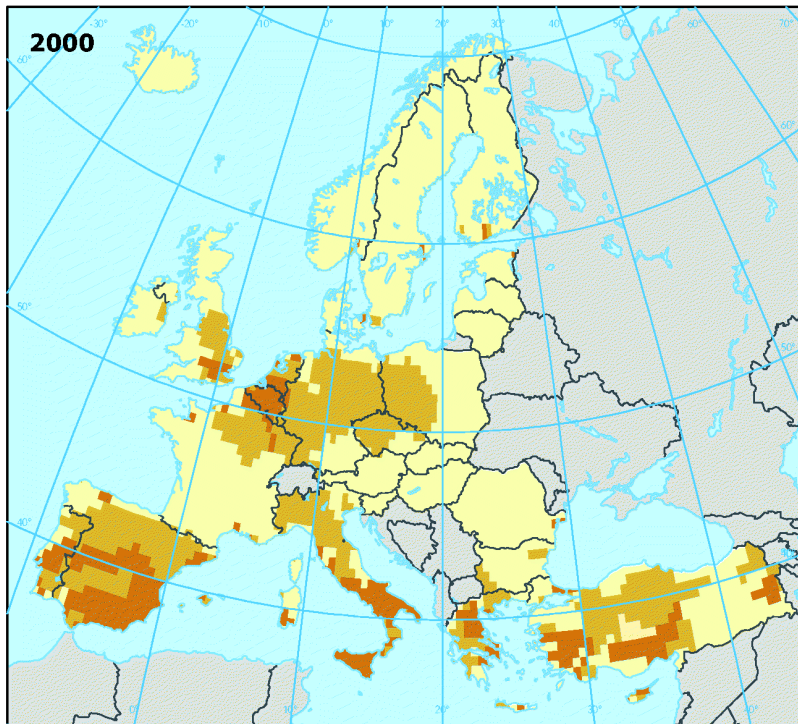


Water stress in Europe?



Water stress in Europe

Water exploitation index (WEI)



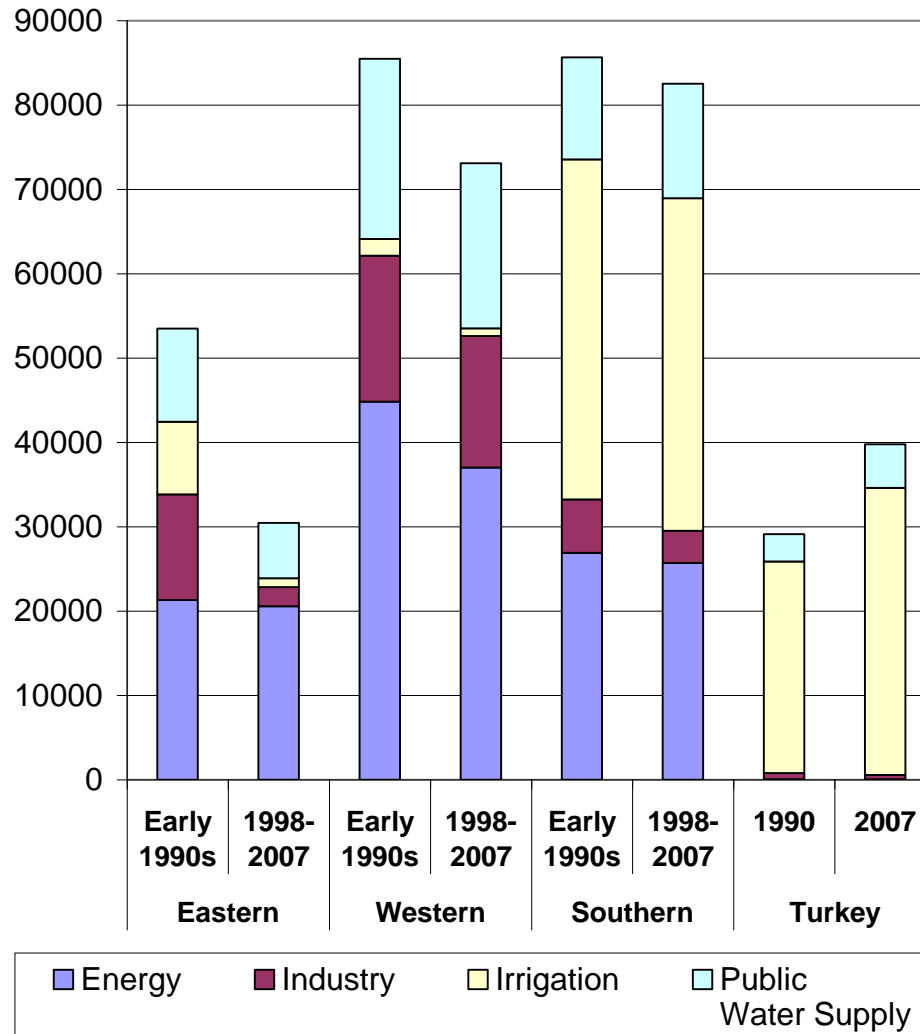
Water stress in European river basins in 2000 (left) and under the LREM-E scenario by 2030 (right)

Water exploitation index (%):

0–20 (low water stress)	20–40 (medium water stress)
> 40 (severe water stress)	Outside data coverage

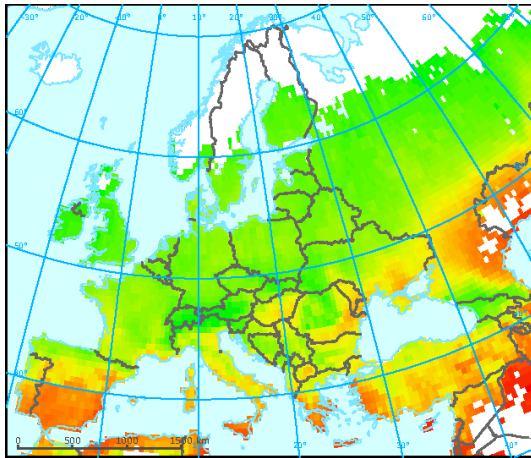
Water uses in European regions

Abstractions (mio m³/year)



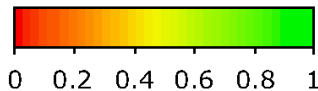
Water stress – agriculture stress

Prognosis: increased stress

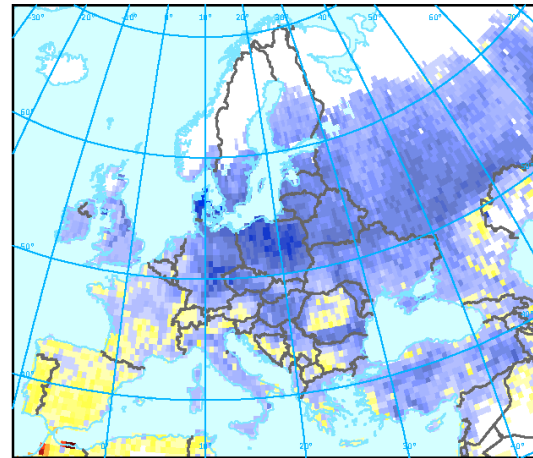


Present (1971–2000) water limitation of crop primary production in Europe under rain fed conditions

Water limitation index

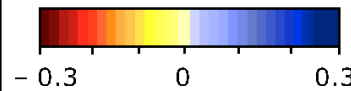


Outside coverage

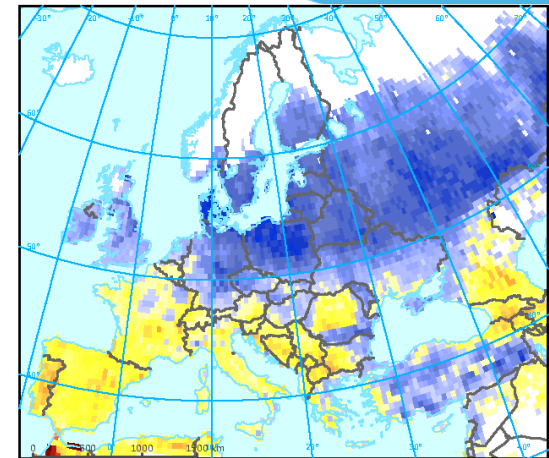


Changes in water limitation of crop primary production in Europe under rain fed conditions, B1 scenario – 2080s (2070–2099)

Change of water limitation

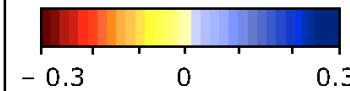


Outside coverage



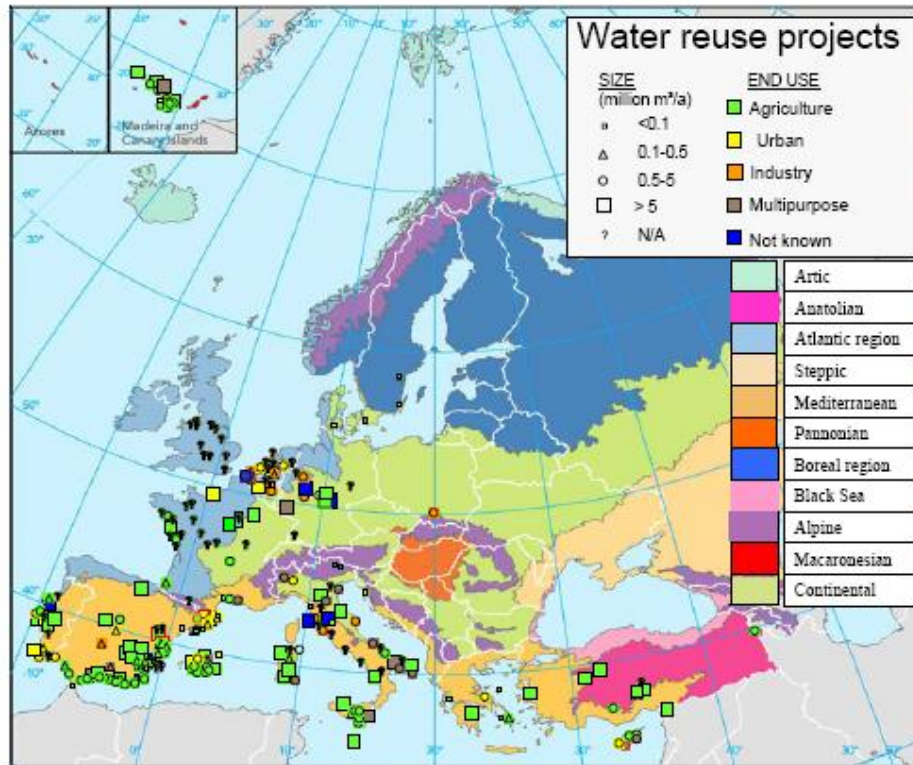
Changes in water limitation of crop primary production in Europe under rain fed conditions, A2 scenario – 2080s (2070–2099)

Change of water limitation



Outside coverage

Wastewater reuse in Europe



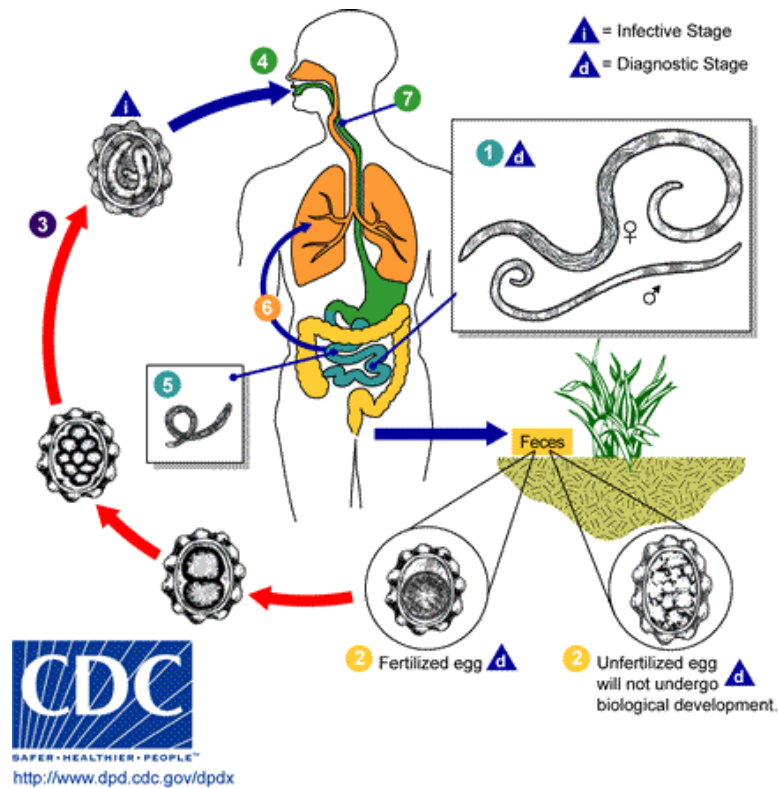
Wastewater reuse for irrigation of fresh produce



Microbial health hazards

Fecal-oral transmission

Ascaris example:



Pathways of exposure to pathogens

Very prominent

- Consumption of contaminated wastewater-irrigated produce
- Human contact with the wastewater before, during or after irrigation (farmers, their families, vendor, local communities)

Less prominent

- Consumption of contaminated drinking-water as a result of wastewater use activities
- Inhalation of wastewater aerosols (workers, local communities).
- Consumption of animals or animal products that have been contaminated through exposure to wastewater.

Pathogens in domestic wastewater

Organism	Number in wastewater (per litre)
Bacteria	
Thermotolerant coliforms	10^8 - 10^{10}
Camphylobacter jejuni	10 - 10^4
Salmonella spp.	1 - 10^5
Shigella spp.	10 - 10^4
Vibrio cholera	10^2 - 10^5
Helminths	
Ascaris lumbricoides	1 - 10^3
Ancylostoma duodenale/Necator americanus	1 - 10^3
Trichuris trichiura	1 - 10^2
Schistosoma mansoni	ND
Protozoa	
Cryptosporidium parvum	1 - 10^4
Entamoeba histolytica	1 - 10^2
Giardia intestinalis	10^2 - 10^5
Viruses	
Enteric viruses	10^5 - 10^6
Rotavirus	10^2 - 10^5

Categories of diseases relevant in wastewater-irrigated agriculture (Mara & Bos, 2010)

Category	Environmental transmission features	Major examples of infection	Exposure groups in urban agriculture and relative infection risks
Non-bacterial faeco-oral diseases	Non-latent ^a Low to medium persistence ^b Unable to multiply High infectivity	Viral: Hepatitis A and E Rotavirus diarrhoea Norovirus diarrhoea Protozoan: Amoebiasis Cryptosporidiasis Giardiasis Cyclosporiasis	Fieldworkers: + ^c Consumers: +++
Bacterial faeco-oral diseases	Non-latent Medium to high persistence Able to multiply Medium to low infectivity	Campylobacteriosis Cholera Pathogenic <i>Escherichia coli</i> infection Salmonellosis Shigellosis	Fieldworkers: + Consumers: +++
Geohelminthiasis	Latent Very persistent Unable to multiply Very high infectivity	Ascariasis Hookworm infection Trichuriasis	Fieldworkers: +++ Consumers: +++

+++ high risk; ++ medium risk; + low risk (These risks refer to the use of untreated wastewaters; treatment and post-treatment health-protection control measures can reduce these risks to the tolerable level of $\leq 10^{-3}$ per person per year, as discussed below.)

^aLatency is the length of time outside a human host required for the pathogen to become infective.

^bPersistence is the length of time that the pathogen can survive in the environment outside a human host.

^cNote that fieldworkers are commonly also consumers.

Source: Feachem et al. (1983)

Burden of disease and mortality of diseases relevant to wastewater reuse in agriculture

Disease	Mortality (deaths/year)	Burden of disease (DALYs)	Comments
Diarrhoea	1,682,000	57,966,000	99.7% of deaths occur in developing countries; 90% of deaths occur in children; 94% can be attributed to environmental factors.
Typhoid	600,000	N/A	Estimated 16,000,000 cases per year.
Ascariasis	3000	1,817,000	Estimated 1.45 billion infections, of which 350 million suffer adverse health effects.
Hookworm disease	3000	59,000	Estimated 1.3 billion infections, of which 150 million suffer adverse health effects.
Lymphatic filariasis	0	3,791,000	Mosquito vectors of filariasis (<i>Culex</i> spp.) breed in contaminated water. Does not cause death but leads to severe disability.
Hepatitis A	N/A	N/A	Estimated 1.4 million cases per year worldwide. Serological evidence of prior infection ranges from 15% to nearly 100%.

N/A = not available.

Source: Prüss-Ustün and Corvalan (2006); WHO (2006)

Ascaris: distribution of disease burden

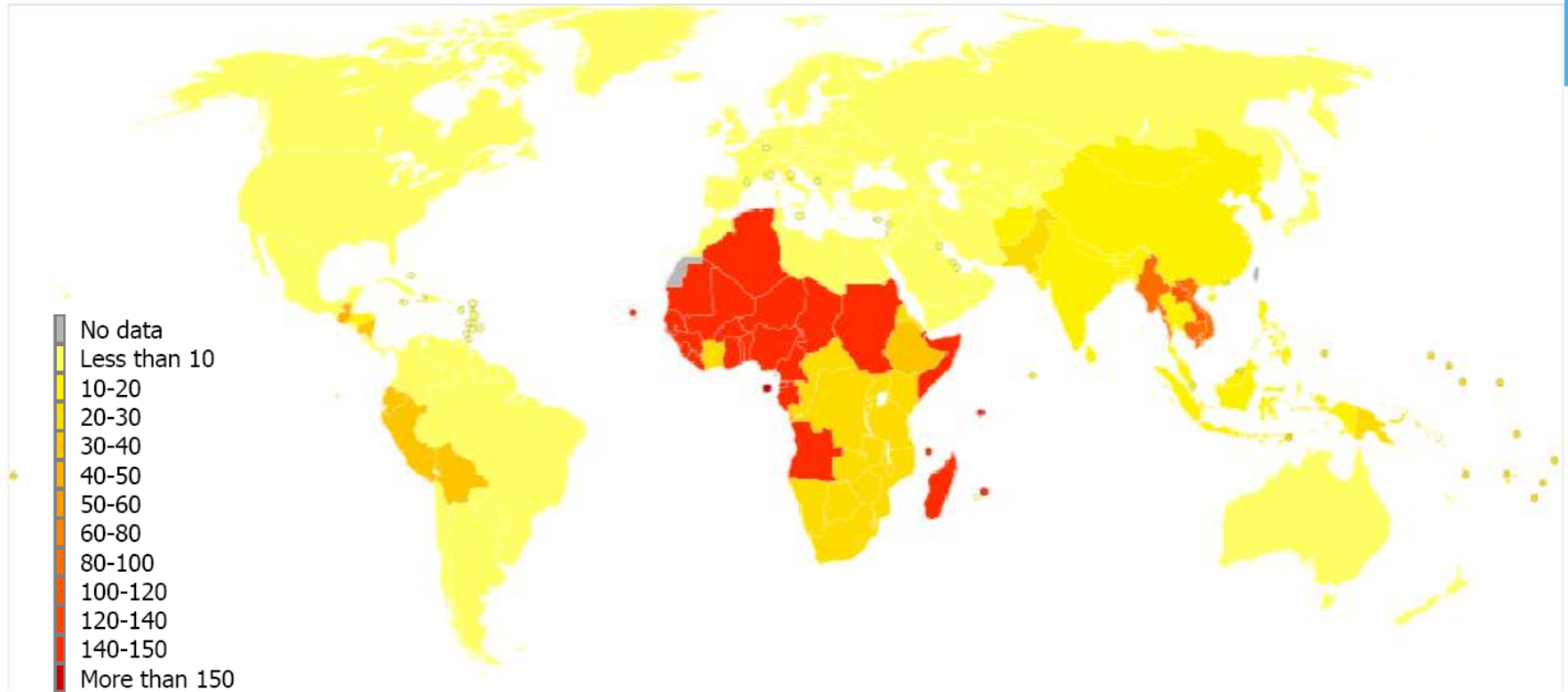


Figure 4: DALY factor for ascariasis per 100,000 inhabitants worldwide in 2002 (WHO, 2002)

Mitigating microbial health risks

- Wastewater treatment: pre-farm
- Irrigation practice: on-farm
- Treatment of fresh produce: post-farm



Wastewater treatment

Pre-farm

Waste stabilization ponds, wetlands
Primary sedimentation
Activated sludge treatment

Enhanced treatment:

- soil-aquifer treatment
- filtration
- coagulation
- disinfection
- membrane bioreactors

Protects workers and consumers



Photo: Biomatrix

Irrigation practice

On-farm

On-farm collection infrastructure

- Reservoirs and weirs: sedimentation traps
- Sand filters

Irrigation practice

- Collection: protective practices and clothing
- Irrigation methods: drip/subsurface vs spray/flood
- Period of no irrigation prior to harvest

Farming practice

- Crop selection: exclude crops eaten uncooked
- Harvesting hygiene: avoid entry of pathogens



Treatment of fresh produce

Post-farm

Transport and storage

- Cool (prevent growth of bacteria)
- Hygiene practices

Processing, packaging and marketing

- Washing: water hygiene (acid, salt, bleach)
- Worker hygiene
- Storage and shelf-life

Point of use

- Peeling, cooking
- Hygiene practice



Wastewater reuse guidelines

WHO, 2006

Different categories of irrigation (fresh produce: unrestricted irrigation)

Risk-based approach:

- safe health target: 10^{-6} DALY
- demonstration of safety with Quantitative Microbial Risk Assessment

Multiple-barrier approach: combination of wastewater treatment, irrigation and farming practice and post-farm treatment to achieve required pathogen reduction

Protection of workers and consumers



Europe

No EU guidelines for wastewater reuse

Existing criteria in EU countries

Need for harmonized guidance

EUREAU: recommends development of EU guidance framework to promote safe wastewater reuse for irrigation

WHO guidelines as basis

Member State	Type of criteria	Comment
Belgium: Flemish Regional Authority	Aquafin Proposal to the Government (2003)	Based on Australian EPA guidelines
Cyprus	Provisional standards (1997)	Quality criteria for irrigation stricter than WHO standards but less than Californian Title 22 (TC < 50/100 ml in 80% of the cases on a monthly basis and < 100/100 ml always)
France	Art. 24 décret 94/469 3 juin 1994 Circulaire DGS/SD1.D./91/n°51	Both refer as water reuse for agricultural purposes. Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set back distances between irrigation sites and residential areas and roadways
Italy	Decree of Environmental Ministry 185/2003	Quality requirements are required for the three water reuse categories defined: agriculture, non-potable urban and industrial. Possibility for the Regional Authorities to change some parameters and implement stricter norms
<i>Regional authorities:</i> Sicily, Emilia Romagna and Puglia	Guidelines	The proposed microbiological standards are similar to those of the Title 22 regulation for Puglia and Emilia Romagna and to WHO standards for Sicily
Spain	Law 29/1985, BOE n.189, 08/08/85 Royal Decree 2473/1985	In 1985 the Government indicated water reuse as a possibility, but no specific regulation followed. A draft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. The proposed microbiological standards range is strongly similar to those of the Title 22 regulations
<i>Regional authorities:</i> Andalucia, Balearic Is. and Catalonia	Guidelines from the Regional Health Authorities	developed their own guidelines concerning wastewater recycling, in particular in the field of the irrigation, based on the WHO guidelines of 1989

Bixio et al, 2006