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Wastewater Reuse on an International Scale: Application and Linked Legislation on Quality Requirements

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Dr. Norbert Kreuzinger

Lejda Toci

40028196

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Affidavit

I, **LEJDA TOCI**, hereby declare

1. that I am the sole author of the present Master's Thesis, "WASTEWATER REUSE ON AN INTERNATIONAL SCALE: APPLICATION AND LINKED LEGISLATION ON QUALITY REQUIREMENTS", 73 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

The world's water resources are becoming scarce as a consequence of increased pressure from urban development, population growth, food production and climate change. The result of this pressure is an increase in water shortage in many parts of the world and a decrease in water quality. In this context, planned reuse of treated wastewater is gaining more and more attention as a sustainable non-conventional source of water. However, wastewater reuse faces several challenges, the most significant of which are health concerns about the quality of reused water. Hazards contained in reused water such as chemical and microbial agents can pose both an immediate and a long-term risk to human health. Thus, numerous guidelines for wastewater reuse have been developed both on a national and international level.

This thesis conducts a survey of the current state of wastewater reuse practice in 193 countries and the quality standards established by countries and international organisations. It focuses on the six main guidelines identified as benchmark standards: Australia, the United States Environmental Protection Agency (US-EPA), California 22, the Food and Agriculture Organisation (FAO), the International Organisation for Standardisation (ISO) and the World Health Organisation (WHO) and compares them in terms of reuse schemes and parameters sets. The results show that the existing guidelines show strong similarities among each other. The similarities are more prominent between the FAO, ISO, and WHO guidelines, while there is a clear gap between those and the more stringent California 22 and Australian guidelines.

The results of the survey can be used to draw recommendations for the development of future guidelines regulating wastewater reuse, as well as for the harmonisation of legislation, particularly at an EU level. This survey identified trends in developed countries taking a more stringent California approach putting safety first at a higher treatment cost, while developing countries lean toward the minimal WHO requirements. These findings suggest that the quality standards need to be placed in a broader context, and are not purely technical considerations. It is important to both ensure that human health is protected and wastewater reuse practice as a sustainable solution to water scarcity remains feasible for countries at all stages of economic development.

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List of Abbreviations

FAO	Food and Agriculture Organisation
ISO	International Organisation for Standardisation
LAC	Latin America and the Caribbean
MENA	Middle East and Northern Africa
NPW	Non-potable water
NZ	New Zealand
NTU	Nephelometric Turbidity Unit
PW	Potable water
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
TSS	Total Suspended Solids
TWW	Treated Wastewater
UN	United Nations
US	United States
US -EPA	United States Environmental Protection Agency
WEI	Water Extraction Index
WHO	World Health Organization
WRI	Water Resources Institute

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Per mamin dhe babin , me mirenjohje pafund!

1. Introduction

Increasing water scarcity is one of the major challenges facing humanity and is currently a top priority in the policy agenda worldwide. Clean water and sanitation is one of the 17 Sustainable Development Goals (SDGs) approved by the United Nations in 2015. It has direct impact on human lives and is closely related to other goals such as poverty reduction, good health, and economic growth (United Nations, 2015). The world's water resources are becoming scarce as a consequence of increased pressure by urban development, population increase, food production, and climate change. The result of this pressure is not only water scarcity on the quantitative side, but also quality deterioration.

According to the Water Exploitation Index (WEI), an indicator of water scarcity defined as the mean annual total abstraction of fresh water divided by the long-term average freshwater resources, "one fifth of Europe's population (approx. 113 million inhabitants) still lives in water-stressed countries (Marcuello & Lallana, 2003). The situation in many other parts of the world is similar, if not more severe. According to United Nations report (United Nations, 2007) Almost one fifth of the world's population lives in areas with physical water scarcity, which means that use of water resources has exceeded sustainable limits. Moreover, one quarter of the world's population lives in areas with economic water scarcity, which means that their countries lack the necessary infrastructure and economic resources to withdraw water, although water resources are available. In the future, with increasing population, the situation is expected to be more severe. By the year 2050, the Middle East is expected to reach the minimum survival level of 100 m^3/capita.yr, a scarcity level that will put a great burden on the economy and development of the region (United Nations, 2007).

In this context, planned reuse of treated wastewater is gaining more and more attention and is a fast increasing practice worldwide since it is a sustainable use of water resources, and also an adaptive measure to the increasing water demand and climate change. According to the World Health Organization (WHO), the driving forces for global wastewater reuse are: "increasing scarcity and stress, increasing populations and related food security issues, increasing environmental pollution from improper wastewater disposal, and increasing recognition of the resource value of wastewater, excreta, and grey water" (WHO, 2006). The major sectors where treated wastewater is currently used worldwide include agriculture, industry, and municipal use. The motivation to use treated wastewater is different in developed and developing countries. Developed countries mostly use wastewater to preserve their water resources and protect the environment. In contrast, in developing countries wastewater is often used untreated and in an unplanned way (WHO, 2006).

Wastewater reuse faces several challenges, the most important of which is health concern about the quality of the reused water. Reused water may contain hazards such as physical, chemical, radiological and microbial agents that can be a risk to human health (WHO, 2006). These health concerns have prompted the development of guidelines and regulations for wastewater reuse in many countries. Additionally, international organizations have developed guidelines for water reuse. Examples of key legislation and guidelines used as benchmark standards on an international scale are those developed by the World Health Organisation (WHO), the United States (US-EPA), California Title 22, Australia, the Food and Agriculture Organization (FAO), and the International Organization for Standardisation (ISO). These guidelines mostly cover wastewater reuse for irrigation, since this sector has more impact on human health, and is the one sector that requires more water (about 70 % of the world's freshwater) (WHO, 2006).

The most frequently used standards are the WHO guidelines, considered as the minimal requirements for human health (UN Water, 2015). These standards have been also used as a starting point, being further elaborated in many countries, including some EU countries. The EU does not have a set of common guidelines on the reuse of treated wastewater. The lack of common guidelines, especially in relation to the agricultural sector, results in different water quality used for irrigation in different countries of the EU. Considering that the agricultural products are then sold in a common European market, the lack of common regulation regarding use of treated wastewater for irrigation may result in a difference in quality and in different levels of physical, chemical, radiological and microbial agents (MED WWR WG, 2007). Additionally, many countries of the world do not have legislation in place to regulate wastewater reuse, a fact that results in questionable quality of the used water, and therefore also questionable levels of physical and chemical agents in the products.

Due to the growing importance of wastewater reuse in many countries, both the non-existence of regulation in many countries that do practice wastewater reuse in many sectors and especially agriculture, and the lack of harmonization of the existing legislation at a regional and international level are issues to be looked at closely in the near future. It is crucial to look at existing legislation and practice worldwide to be able to draw recommendations and steps for the future. With technological developments, wastewater reuse is an attractive and sustainable method to protect water resources in the future, but its development should be accompanied with extensive research on quality requirements and effects on human health, especially when used in sectors such as agriculture and groundwater recharge.

2. Aims and goals

The aim of this thesis is to conduct a survey on a worldwide scale of existing legislation on water reuse and the quality standards applied by individual states and international and national organizations, the reuse schemes, and the water quality parameters applied in the main guidelines. *Reuse schemes* are defined here as the different classifications that guidelines allocate in order to distinguish between different sectors in which treated wastewater can be reused. Each of the schemes corresponds to a certain water quality requirement, which is determined by the *parameter sets*, defined as threshold values for physical, chemical, radiological and microbial agents that can be a risk to human health.

The survey will be limited to the direct reuse of treated wastewater. Indirect reuse of treated wastewater is not a central part of the thesis. Because it is often unintended, this type of wastewater reuse is difficult to assess. Moreover, indirect reuse has nature as an additional barrier, which makes the quality assessment even more difficult.

The review will be organized in 3 pillars, answering the following questions:

1. What are the differences and similarities among the reuse schemes of the main guidelines for wastewater reuse?
2. What is the current state of wastewater reuse and linked legislation on a worldwide scale?

3. What are the differences and similarities among the parameter sets of the main guidelines for wastewater reuse?

The results of the thesis will help draw recommendations on how a common and strong legislative base, instead of a convergence of water reuse regulations, can help the further development of wastewater reuse worldwide and especially within the European Union, as a key component in urban water management, development, and trade in agricultural goods.

2.1 Structure

One hundred and nighty three countries of the world which are members of the United Nations (UN) have been reviewed to identify those that practice wastewater reuse in any sector. The countries are organized into continents, with a few adaptations due to cultural considerations, for example in the case of the Middle East and North Africa as a separate section, and Latin America and the Caribbean which also includes Mexico.

In the fourth chapter, the reuse schemes of the main benchmark standards (Australia, US-EPA, California 22, FAO, ISO and WHO) are analysed, to identify the similarities and differences among them.

In the fifth chapter, the countries that practice wastewater reuse are looked into in more detail to see for which purpose they use the treated wastewater, and whether they have legislation in place. The survey is organized into regions, showing the similarities based on water shortage situation and economic development.

Lastly, in the sixth chapter the comparison will be made on a parameter-scale to identify further synergies among the identified benchmark standards.

The results will be followed by a discussion on the findings of the survey on the current state of the practice of wastewater reuse and its linked legislation at a worldwide scale, the implications, and recommendations regarding harmonization and elaboration of the standards within the EU in the future.

3. Methodology

This thesis is a literature review of international and national legislation on wastewater reuse. After compiling a matrix with all the results, it analyses them to identify trends in terms of economic development and geography. The results will help gaining an overview of the global importance of wastewater reuse, and the regional specifics in terms of sectors in which treated wastewater is mostly used.

The majority of the national legislations are based on the recommendations of international organizations such as WHO, FAO, and ISO, but also on some of the most elaborated regional and national standards such as California 22, and Australia. For this reason, the first step was an analysis of the identified benchmark standards and the reuse schemes in each of them. A matrix facilitated drawing conclusions on the similarities and contrasts between these benchmark standards.

As a next step, the presence of legislation and guidelines regarding reuse was analysed in every country, and presented organized in continents, showing the trends for each region based on the specifics in terms of water stress level, and economic development.

As a third step, the analysis between the benchmark standards was conducted at a parameter level, to be able to further examine the synergies between the different standards. This helps draw conclusions on the current state of the practice at a worldwide scale, and the legislation in place.

3.1 Definitions

The terms used to describe the situation of water resources around the world often have different meanings from one study to another and from one country to another. It is therefore important to define the technical terms used in each case. This section summarizes and defines the most used terminology in the presentation of the results of the survey.

Agriculture

Science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food or other products (ISO, 2015).

Aquifers

Underground layer of water-bearing permeable rock or unconsolidated materials

(gravel, sand, or silt) from which groundwater can be extracted (ISO, 2015).

Barrier

Any means including physical or process steps that reduces or prevents the risk of human infection by preventing contact between the TWW) and the ingested produce or other means that, for example, reduces the concentration of microorganisms in the TWW or prevents their survival on the ingested produce (ISO, 2015).

Direct reuse

Reuse of treated or untreated wastewater by directly transferring it from the site where it is produced to the conveyance facilities for its use (Jimenez & Asano, 1998).

Fodder crops

Crops not for human consumption such as pastures and forage, fiber, ornamental, seed, forest, and turf crops (ISO, 2015).

Food crops

Crops which are intended for human consumption, often further classified as to whether the food crop is to be cooked, processed, or consumed raw (ISO, 2015).

Environmental Reuse

The uses of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow (ISO, 2015).

Freshwater

Naturally occurring water on the Earth’s surface (ice, lakes, rivers, and streams) and underground as groundwater in aquifers (ISO, 2015).

Groundwater recharge

The use of reclaimed water to recharge aquifers that are not used as a potable water source (ISO, 2015).

Indirect reuse

Reuse of treated or untreated wastewater after its discharge to a water body from which it is taken to be used once again (Jimenez & Asano, 1998).

Industrial reuse

The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels (ISO, 2015).

Non-potable water

Water that is not of drinking water quality (ISO, 2015).

Parameter/Parameter sets

Threshold values for physical, chemical, radiological and microbial agents that can be a risk to human health.

Potable water

Water that is of drinking water quality (Jimenez & Asano, 1998).

Restricted irrigation

Use of TWW for non-potable applications in settings where public access is controlled or restricted by physical or institutional barriers (ISO, 2015).

Reuse Scheme

Different classifications that guidelines have in order to distinguish between different sectors in which treated wastewater can be reused.

Unrestricted irrigation

Use of TWW for non-potable applications in settings where public access is not restricted (ISO, 2015).

Non-potable reuse

Use of treated wastewater for non-potable applications in settings where public access is controlled or restricted by physical or institutional barriers (Jimenez & Asano, 1998).

Wastewater

Wastewater collected principally by municipalities that can include spent or used water from domestic, institutional, commercial, or industrial sources and can include storm water (ISO, 2015).

Wastewater reuse

Use of treated wastewater for beneficial use, here defined as direct reuse of treated wastewater (ISO, 2015).

Water availability per capita

Ratio of renewable water resources within a region to the number of people living there (Jimenez & Asano, 1998).

If <1700 Water Stress

If <1000 Water Scarcity

If <100 Minimum survival level

Water Exploitation Index (WEI)

Mean annual total abstraction of fresh water divided by the long-term average freshwater resources (Marcuello & Lallana, 2003).

WRI Water Stress Index

According to Gassert et al. (2013) Water Stress Index is “an Index that estimates of the average level of exposure to five of Aqueduct’s physical water quantity risk indicators for all countries and major river basins worldwide. These indicators include:

Baseline water stress: the ratio of total annual water withdrawals to total available annual renewable supply.

Inter-annual variability: the variation in water supply between years. Seasonal variability: the variation in water supply between months of the year.

Flood occurrence: the number of floods recorded from 1985 to 2011. Drought severity: the average length of droughts times the dryness of the droughts from 1901 to 2008" (Gassert et al., 2013).

4-5 Extremely high stress

3-4 High stress

2-3 Medium high stress

1-2 Low medium stress

0-1 Low stress

4. Reuse Schemes

This chapter will focus on a more detailed analysis of the main standards used at a worldwide level, namely Australia, California Title 22, FAO, ISO, US-EPA, WHO, and their reuse schemes. All these international and national guidelines have been the basis of the reuse schemes and parameters implemented by the majority of the other national guidelines worldwide. This is especially the case with the WHO standards, and California Title 22 (Jimenez & Asano, 1998).

Reuse schemes are defined here as the classifications among the different purposes for which treated wastewater is reused. Their importance is in the fact that based on the reuse sector/purpose determined, there is a different quality requirement for the water in order to not have adverse health impacts in the population depending on the level of exposure and the possibility of transmission of chemical and microbiological agents.

By analyzing and then comparing the reuse schemes, this thesis aims at finding out whether there are substantial differences among them, or if the inconsistencies are small and not in main issues. This analysis will be then extended to an even more detailed comparison of the schemes for agriculture, and a comparison at a parameter level for both these sectors (Chapter 6). The final aim is to be able to draw recommendations based on the results, on the development of EU-wide guidelines for wastewater reuse.

4.1 Wastewater Reuse Schemes in the major guidelines

The majority of national guidelines are based on one of the 5 major guidelines on wastewater reuse: Australia, California Tittle 22, FAO, ISO, US-EPA, and especially WHO. Since the scope of the guidelines is often different to each other, there are differences in the classification of the reuse schemes. This chapter will give an overview of the reuse schemes in each of the benchmark standards, followed by an analysis of the results with a focus on the schemes for agriculture, as the most elaborated and detailed in each of the guidelines.

4.1.1 Australia

Australia is the world's driest continent. Therefore, the increasing demand for water that is needed in agriculture, industry, and for domestic use, has raised the need for cautious water management to avoid shortages in the future. Currently, Australia has the third highest per capita water consumption among the OECD countries after the USA and Canada (Australian Academy of Technological Sciences and Engineering, 2004).

Wastewater reuse is an attractive option for water management. The "Australian Guidelines for Water Recycling: Managing Health and Environmental Risks" were published in 2006 and are one of the most elaborated standards worldwide. The Guidelines are divided into 2 phases according to the different reuse schemes, and have replaced the previous state guidelines through a national standard.

A summary of the categories and subcategories for reuse schemes can be found in Table 1: Reuse schemes in Australia. In general, the Guidelines distinguish between (1) Agricultural use, (2) Fire Control Use, (3) Managed aquifer recharge, (4) Municipal uses, (5) Residential and commercial property uses, (4) Industrial and commercial uses, and (5) Environmental uses (Australian Guidelines for Water Recycling, 2006). In addition, there are 4 classes of water quality (A to D), and there is a requirement for each use about the water quality that is needed to be met and the treatment process required to achieve it. Class A corresponds to urban use with uncontrolled public access, irrigation of food crops consumed raw, and industrial open systems with worker exposure. Class B corresponds to other agricultural uses such as for example dairy cattle grazing, and industrial uses such as wash-down water. Class C corresponds to urban use with controlled public access, agricultural use such as human food crops that will be cooked or processes, and industrial systems with no potential worker exposure. Lastly, class D corresponds to irrigation of non-food crops (Australian Guidelines for Water Recycling, 2006).

Table 1: Reuse schemes in Australia

	1	2	3	4	5	6	7
	Agricultural use	**Fire Control Use**	**Managed Aquifer recharge**	**Municipal use**	**Residential and commercial property uses**	**Industrial and commercial uses**	**Environ mental Uses**
A	Human food crops consumed raw	Controllin g fire		Irrigation of public parks and gardens, roadsides, sporting facilities	In-building (toilet-flushing)	Cooling water	Streams and creeks
B	e.g. dairy cattle grazing	Testing and maintenan ce of fire control systems		Road making and dust control	Garden watering, car washing	Process water	Rivers
C	food crops cooked/ processed, grazing/fodder for livestock	Training facilities for fire fighting		Street cleaning	Water features and systems (ponds, fountains, cascades)	Wash-down water	Lakes and dams
D	non-food crops including instant turf, woodlots and flowers				Utility washing (paths, vehicles, fences, etc.)		

4.1.2 US-EPA

The USA is the country with the highest per capita water consumption in the world. According to a UN study in 2013, the annual treated wastewater in North America roughly equals the volume of the Niagara Falls and less than 4 percent is reused (United Nations University, 2013).

The US Guidelines for Water Reuse developed by the U.S Environmental Protection Agency include national and state-level guidelines and requirements for water quality. They were developed in 1980, and were updated in 1992, 2004, and 2012. The standards are a guideline for the individual states when they either lack state-level standards or when they are in the process of revising them. There are in addition to the national guideline, many stale-level guidelines which are based on the specifics of every state.

According to US-EPA, the states that most practice wastewater reuse are Florida (34%), California (31%), Texas (13.6%), and Arizona (12%). All these states have developed their own guidelines for wastewater reuse, which are partially based on the US-EPA guidelines. Many states have also incentives in place to encourage wastewater reuse.

Regarding reuse schemes, the US-EPA establishes one of the most comprehensive and most used categorization worldwide, as below:

Table 2: Reuse schemes according to US-EPA

1	**2**	**3**	**4**	**5**	**6**
Urban reuse	**Agricultural reuse**	**Impoundments**	**Environmental reuse**	**Industrial reuse**	**Groundwater recharge**
Unrestricted	Food crops	Unrestricted	Wetlands	Cooling towers	Non potable
Restricted	Processed food crops and non-food crops	Restricted	River or stream flow augmentation	Boiler Water Makeup	Potable (direct/ indirect)

The schemes used in US-EPA are the general classification used in literature and policy papers for wastewater reuse. The scheme is considered as a reference for further elaboration at a stale-level, based on the type of use, and different characteristics of each state.

4.1.3 California Title 22

California is the state with the highest population in the United States, and also one of the driest ones. For this reasons, wastewater reuse has been an attractive option to reduce water shortage. California has been at the forefront of wastewater reuse for more than 100 years, and has increasingly used treated wastewater for agriculture (Pacific Institute, 2014) . In the last 3 years, the importance of wastewater reuse in the region has increased even more, due to the severe drought, considered as the worst in 500 years (Cooley & Donnelly, 2015). Therefore, the State of California is considering expanding water reuse to achieve both water supply and water quality benefits ((Pacific Institute, 2014)). By 2030, the use of treated wastewater will quadruple, compared to 2002. The majority (82%) of this amount will be used for non-potable purposes and the other part (18%) for potable purposes (Asano et al., 2007)

The California standards for wastewater reuse are considered and one of the most stringent standards worldwide, and are used as a basis for many other national guidelines, especially in countries with high water scarcity and a broad range of water reuse sectors. The reuse schemes are consequently much elaborated and complex. The first sets of regulations were developed in 1918 (Water Resources Control Board, 2009)

Tittle 22 of the California Code of Regulations establishes a detailed classification of reuse purposes and the appropriate treatment levels. In the schemes regarding agriculture and irrigation, there is differentiation among crops depending on their contact with humans, and their use. It should be noted that also vegetables eaten raw are allowed to be irrigated with treated wastewater that meets the according quality requirements. The categories of treatment are (1) Disinfected tertiary recycled water; (2) disinfected secondary-23 recycled water, and (3) disinfected secondary-2.2 recycled water (State of California, 2001).

A summary of the schemes is presented in the table below:

Table 3: Reuse schemes according to California 22

1				2	3	4		
Irrigation				**Impoundments**	**Cooling**	**Other purposes**		
a)	**b)**	**c)**	**d)**			**a)**	**b)**	**c)**
Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop	Food crops where the edible portion is produced above ground and not contacted by the recycled water	Cemeteries	Orchards where the recycled water does not come into contact with the edible portion of the crop	Nonrestricted recreational impoundments	Industrial and commercial cooling or air conditioning that does involve the use of a cooling tower, evaporative condenser, spraying, or any mechanism that creates a mist	Flushing toilets and urinals	Industrial boiler feed	Flushing sanitary sewers
Parks and playgrounds		Freeway landscaping	Vineyards where the recycled water does not come into contact with the edible portion of the crop	Restricted recreational impoundments and for any publicly accessible impoundments at fish hatcheries	industrial or commercial cooling or air conditioning that does not involve the use of a cooling tower, evaporative condenser, spraying, or any mechanism that creates a mist	Priming drain traps	Non-structural fire fighting	

1				2	3	4		
Irrigation				**Impoundments**	**Cooling**	**Other purposes**		
a)	**b)**	**c)**	**d)**			**a)**	**b)**	**c)**
School yards		Restricted access Golf courses	Non-food-bearing trees	Landscape impoundments that to don’t utilize decorative fountains		Industrial process water that may come into contact with workers	Backfill consolidation around non-potable piping	
Residential landscaping		Ornamental nursery stock and sod farms where access by the general public is not restricted	Fodder and fiber crops and pasture for animals not producing milk for human consumption			Structural fire-fighting	Soil compaction	
Unrestricted access golf courses		Pasture for animals producing milk for human consumption	Seed crops not eaten by humans			Decorative fountains	Mixing concrete	

1				2	3	4		
Irrigation				**Impoundments**	**Cooling**	**Other purposes**		
a)	**b)**	**c)**	**d)**			**a)**	**b)**	**c)**
Any other irrigation use not specified in this section and not prohibited by other sections of the California Code of Regulations		Any non-edible vegetation where access is controlled so that the irrigated area cannot be used as if it where part of a park, playground, or schoolyard	Food crops that must undergo commercial pathogen-destroying processing before consumed by humans			Commercial laundries	Dust control on roads and streets	
			Ornamental nursery stock and sod farms provided no irrigation with recycled water occurs for a period of 14 days prior to harvesting, retail sale, or allowing access by the general public			Consolidation of backfill around potable water pipelines	Cleaning roads, sidewalks and outdoor work areas	

1				2	3	4		
Irrigation				**Impoundments**	**Cooling**	**Other purposes**		
a)	**b)**	**c)**	**d)**			**a)**	**b)**	**c)**
			No recycled water used for irrigation, or soil that has been irrigated with recycled water, shall come into contact with the edible portion of food crops eaten raw by humans unless a)			Artificial snow making for commercial outdoor use	Industrial process water that will not come into contact with workers	
						Commercial car washes, including hand washes if the recycled water is not heated, where the general public is excluded from the washing process		

4.1.4 FAO

The Food and Agriculture Organisation (FAO) as a leader in the international efforts to defeat hunger, which operates both in developed and developing countries. Since water is a key resource for food production, the protection of water resources is at the core of FAO's efforts worldwide. Consequently, wastewater reuse as a form of non-conventional water resource is of increasing importance for the organisation, especially as a solution for arid areas of the planet.

FAO regulates quality for treated wastewater use in agriculture focusing on the effects on human health. It defines the health protection measures in 4 categories: wastewater treatment, crop restriction, control of wastewater application, and human exposure control and promotion of hygiene (FAO, 1992). In general, the recommendations made by FAO are based in the quality guidelines developed by WHO. It elaborates on the irrigation methods like amount of water to be applied, quality of water to be applied, irrigation methods, and scheduling of irrigation.

FAO classifies the water quality requirements in 3 categories depending on the quality parameters, the treatment level, and the exposed group to wastewater. The reuse conditions for each of the categories are presented in the table below:

Table 4: Reuse schemes according to FAO

A	B	C
Crops to be eaten uncooked	Cereal crops	Irrigation of crops in category B if no exposure of workers occurs
Sports fields	Industrial crops	
Public parks	Fodder crops	
	Pasture and trees	

The reuse schemes are limited to agriculture, and the main classification is between restricted and unrestricted use. The area where FAO focuses its recommendations concerns the irrigation methods.

4.1.5 ISO

The International Organisation for Standardisation has also recognized the need for the standartisation of wastewater reuse for any purpose. ISO published a 4 part-guideline for wastewater reuse in irrigation. ISO (2015) differentiates between categories of reuse, water quality categories (A to E), and irrigation systems.

A summary of the reuse schemes included in the first part of the guidelines on wastewater use for irrigation is presented below:

Table 5: Reuse schemes according to ISO

1	2	3	4
Unrestricted irrigation of agricultural crops	Restricted irrigation of agricultural crops	Irrigation of public and private gardens and landscape areas (parks, cemeteries, sports areas, etc.)	Irrigation of private individual gardens

Also here, the main differentiation is between the use of treated wastewater for restricted and unrestricted irrigation of agricultural crops. The level of treatment and water quality is based on the level of the exposure and possibility for adverse effects on human health. The same criteria are applied also for the use for irrigation of gardens, parks, and sports areas. The guidelines are developed for the purpose to be used by professional irrigation companies and local authorities. In the case of local farmers, the guideline recommends additional specifications and considers the ones included as non-exhaustive (ISO, 2015).

The other 3 parts of the guidelines are focused respectively on the development of the project, components of a reuse project for irrigation, and monitoring (ISO, 2015).

4.1.6 WHO

The “WHO Guidelines for the Safe Use of Wastewater, Excreta, and Greywater” are developed in 2 volumes. The first volume elaborates on policy and regulatory aspects, and the second one specifically on wastewater use in agriculture as the most closely related use to public health. The latest edition was published in 2006, based on previous editions of 1973 and 1989 (WHO, 2006).

The WHO guidelines are the basis of most of the other national regulations and guidelines. They also serve as minimal requirement and reference for countries that do not have developed their own legislation regarding wastewater reuse yet. The guidelines use a risk management framework, to maximize the protection of human health and the environment from adverse effects resulting from wastewater reuse. They therefore assess the health risk posed before setting health-based targets. The benefit of this approach is that it allows different countries that base their national legislation on the WHO guidelines, to adopt them to their specific characteristics (Alcalde Sanz, 2014).

Regarding reuse schemes, the guidelines focus on the use for irrigation in agriculture and aquaculture, differentiating between restricted, unrestricted, and localized use in agriculture. The focus here is on the parameters and the guidelines establish health-based targets for each of the categories, health protection measures, and monitoring mechanisms. The management of health risks is based on the tolerable risk, which is determined by the disability-adjusted life years (DALYs). The method to identify the risk connected to the scheme is determined through the use of quantitative microbial risk assessment. The process consists for four main steps: hazard identification, dose-response, exposure assessment, and risk characterization (Alcalde Sanz, 2014).

4.2 Summary

This chapter focused on the reuse schemes used in the main worldwide standards for wastewater reuse, namely Australia, California Title 22, FAO, ISO, US-EPA, and WHO, to identify similarities and differences in the categories of each guideline.

When it comes to the reuse schemes based on the general purpose of reuse of treated wastewater, the main categories are agriculture, urban, environmental, and groundwater recharge. For each of the categories there are further sub-categories based on the level of elaboration of each of the guidelines. For example, California 22 has a very detailed classification and describes different levels of water treatment and quality based on the use purpose. On the other hand, other guidelines such as WHO, ISO, and FAO have a focus on the agricultural sector. The main differentiation they make is between restricted and unrestricted use. A differentiation is made also regarding to the level of exposure of humans and workers. This is the case both for irrigation of crops, and the irrigation of public spaces such as parks, gardens, cemeteries, and sport areas.

All of the main guidelines show similarities in the way they organize the reuse schemes, and the difference is mainly the level of detail and specifications that different guidelines have. For example, the California Title 22 has a very detailed categorisation based on the specific uses and requirements of the state of California, while the US-EPA has a more general scheme that includes all the main sectors of reuse in the United States. The same apples for Australia, whose national standards are also seen as a reference for more specific legislation on a state-level. For each of the reuse applications, every guideline has a corresponding quality parameter set, and a required treatment level to achieve it. Table 6: Summary of reuse schemes in agricultur summarizes the sub-schemes for agriculture of all of the guidelines discussed in this chapter.

5. Overview of international Wastewater Reuse and legislation

This chapter looks at water reuse at a global level, and identifies the countries that reuse treated wastewater for different purposes. It includes information from 193 countries regarding planned use of treated wastewater. It is important to mention at this stage that the analysis includes only available sources of official information. Many developing countries, however, do reuse treated or even untreated wastewater unintentionally as a consequence of lack of sanitation and water management. This type of reuse is not the focus of this overview, which is limited to planned water reuse projects, and is therefore only mentioned in the cases where the practice is very common and a cause of concern due to proven effects on public health. The chapter also looks at the main sectors for reuse, and the trends in reuse according to development and geographical conditions.

Secondly, the chapter looks at the legislation in place in every country that does practice wastewater reuse, and whether the legislations are based on any of the benchmark standards discussed in the previous chapter.

Table 6: Summary of reuse schemes in agriculture

California 22	**U-SEPA**	**Australia**	**WHO**	**FAO**	**ISO**
Surface irrigation (food crops)	Food crops	A: human food crops consumed raw	Restricted	A: Crops to be eaten uncooked	Unrestricted irrigation of agricultural crops
Surface irrigation of food crops where the edible portion is produced above ground and not contacted by the recycled water	Processed food crops	B: e.g., dairy cattle grazing	Unrestricted	B: Cereal crops Industrial crops Fodder crops Pasture and trees	Restricted irrigation of agricultural crops
Recycled water used for surface irrigation of ornamental nursery stock and sod farms that are not restricted, pasture for animals producing milk for human consumption, any non-edible vegetation where access is controlled	Non-food crops	C: e.g., human food crops cooked/ processed, grazing/fodder for livestock	Localised	C: Irrigation of crops in category B if no exposure of workers occurs	
Surface irrigation of orchards where the recycled wastewater does not come into contact with the edible portion of the crop, vineyards where the recycled water does not come into contact with the edible portion of the crop, non-food bearing trees, fodder and fiber crops and pasture for animals non-producing milk for humans, seed crops not eaten by humans, food crops that must undergo commercial pathogen- destroying processing before being consumed by humans		D: non-food crops including instant turf, woodlots and flowers			
No recycled water used for irrigation or soil that has been irrigated with recycled water, shall come into contact with the edible portion of food crops eaten raw by humans unless a). NT2 <2					

5.1 International Wastewater Reuse

Today, 60 out of 193 countries reuse treated wastewater for different purposes in a planned way, mostly as a result of water scarcity but also for environmental protection. This section looks at the sectorial use in each of the 60 countries divided into 6 main regions based on geography and water availability situation: Africa, Asia, Australia and New Zealand, Europe, North Africa and the Middle East, and North America.

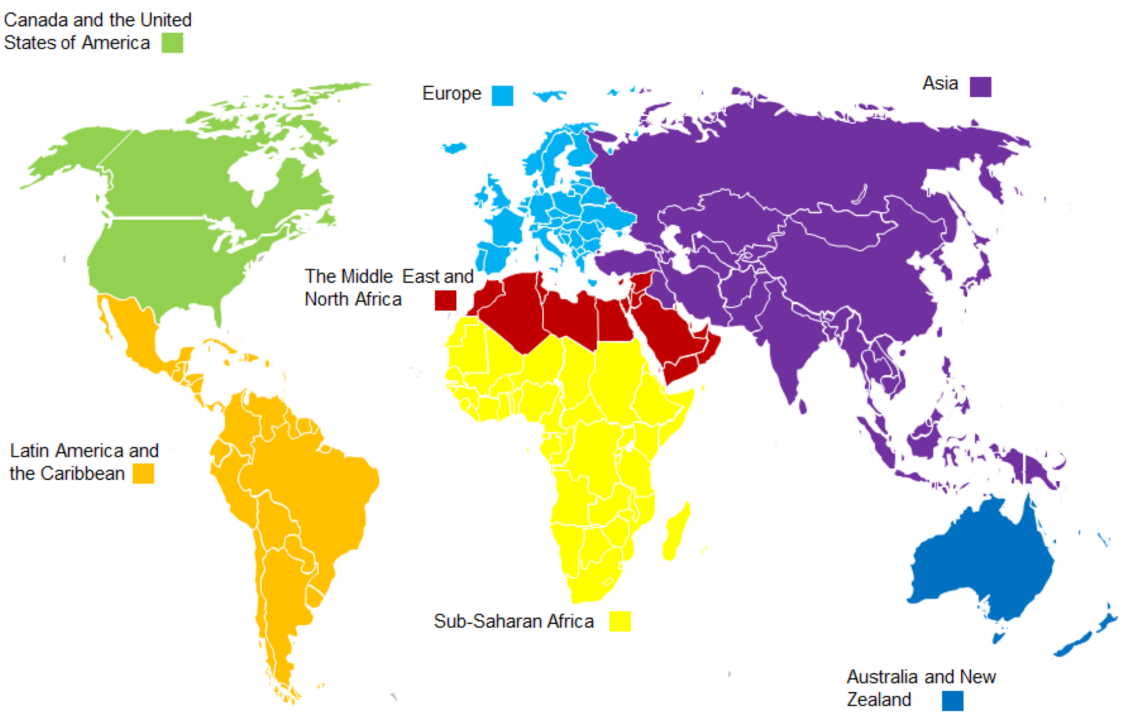

Figure 1: Overview of regions

5.1.1 Sub-Saharan Africa

This section includes the situation in the African continent, excluding Northern African countries, which are included in another section together with the Middle East. Planned wastewater reuse is not a common practice in Africa, despite the water scarcity level in the region (Jimenez & Asano, 1998). The lack of practice is mainly due to economic reasons. Moreover, countries in Sub-Saharan Africa (SSA) have low levels of sanitation and water management, and therefore unplanned wastewater reuse is common. The consequences are health risks such as epidemic diseases (WHO, 2006).

When it comes to legislation, exceptions are South Africa and Namibia, which have elaborated guidelines in place. Namibia is a pioneer in wastewater reuse, practicing it for more than 40 years already, and also having the only treatment facility for potable use in Africa (Jimenez & Asano, 1998).

The population increase and urbanization rate in SSA are the highest in the world. Therefore, wastewater treatment and reuse are both a necessity and a solution for managing the water resources in a sustainable and integrated manner.

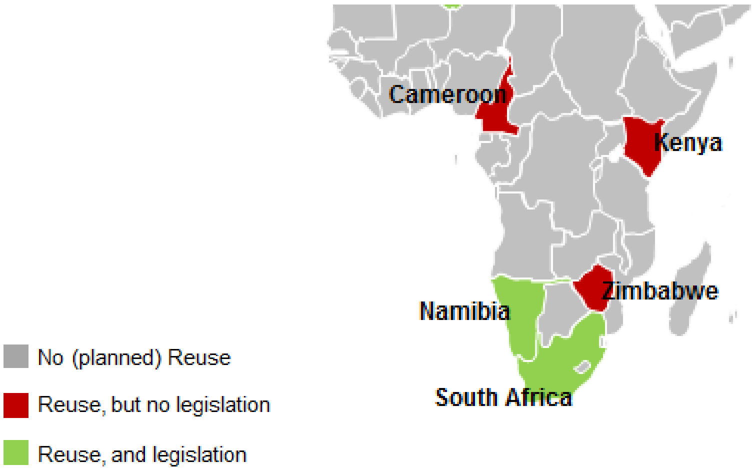

Figure 2: Wastewater reuse in Sub-Saharan Africa

Cameroon

Cameroon is characterized by a high population increase and high rural-urban migration shift. Approximately 45% of the population does not have access to quality drinking water and sanitation is a major issue causing water-related diseases (Eko Victor, 2013)

In Cameroon, treated/untreated wastewater used in agriculture, but there are no guidelines yet. There are studies for the quality of the water used for irrigation in Yaoundé that show that the water does not meet the WHO standards, and poses health risks, especially for vegetables that are consumed raw (Endemana et al., 2003). Lettuce, for example, has been shown to have high levels of pathogenic micro-organisms such as fecal coliforms and parasites (Tsama et al., 2015)

Literature: Wastewater Reuse for Urban and Periurban Agriculture in Yaoundé Cameroon; Opportunities and Constraints,2003

Kenya

Kenya is a country with a high water scarcity, and therefore the need for alternative water sources is high, especially in the capital Nairobi, which has a water availability of less than 100 l per capita daily. Wastewater reuse is therefore a viable option for the future, although yet recognized as such until now. However, unofficially, treated and untreated wastewater is used for agriculture and industry in Kenya. There are no standards in place regarding the use of wastewater, but the Kenya National Environment Management Authority (NEMA) has developed requirements for the quality of water sued for irrigation and discharge into the environment. Wastewater is also used in industry.

Literature: T*owards a National Policy on Wastewater Reuse in Kenya, 2011*

Namibia

Namibia is characterized by a very arid climate, due to its geographical position in proximity to the Namib and Kalahari Desert. More than 80% of the surface of the country consists of desert or semi-desert, and all potable water resources have been already exploited. For this reason, wastewater reuse has been recognized as a solution and is practiced since the construction of the Goreangab Water reclamation Plant 30 years ago, which was replaced in 2002 by the New Goreangab Water Reclamation Plant. The water produced, is used as direct potable water, and meets the WHO standards, the South African Potable Water Quality Criteria, and the Namibian Guidelines for Group A water. The Windhoek plant is considered as a model for other arid regions and an example of Water management Policy (Lahnsteiner and Lempert, 2007).

Literature: Water Management in Windhoek, Namibia, 2007

South Africa

South Africa is a semi –arid country, and evaporation exceeds rainfall causing an annual water deficiency. Traditionally, treated wastewater has been used for irrigation of recreation facilities. However, wastewater reuse has been practiced for many decades already in sectors like agriculture, groundwater recharge, and industry. The practice in South Africa is different to most other countries in the region, and highly regulated. The treated effluent must be returned to the source from which it was abstracted to allow use, and no direct use for irrigation is allowed. Moreover, no irrigation with treated sewage effluent is allowed on crops that may be eaten raw.

Literature: Treated Wastewater Reuse in South Africa: Overview, Potential, and Challenges, 2010

Zimbabwe

Zimbabwe has a 97% level of sanitation in urban centers, which makes up for a big potential for wastewater reuse. At the same time, water availability in the country is less than 1700 m^3/ year, making it a water-stressed country. Wastewater reuse is common practice for agriculture, but there is no legislation in place yet. However, there are regulations regarding the disposal of wastewater and the legislation forbids the irrigation of food crops. These legislation is, however, often not enforced, and use of untreated wastewater for irrigation is common (Thebe and Mangore, 2012)

Literature: Wastewater Production, Treatment, and Use in Zimbabwe, 2012

5.1.2 Asia (excluding the Middle East)

Despite the differences in water availability and climate, Asian countries show similarities in terms of challenges and opportunities regarding wastewater reuse. The main reasons behind the increasing interest for the practice in the region are rapid population increase, rapid urbanization, and increasing water demand that exhausts the available freshwater resources. For this reason, many countries in Asia practice both planned and unplanned wastewater reuse, mainly for irrigation of crops but also for industry and municipal use. Unplanned use and related health risks are a big concern in countries such as India, Pakistan, and Vietnam Increasing pollution of the water bodies is another problem, coupled with fast industrial development in countries such as China, Thailand, and India.

Regarding regulation, some countries such as China and Japan have a number of legislations in place that regulate wastewater reuse and discharge into water bodies.

Other countries lack these guidelines, and have a highly unregulated use of wastewater that has both documented and non-documented health concerns. Legislations are based on the benchmark standards for wastewater reuse, mainly the WHO guidelines, and California 22.

An exemplary country in terms of wastewater reuse is Singapore, which due to its high water scarcity has developed a very advanced wastewater treatment technology for direct potable reuse. NEWater is a brand of drinking water produced from treated wastewater that exceeds the WHO recommendations for drinking water quality.

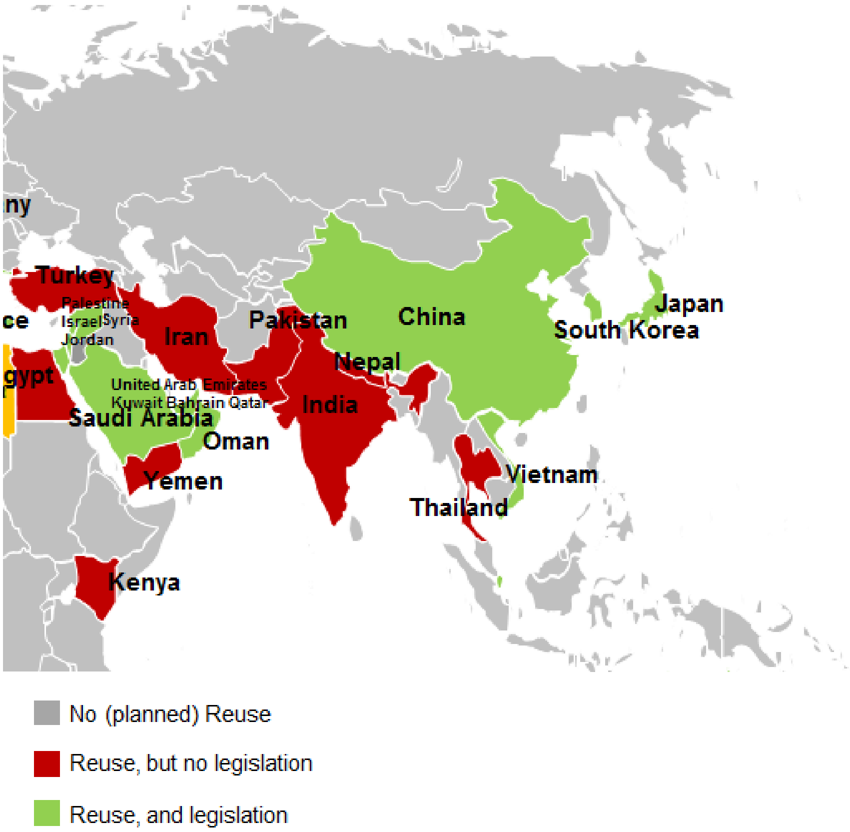

Figure 3: Wastewater reuse in Asia

China

China has very limited per capita water availability (2200 m^3/year) due to the very high population, despite its abundant water resources. On the other hand, a big part of the untreated wastewater is discharged in water bodies which are consequently heavily polluted.

The Chinese government has made continuous efforts to promote wastewater reuse. In the northern part of the country, the practice has proven to be successful, such as for example in Beijing, where in 2008, 18.4% of the total water supply in the city was recycled water (Waterworld,2015), The sectors of wastewater reuse include industry, municipal use, groundwater recharge, and agriculture.

Due to the wide use of reclaimed wastewater, there are also numerous national guidelines for the reuse, depending on the 5 reuse sectors: agriculture, forestry, farm and fishery, urban water consumption, industrial water consumption, water for environmental use, and supply to the water source.

Literature: An Overview of Reclaimed Water Reuse in China, 2011

India

India is facing a challenge in water management due to its rapid population, urbanization, and economic growth of the past decades. It is estimated that the amount of wastewater generated is about 60-70% higher than the treatment capacity (Amerasinghe et al, 2013).

In India, direct reuse of untreated/ partially treated wastewater is common due to high treatment costs, mostly for cereal growth (rice), vegetables, fodder crops, aquaculture, and agroforestry (Mekala et el, 2008) .Treated wastewater is also used in the industrial sector, mostly in the Chennai region. The irrigation of salad vegetables is prohibited but yet widespread. Studies have shown that wastewater reuse practices require more attention, for both health and water management reasons.

Literature: Urban Wastewater and Agricultural Reuse Challenges in India, 2013 Wastewater Reuse and Recycling Systems: A Perspective into India and Australia, 2008

Iran

Iran has a predominately arid or semi-arid climate and the majority of water is extracted from surface and groundwater, with a very low use of alternative sources including wastewater reuse.

In Iran, untreated wastewater in irrigation and agriculture is prohibited but yet common, resulting in related health problems. There is no legislation in place yet, and WHO and

US-EPA guidelines are used. However, there is no data available regarding the extent to which wastewater is reused both in a direct and indirect way.

Literature: Wastewater Treatment and Reuse in Iran: Situation Analysis, 2011

Japan

In Japan, treated wastewater is used in agriculture and industry, since the country experienced a severe water shortage in 1978. The first purpose for reuse was toilet flushing in Fukuoka city in 1980 (2002). The categories for reuse are: toilet flushing, spraying use, landscape use, and recreational use. The main reuse sector is environmental reuse, which accounts for 63% of the use of treated wastewater. There is legislation in place that regulates the parameters of the treated wastewater for each of the categories.

Literature: Present State of the Treated Wastewater Reuse in Japan, 2001

Nepal

Nepal has a water availability of 8,900 m3/capita/per year, and water is one of the main natural resources in Nepal, and used in many economic activities, especially in agriculture which contributes to approximately 40% of GDP. However, an increase in population and high urbanization rate has also increased the demand for water.

Unplanned use in agriculture is common, particularly in the Kathmandu valley, but the health consequences are not documented. Although there is legislation in place regarding wastewater treatment and water resource management, there is a lack of legislation concerning wastewater reuse in agriculture.

Literature: Wastewater Production, Treatment, and Use in Nepal, 2012

Pakistan

Pakistan currently has a water availability of 1,100 m^3/capita/year, and is expected to decrease further to reach 700 m^3 by 2025 (Murtaza and Zia, 2012). For these reason, alternative water resources such as wastewater reuse are gaining importance, especially in the agricultural sector.

Like in India, the use of untreated wastewater for irrigation is a common practice in Pakistan, although limited information is available regarding the quality of the water and the health consequences. Currently, there is no national legislation in place regarding wastewater reuse in agriculture and in any other sector.

Literature: Wastewater Production, Treatment, and Use in Pakistan, 2012

Singapore

Singapore is a powerful economy, but is very poor in water resources, with a water availability of. The country is one of the pioneers in wastewater reuse, and currently uses treated wastewater for direct potable reuse. The drinking water produced from reclaimed wastewater, NEWater, exceeds WHO standards, and is monitored by an international panel of experts. Additionally, water reuse in Singapore is common in sectors such as agriculture, municipal, and industry. The legislation in place is formulated based on the WHO and USEPA standards.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

South Korea

Wastewater reuse is a necessity in South Korea, due to a high water stress caused by a low intake rate of rivers (36%). Wastewater reuse is practiced in industry and municipal use. The quality standards for use in agriculture are currently being developed and the draft consist of a hybrid guideline based on the major benchmarks such as the WHO, US-EPA, and California 22.

Literature: Irrigation Water Quality Standards for Indirect Wastewater Reuse in Agriculture: A Contribution Toward Sustainable Wastewater Reuse in South Korea, 2016

Thailand

Thailand has an uneven distribution of water through its territory, which does not match the water demand in different regions. The increase in industrial and agricultural activities has put pressure into the water resources together with an increasing population and urbanization.

Currently, treated wastewater is used in agriculture, industry, and groundwater recharge, mainly due to the increase in the water tariff of the past years. An important sector in Thailand is aquaculture, where treated wastewater is used in fish-farming. There is also unintentional use due to poor sanitation.

In Thailand, there is currently no legislation in place for wastewater reuse, but the increasing practice requires guidelines that would prevent environmental and health risks in the future.

Literature: Wastewater Reuse Potentials in Thailand, 2006

Turkey

Turkey has a waver availability of 1500 m3/capita/year, which classifies it as water stressed country. The increasing population will continue to put pressure on the water resources and decrease the number even further (Arslan-Alaton et al., 2014).

Wastewater reuse is mainly done not in an official way, and in agriculture as a consequence of the discharge of untreated wastewater in rivers and other water bodies. However, recently planned wastewater reuse has also started being practiced.

Legislation on wastewater reuse in agriculture has been implemented in 1991 based on the WHO Guidelines, but has not been reviewed since.

Literature: Future of Water Resources and Wastewater Reuse in Turkey, 2011

Vietnam

Use of untreated wastewater is common in agriculture, and treated wastewater is used in agriculture as well, but also for municipal use and aquaculture. There is a lack of studies on the use of treated and untreated wastewater in Vietnam. Also there is no legislation in place to regulate the use of wastewater in agriculture and aquaculture, and the WHO guidelines are used as a minimal requirement.

Literature: Wastewater Reuse in Agriculture in Vietnam: Water Management, Environment and Human health Aspects, 2001

Wastewater Production, Treatment, and Use in Vietnam, 2012

5.1.3 Australia and New Zealand

Australia and New Zealand have different water availability situations, with Australia being the world's most arid continent and New Zealand one of the most water abundant countries in the world. However, wastewater reuse is a widely developed practice in both countries, even though in Australia because of the arid climate and in New Zealand for environmental protection. Both countries have legislation in place. Australia and its guidelines have already been discussed in Chapter 3, and therefore this section will include only a brief overview.

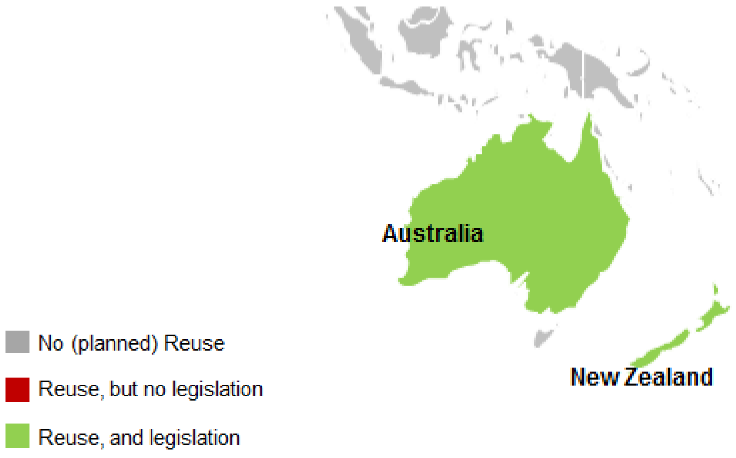

Figure 4 Wastewater reuse in Australia and New Zealand

Australia

Wastewater reuse in Australia has been discussed in the previous chapter. As already mentioned, wastewater reuse has been of increasing importance in Australia in the last 10 years. Currently, treated wastewater is mainly used in rural areas that are far from the coast. Australia uses wastewater in all sectors (Agriculture, groundwater recharge, industry, and municipal). When it comes to legislation, it has in place one of the most detailed national guidelines in the world, which replaced the state based previous guidelines.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Wastewater Reuse and Recycling Systems: A Perspective into India and Australia, 2008

New Zealand

New Zealand is one of the countries with most abundant water resources on the planet. Therefore, New Zealand mainly practices wastewater reuse for environmental protection and not because of lack of freshwater resources as in many other countries. However, in parts of New Zealand, were droughts are starting to become common, use of treated wastewater is being considered as an attractive option for irrigation of food crops.

However, there are guidelines in place for reuse possibilities in different sectors including irrigation and industry. However, with the increasing plans for wastewater reuse, there is a need to review and fill the gaps in the existing legislation (Crosby et al, 2008)

Literature: Recycled Water in New Zealand – is the Time Right?, 2008

5.1.4 Europe

Wastewater reuse is currently a common practice in the EU, particularly in the Mediterranean countries due to irregular water supply and low precipitation, especially in the summer months (Angelakis, 1999). Because of climate change, these problems have been more severe in the last years, and droughts have become more common in countries such as France, Bulgaria, the UK, and Belgium.

Treated wastewater reuse is one of the main strategies to decrease freshwater consumption, and it is widely used in many European countries mainly in agriculture, industry, and municipal use. However, each of the EU countries has its own guidelines and standards for wastewater reuse.

This section will focus on the countries of the European Union. Other European countries which are not part of the EU such as Albania, Serbia, Montenegro, and Bosnia and Herzegovina do not yet practice wastewater reuse, and lack the required level of treatment facilities. However, unplanned and direct wastewater reuse is common practice, although there is a lack of data on the practice and related environmental and health impacts.

There is also a lack of data for other non-EU European countries that have high water availability and therefore do not practice wastewater reuse in agriculture despite the highly developed wastewater treatment technology such as Switzerland, Iceland, and Norway.

The water stress indexes used in this section are taken from the 2013 study on hydrological indicators of the World Resources Institute (Gasert et al, 2013). The definitions used are explained in Chapter 3.1 Definitions.

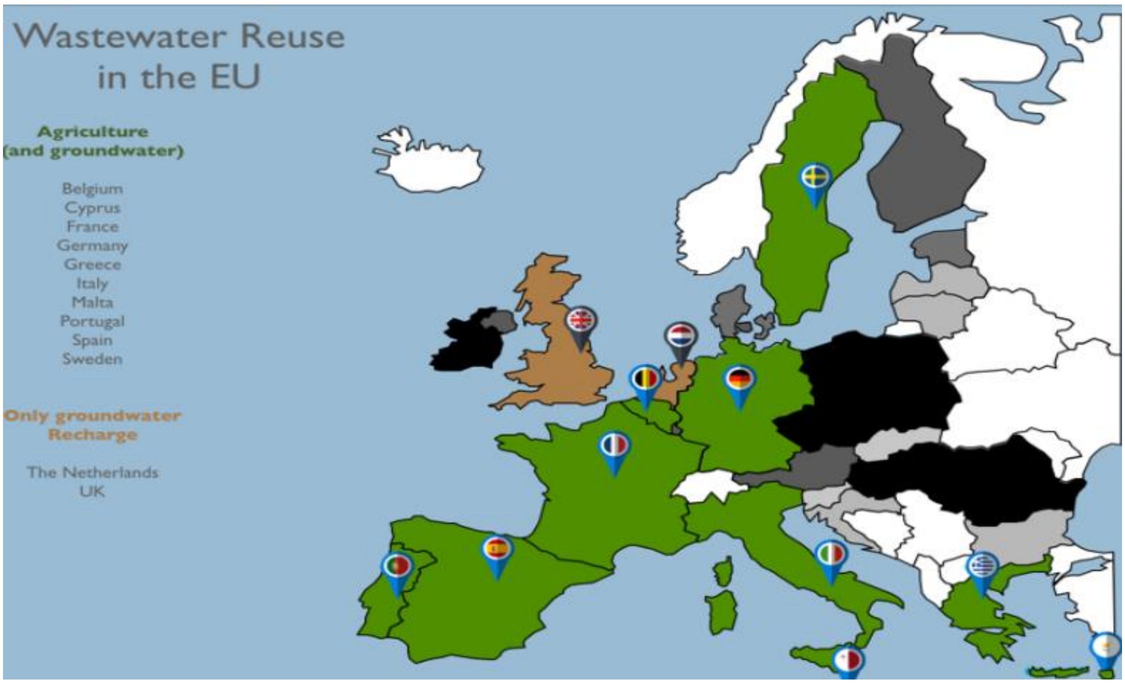

Figure 5 Wastewater reuse in Europe

Austria

Austria has a low water stress (Water stress Index 0.31) and therefore wastewater reuse it is not a necessity and only practiced for environmental purposes. Consequently, there is no legislation in place regarding wastewater reuse. In terms of sectors, reuse is practiced only in the industrial sector.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Belgium

Belgium has a higher water stress level compared to other European countries, with a Water Stress Index of 3.16. However, wastewater reuse has not been a common practice, and it is gaining importance only in the last decades. Currently, only a small fraction of the treated wastewater is used in sectors such as agriculture and industry. Consequently, the guidelines for water reuse are under preparation.

Literature: Water Reuse in Europe, 2007

Updated Report on Wastewater Reuse in the European Union, 2013

Bulgaria

Bulgaria has a low medium water stress, with a Water Scarcity Index of 1.27. There is still no wastewater reuse whatsoever, with the only exception of industry.

There is no legislation in place yet. However there are considerations about both an increase in wastewater reuse practices and a guideline for the implementation.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Cyprus

Cyprus is the country with extreme water scarcity (Water Scarcity Index 5.00) and this factor is a constraint to the important and growing tourism industry. For this reason, wastewater reuse is a common practice, especially in agriculture and municipal use, but also for industry and groundwater recharge.

Because of the importance of wastewater reuse to counter water scarcity, Cyprus has developed provisional standards for reuse already in the 1990, which have than been finalized in 2005. The standards are stricter than the WHO standards.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Czech Republic

Until now, there is no direct implementation of wastewater reuse and legislation in place. However, due to the increasing droughts and floods associated with climate change, wastewater reuse has a lot of potential for the future.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Denmark

Wastewater reuse has not been a priority in Denmark until now, and there are no guidelines in place yet. The only reuse sector so far is industry.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Estonia

Similarly, despite a high level of treatment, wastewater reuse is not a common practice in Estonia, with the exemption of industry to a limited extend. There are no guidelines in place.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Finland

Due to the low level of water stress (Water Stress Index is 0.98) wastewater reuse in Finland is limited to the industrial sector, and therefore there are no guidelines in place.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

France

France has been implementing wastewater reuse since the 1990s, and is currently practicing it in all sectors. However, the most important one remains agriculture and irrigation. The majority of the reuse projects are in the coastal area and in the islands, but there are also projects in other parts of the country.

The Guidelines regarding use for irrigation were adopted in 1991 and follow the WHO guidelines in principle, although they add a few more stringent restrictions and measures. In 1996, technical recommendations were also published. In a few weeks, the French authorities will publish new guidelines regarding aquifer recharge (May 2016).

Literature: Water Reuse in Europe, 2007

Updated Report on Wastewater Reuse in the European Union, 2013

Germany

Germany is a country with a low medium water stress (Water Stress Index is 1.90), and therefore there is little incentive for wastewater reuse. However, the practice is used in the sectors of agriculture, industry, and in some regions also for groundwater recharge and municipal. There are no guidelines in place yet.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Greece

In Greece, wastewater reuse is practiced in a limited amount in the sectors of agriculture and industry. However, due to the increasing water imbalances and high demand for water in the summer, it has a big development potential in the future.

There is legislation in place which determines the parameters and processes required, but they are under consideration.

Literature: Water Reuse in Europe, 2007

Hungary

There is no practice of wastewater reuse in Hungary so far, and there is still no legislation regarding wastewater reuse. However, there are plans for the future.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Ireland

Due to the high precipitation throughout the year, there is no need for recycled water in agriculture in Ireland. Therefore, wastewater reuse is not practiced so far, and there are no guidelines in place.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Italy

The reuse of treated wastewater is of growing importance in Italy, especially in regions affected by droughts such as Sicily and Puglia. Treated wastewater is used for agriculture, industry, groundwater recharge, and municipal use in Italy, with agriculture being the major interest.

The legislation has been adopted in 1976, and later updated in 2003 with stricter parameters. Some of the parameters require drinking water quality for recycled water, increasing thus the cost of the process and making it unattractive, especially for the Southern part of the country where use for irrigation would be more profitable but at the same time there are more financial constraints. Recycled water is also used in the industry sector, as for example in the area of Turin. A new guideline on risk assessment in water reuse will be issued in the next few months (May 2016).

Literature: Water Reuse in Europe, 2007

Updated Report on Wastewater Reuse in the European Union, 2013

Wastewater Reuse in Italy, 2001

Latvia

Water reuse has not been a priority for Latvia, which is currently not practicing it for any sector, and there are no guidelines to be found. However, there are plans for the future.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Lithuania

Lithuania is currently not practicing wastewater reuse in any sector, and there are no guidelines in place. There are plans for the introduction of the practice in the future.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Luxembourg

The only sector in which there is incentive for wastewater reuse is industry, due to the high amount of water resources. There is currently no legislation in place regarding wastewater reuse.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Malta

Due to the extreme level of water scarcity (Water Stress Index is 5.00), and the high share of agriculture in the economy, wastewater recycling has been practiced for irrigation widely. Recycled water is being used also in the industrial and municipal sector. However, there are no guidelines in place yet.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Netherlands

In the Netherlands, treated wastewater is increasingly used in industry, but also for groundwater recharge and municipal use. However, there are no regulations in place yet.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Poland

There is no practice of wastewater reuse in Poland yet, and there are no regulations in place.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Portugal

Portugal has a high water scarcity level (Water Stress Index is 3.34) with 57.55% of the country suffering a water deficit. Therefore water reuse is an attractive option for many sectors especially agriculture and industry, but also groundwater recharge, and municipal. In the last years, there has been an increase in the use of treated wastewater for the irrigation of golf courses.

The regulation, adopted in 1998, and updated in 2005, 2007, and 2010, includes parameters for recycled water reused for both agricultural and landscape irrigation. The regulation also provides guidelines on selection of methods, and monitoring procedures for areas that are irrigated with treated wastewater.

Literature: Water Reuse in Europe, 2007

Updated Report on Wastewater Reuse in the European Union, 2013

Romania

Romania is not practicing wastewater reuse so far, due to the lack of wastewater treatment facilities. Consequently, there are also no guidelines in place yet. Wastewater reuse is, however, a good option for the future, considered by the authorities.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Slovakia

There is no use of treated wastewater in Slovakia until now, due to the lack of wastewater treatment facilities. There are no guidelines in place.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Slovenia

There is no use of treated wastewater in Slovenia, and there is no legislation in place. However, there are plans for future development in the field, especially in areas with increasing tourism development.

Literature: Updated Report on Wastewater Reuse in the European Union, 2013

Spain

Due to the high water shortage (Water Stress Index is 3.73), Spain is practicing wastewater reuse for agriculture (main sector), industry, municipal use, and groundwater recharge. The majority of treated wastewater is used for irrigation (79.2%), urban uses (8.1%), and recreational uses including gold courses (6.0%). Reuse is more widespread in the coastal Mediterranean regions and in the islands of Canarias and Baleares.

There is legislation in place, which is often regional in nature. The southern regions with higher water scarcity have mostly developed standards based on the WHO guidelines and encourage wastewater reuse for activities such as irrigation of golf courses.

Literature: Water Reuse in Europe, 2007

Updated Report on Wastewater Reuse in the European Union, 2013

Sweden

In Sweden wastewater is being reused in agriculture, industry, and groundwater recharge mostly for the purpose of environmental protection, since Sweden has a low medium water scarcity (Water Stress Index is 1.30). The majority of the projects are in the southeastern region because of the low precipitation.

However, no legislation and guidelines have been adopted yet.

Literature: Water Reuse in Europe: Relevant Guidelines, Weeds for and Barriers to Innovation, 2014

United Kingdom

In the United Kingdom, treated wastewater is used in all sectors but agriculture. Despite the richness in water resources, the UK has implemented wastewater reuse projects for indirect potable reuse.

The guidelines are under preparation.

Literature: Water Reuse in Europe, 2007

5.1.5 Latin America and the Caribbean

The water availability situation in the countries of Latin America and the Caribbean (LAC) is diverse, with a few countries having a very low Water Stress index, such as Brazil, Argentina, and Costa Rica and others with a high Index such as Chile, Mexico and the Dominican Republic. However, the region is characterized by a very high demand for water mainly for agriculture.

The use of wastewater is an established practice for many years, and is mainly done in an unplanned manner, due to the discharge of wastewater in water bodies, or the irrigation with untreated wastewater. However, there are also projects for planned wastewater use, and also plans for the increase of these projects in the future.

Regarding legislation, the majority of the LAC countries have legislation in place that regulates wastewater reuse in agriculture. They are mostly based on the WHO standards, with a few countries that have developed their own guidelines such as Mexico and Brazil.

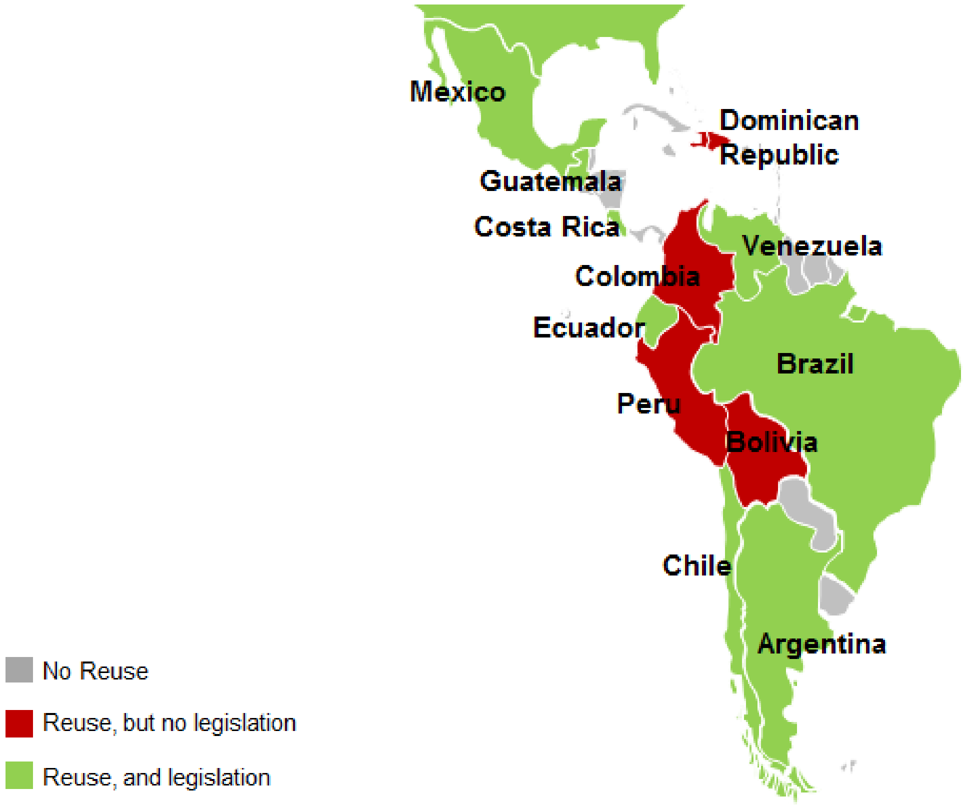

Figure 6 Wastewater reuse in Latin America and the Caribbean

Argentina

In Argentina, treated and untreated wastewater is reused in agriculture and industry. Reuse is considered as a goal to preserve freshwater resources in the country.

The legislation is based on the WHO criteria and defines types of crops that can be used where treated wastewater is used for irrigation. The areas where this type of crops can be grown are called ACRES (restricted cultivation areas).

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Bolivia

Bolivia has one of the lowest water stress indexes in the region. 0.68. Treated wastewater is used for agriculture. It is also possible that untreated wastewater is also used for irrigation, but there are no figures available. There is no legislation in place yet, but the discharging of wastewater into the water bodies is regulated.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Brazil

Brazil is the country with low water stress (Water Stress index 0.91). Water sanitation is a big problem in the country, and therefore unplanned use of wastewater in agriculture is common. There is also planned use in agriculture and municipal use, and the government policy considers wastewater reuse a high priority. Due to the increase in freshwater price, wastewater reuse in industry and for groundwater recharge is an attractive water source for the future.

Regarding legislation, WHO guidelines are used as a basis, and irrigation with treated wastewater is forbidden on crops consumed uncooked, and on vegetables growing at ground level. There is also interest for future use of treated wastewater in industry and for groundwater recharge. There are also limits for trace metals and salt content. The guidelines for all the reuse sectors are being currently reviewed.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Chile

The level of water scarcity in Chile is high compared to other countries in the region (Water Stress Index is 3.21), therefore wastewater reused is it widely practiced in agriculture and industry. However, after the Cholera outbreak in 1992, the use of only treated wastewater is allowed, and that only for certain types of crops which are not to be eaten raw. In regions such as Antofagasta and Santiago that are highly industrialised, wastewater is widely used in industrial processes as well.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Colombia

Wastewater is reused in Colombia in agriculture mostly indirectly after being discharged untreated into rivers. The legislation sets only limits for fruits and vegetables to be consumed raw.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Costa Rica

Costa Rica is a country with low water stress (Water Stress Index). However, untreated wastewater is discharged in rivers, and the water is indirectly used for irrigation of crops. In terms of planned reuse, treated wastewater is used in agriculture for irrigation of crops that will undergo future industrial processes and excludes those for direct human consumption. Treated wastewater is also used for municipal reuse such as car washing, firefighting, and construction.

There are numerous regulations regarding e types of wastewater reuse. For agricultural use, the only regulated parameter is fecal coliforms.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Dominican Republic

The Dominican Republic is a country with a high water stress level (Water Stress Index is 3.49). Wastewater reuse is practiced in agriculture through the use of water from rivers where untreated wastewater is discharged. There is legislation in place which regulates the quality of the wastewater discharged into receiving bodies and also regarding the quality of treated wastewater used for irrigation.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Ecuador

Treated wastewater is used in agriculture and the legislation defines different parameters for fruits and vegetables for raw consumption, and crops used for industrial consumption, and for localized irrigation with no exposure to workers.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Guatemala

In Guatemala, the use of raw wastewater for agricultural irrigation is not allowed. The legislation in place defines 3 types of reuse: agricultural irrigation, aquaculture, and recreational activities and specifies parameters accordingly. The only regulated parameter is fecal coliforms.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Mexico

In Mexico, treated wastewater is used on agriculture, groundwater recharge, municipal use, and industry. It is considered a priority and regulated since 1982, due to the high water scarcity level (Water Stress Index is 3.52). Moreover, the use of untreated wastewater for irrigation is common, due to lack of sanitation. It is estimated that around 80% of the wastewater used in agriculture in Mexico is not treated (Lencioni et al, 2011). The practice is more common is large cities in the center and north of the country.

The regulations therefore are 2, one regarding the discharge of wastewater into water bodies and based on the WHO guidelines, and one regarding wastewater reuse in public works. The limit for helminth eggs is higher than the WHO recommendation, due to the lack of treatment technology to achieve the recommended value.

Literature: A Review of Policy and Standards for Wastewater Reuse in Agriculture: A Latin American Perspective, 2000

Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Nicaragua

Planned and unplanned wastewater reuse is a common practice in Nicaragua. However, there are no regulations for wastewater reuse in place yet.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Peru

Peru has a high water stress index of 3.20. Treated wastewater is used in agriculture and for groundwater recharge. There is legislation in place that regulates wastewater discharges and irrigation of vegetables.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Venezuela

Treated wastewater is used in agriculture, but irrigation with untreated wastewater is prohibited and only certain types of crops are allowed to be irrigated with treated wastewater.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

5.1.6 Middle East and North Africa

The North Africa and Middle East (MENA) region is one the most arid regions in the world, with the majority of countries having an extremely high Water Scarcity Index. (Water Availability Index in 2006 was 1,383 m3/capita/year).For this reason, wastewater reuse has been traditionally practiced in the region, both in a planned and unplanned way in many sectors, mainly agriculture, municipal, and landscape irrigation. There are differences among countries with high income such as Bahrain and Kuwait, and countries with lower incomes.

Consequently, the majority of the MENA countries have regulated wastewater reuse. Some of the countries guidelines are based on the WHO standards, and a few others on the more stringent California 22 standards. High income countries use standards that are based on the California 22 standards, and low income countries follow WHO guidelines as minimal requirements. There are still a few countries in the region that have not yet developed their own guidelines, such as Egypt, Lebanon, and Morocco.

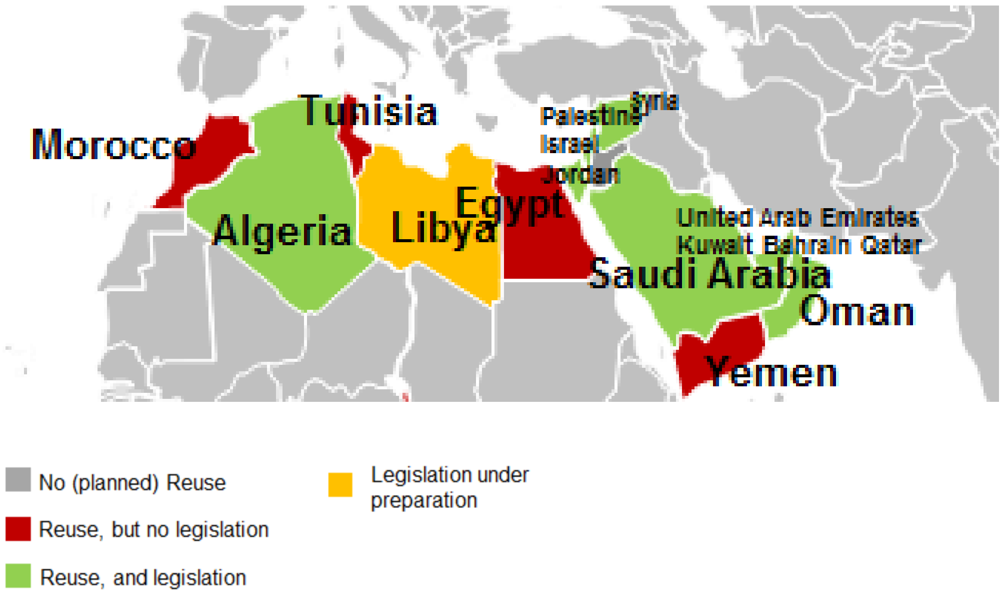

Figure 7 Wastewater reuse in Middle East and North Africa

Algeria

As a country with a high water scarcity level (Water Stress Index is 3.44) wastewater reuse is an important alternative to ease the situation. Algeria currently reuses wastewater in agriculture for the production of fodder crops, pasture, and trees. However, the law prohibits the reuse of treated wastewater for the irrigation of vegetables that are eaten raw (paper on Mediterranean basin)

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Bahrain

Bahrain has an extremely high water scarcity (Water Stress Index is 5.00). The country mainly relies on desalination and it uses treated wastewater in agriculture and municipal sector. The legislation is quite elaborated, and is based on the US-EPA regulation. The use of untreated wastewater is prohibited.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Egypt

Wastewater reuse is a common practice in Egypt. The main sectors for reuse are agriculture, groundwater recharge, and municipal use. There are no specific regulations for reuse but there is legislation in place that prohibits the use of untreated wastewater for vegetable irrigation and that regulates water pollution from wastewater discharge. Wastewater reuse in industry is low, because of the belief that the treated water may have on machinery.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Kuwait

In Kuwait, due to the arid conditions and extremely high water scarcity (Water Stress Index is 4.96), treated wastewater is used in all sectors, agriculture, groundwater recharge, industry, and municipal use. There are stringent quality standards in place.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Libya

Libya has an extremely high Water Stress Index of 4.84.Wastewater reuse is practiced in agriculture, and guidelines are under preparation.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Morocco

There are no regulations for wastewater reuse in place yet, and WHO standards are used as basic guidelines, exempt for the standards used for irrigation.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Tunisia

In Tunisia treated wastewater is used in agriculture, groundwater recharge, and for municipal use. There is legislation in place, which is based on the WHO standards for restricted irrigation.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Israel

Due to extremely high water scarcity (Water Stress Index is 4.83), wastewater reuse is common practice in Israel since the 1970s. The main sectors are agriculture, groundwater recharge, industry, and municipal use.

There are regulations in place that follow the California Title 22 guidelines. The new guidelines have implemented only a single standard for unrestricted irrigation.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

New Standards for Treated Wastewater Reuse in Israel. Wastewater Reuse-Risk Assessment, 2007

Jordan

Being a country with an extremely high water scarcity (Water Stress Index is 4.59), Jordan uses treated wastewater for agriculture and also for groundwater recharge.

The legislation describes standards for different categories. Groundwater recharge is not allowed if aquifer is used for drinking purposes, and also the irrigation with treated wastewater of vegetables eaten raw.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Oman

In Oman, use of treated wastewater is common due to arid conditions (Water Stress Index is 4.91), and is used in agriculture, groundwater recharge, municipal use, and industry. There are 2 categories of crops; the first one is the fruits and vegetables to be eaten raw, controlled aquifer recharge, and landscapes with public access. The second one is for cooked vegetables, cereals, and areas with no public access.

There is legislation in place, based on the California 22 standards.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Palestine

Similarly to its neighboring countries, with similar water stress level (Water Stress Index is 4.63) in Palestine wastewater reuse is practiced in sectors such as agriculture and groundwater recharge. The legislation in place is based on the WHO guidelines.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

Qatar

In Qatar, treated wastewater is used in agriculture and industry, and the standards applied are based on the strict California Title 22.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Saudi Arabia

In Saudi Arabia, treated wastewater is used for agriculture, groundwater recharge, industry, and also for municipal use due to the extreme Water Stress Index of 4.99. The quality standards are based on the California Title 22 standards and irrigation of vegetables is forbidden. Wastewater reuse is considered as part of water policy, and full utilization for non-potable reuse is aimed.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Syria

In Syria wastewater reuse is practiced in agriculture, groundwater recharge, and for municipal use. There are currently no guidelines, but irrigation with treated wastewater is prohibited for vegetables.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

United Arab Emirates

The United Arab Emirates have an extremely high water stress Index of 5.00. Treated wastewater is used in agriculture and municipal use. There is legislation in place which is based on the California Title 22 standards.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, 2005

Yemen

Yemen has an extremely high water stress level with a Water Stress Index of 4.67.Wastewater reuse is common in agriculture, groundwater recharge, industry, and for municipal use. However, there are no national standards and the WHO guidelines are used as the main guideline.

Literature: Water Reuse: An International Survey of Current Practice, Issues, and Needs, 2008

5.1.7 North America

The United States and Canada have both a high potential and are already practicing wastewater reuse since many years. Both countries are characterized by regional and state level differences in terms of extent of wastewater reuse, purpose, and regulation. The United States of America has an extensive legislation in place that regulates wastewater reuse. In contrast, Canada does not have national guidelines, but only state level regulations in some of the states. Moreover, Canada, due to its abundance in water resources does practice reuse mostly for environmental protection, and the US does practice it due to low water availability, mostly in the states of California, Florida, Texas, and Arizona.

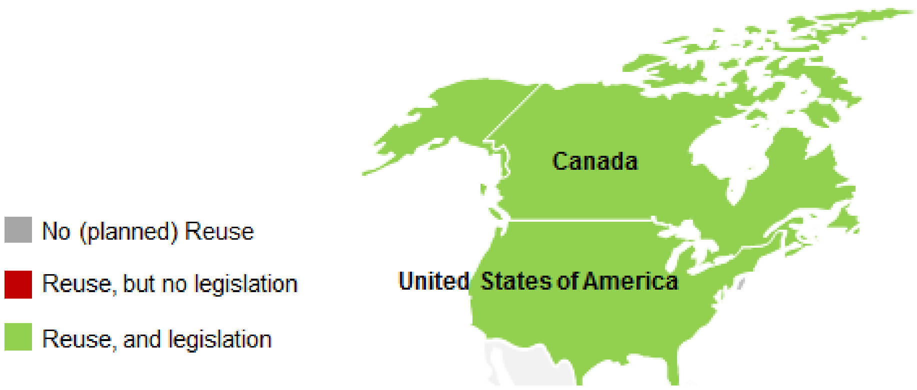

Figure 8: Wastewater reuse in North America

Canada

Canada has a medium low Water Stress Index of 1.21, and is abundant in water resources. However, wastewater reuse has been recognized as an opportunity to decrease the actual high use of fresh water resources, and for environmental protection. Currently, treated wastewater is used in agriculture for irrigation of non-food crops, and for municipal use such as for golf courses and landscape irrigation. The reuse is expected to increase due to the increasing water demand.

There are no national guidelines for water reuse, but only some regulations on a state level such as in Alberta, and British Columbia.

Literature: Water Reuse and recycling in Canada: A Status and Needs Assessment, 2004

United States of America

The current state of wastewater reuse in the United States of America is discussed in Chapter 3.1. As already mentioned, wastewater reuse is a common practice in the US, especially in states with high water scarcity such as Florida, California, Texas, and Arizona. The main use is for non-potable purposes such as agriculture, landscape irrigation, and golf courses. Another sector is industry, where treated wastewater is used for power plants and industrial facilities. When it comes to potable uses, the main sector is groundwater recharge.

The US is also one of the countries with the most legislation regulating wastewater reuse. It consists of many guidelines on a state level, and also the US-EPA on a national level. The more stringent standards are the California Tittle 22.

Literature: United States Environmental Protection Agency – Guidelines for Water Reuse, 2012

5.2 Summary

Today, 60 out of 193 countries reuse treated wastewater for different purposes. One important issue here is the differentiation between intended and unintended use, as many developing countries use wastewater in an intended way due to lack of sanitation. When it comes to the sectors (Figure 9:International wastewater reuse by sectors), agriculture by far the most important reuse option, (51 countries) followed by municipal use (33 countries), and groundwater recharge (26 countries). When looking at the regional dynamics of wastewater reuse, first it is necessary to look at the drivers which are different in developed and developing countries. In developing countries, the main driver is lack of water, ensuring a reliable source of water, but also for environment protection and economic benefits. When it comes to developing countries, environmental protection is not a driver, but rather the lack of sanitation is a major factor, together with the lack of water as a resource in many countries.

As a consequence, as expected, countries with a high water scarcity level which are developed are the main users of wastewater for several purposes. Examples are countries in Southern Europe, and the Middle East. Countries with a high water scarcity level, but that are less developed, such as Sub-Saharan countries, mostly use wastewater in an unintentional way due to lack of sanitation. When it comes to developed countries with low water scarcity, such as Northern European countries, the tendency there is to use wastewater more for environmental protection and industrial use.

When it comes to legislation, there is a clear difference between developed and developing countries. The biggest number of developed countries has already quality standards in place, and in developing countries wastewater used informally in agriculture, often untreated. Another expectable trend is that there is a correlation between water scarcity and development of legislation on wastewater reuse, mostly because countries with high water scarcity use treated wastewater in more widely and in sectors that are also more in contact with humans such as agriculture and municipal use. This is consequently reflected in the degree of elaboration of the standards. Another finding is that the majority of countries without national regulations indirectly applies WHO guidelines as minimum standards regarding water quality, and often regulates only the quality of wastewater discharged in water bodies, which will then be indirectly reused for irrigation after dilution. When it comes to countries that have developed their own regulation, they are either based on the WHO standards, on the California 22 standards, which are far more stringent, or have developed their own depending on the reuse purpose. In some countries such as Canada and the United States, there are also different legislation and standards at a state or regional level. Lastly, due to the fact that wastewater reuse is increasing in importance and the reuse purposes are becoming broader, many other countries in which the guidelines are missing or incomplete are in the process of developing them.

In the European Union, 18 countries are reusing wastewater, and 7 countries have plans to do so in the future. Of the countries that to not practice wastewater reuse at all or the reuse is very limited, some of them do so because of the high amount of water resources (Austria, Finland,etc.), and some others due to the lack of advanced wastewater treatment facilities (Romania, Slovakia, etc.).When it comes to countries that do practice wastewater reuse, they can be classified into countries that practice reuse as a necessity due to the high water scarcity (Cyprus, Malta, Portugal, Spain) and countries that practice it mostly for environmental purposes (Sweden, Germany). The main sector for reuse is industry (17 countries), followed by agriculture (10 countries), and groundwater recharge and municipal use (9 countries). The use for potable water is the least common sector in the EU with only 5 countries practicing it (Figure 10: Wastewater reuse by sectors in the EU).

Regarding legislation, 7 EU countries already have implemented their legislation regarding wastewater reuse and 6 other countries are in the process of development. WHO guidelines are used as a minimal requirement, and in some cases they are elaborated even further and made more stringent as in the case of Spain and Italy. On these two countries, there are also regional legislations found, depending on the water scarcity level, and development of sectors such as agriculture and industry.

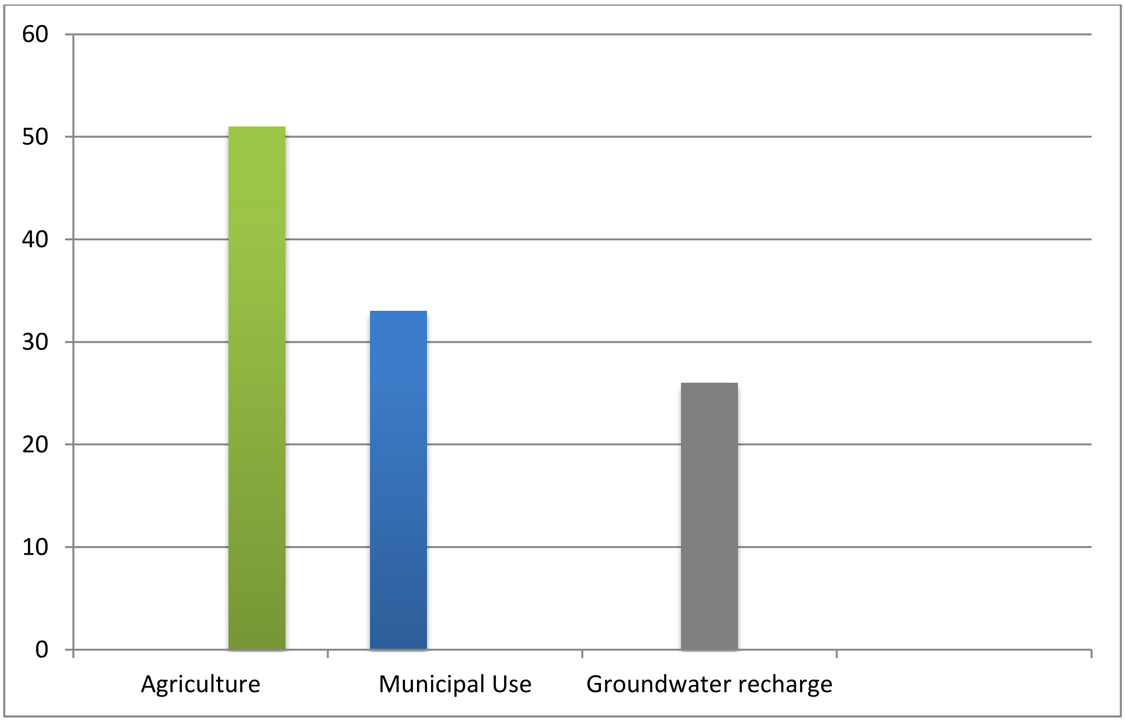

Figure 9:International wastewater reuse by sectors

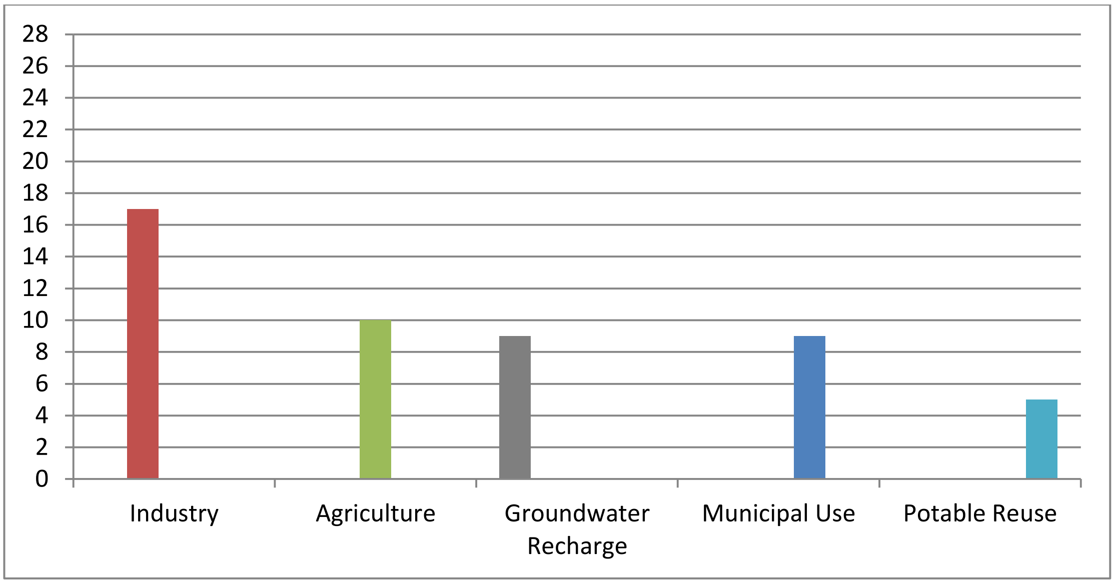

Figure 10: Wastewater reuse by sectors in the EU

6. Parameters

After comparing the reuse schemes used in the benchmark standards, this chapter continues the analysis on a parameter level. As defined in 3.1 Definitions, parameters are the threshold values recommended for the different quality standards depending on the reuse purpose. The chapter looks at the individual values for the most present parameters in all of the guidelines to be able to find similarities and eventually contrasts in the different values. The analysis is conducted for the reuse in agriculture, as the sector with the highest impact on the environment and human health, and therefore requiring the highest water quality after potable water. Taking into consideration the reuse schemes discussed in Chapter 3, the comparison will differentiate between the different reuse schemes for agriculture as in Table 6: Summary of reuse schemes in agriculture.

The analysis is not limited to the presence of limit values for different microbial agents and quality parameters, but also looks at the numerical values to identify whether there are any contrasts among the recommendations, and examine the reasons of the inconsistencies.

It is expected that the majority of the parameters will show similarities and be based on the WHO recommendations, with a few ones having more stringent and conservative values, such as for example California Tittle 22.

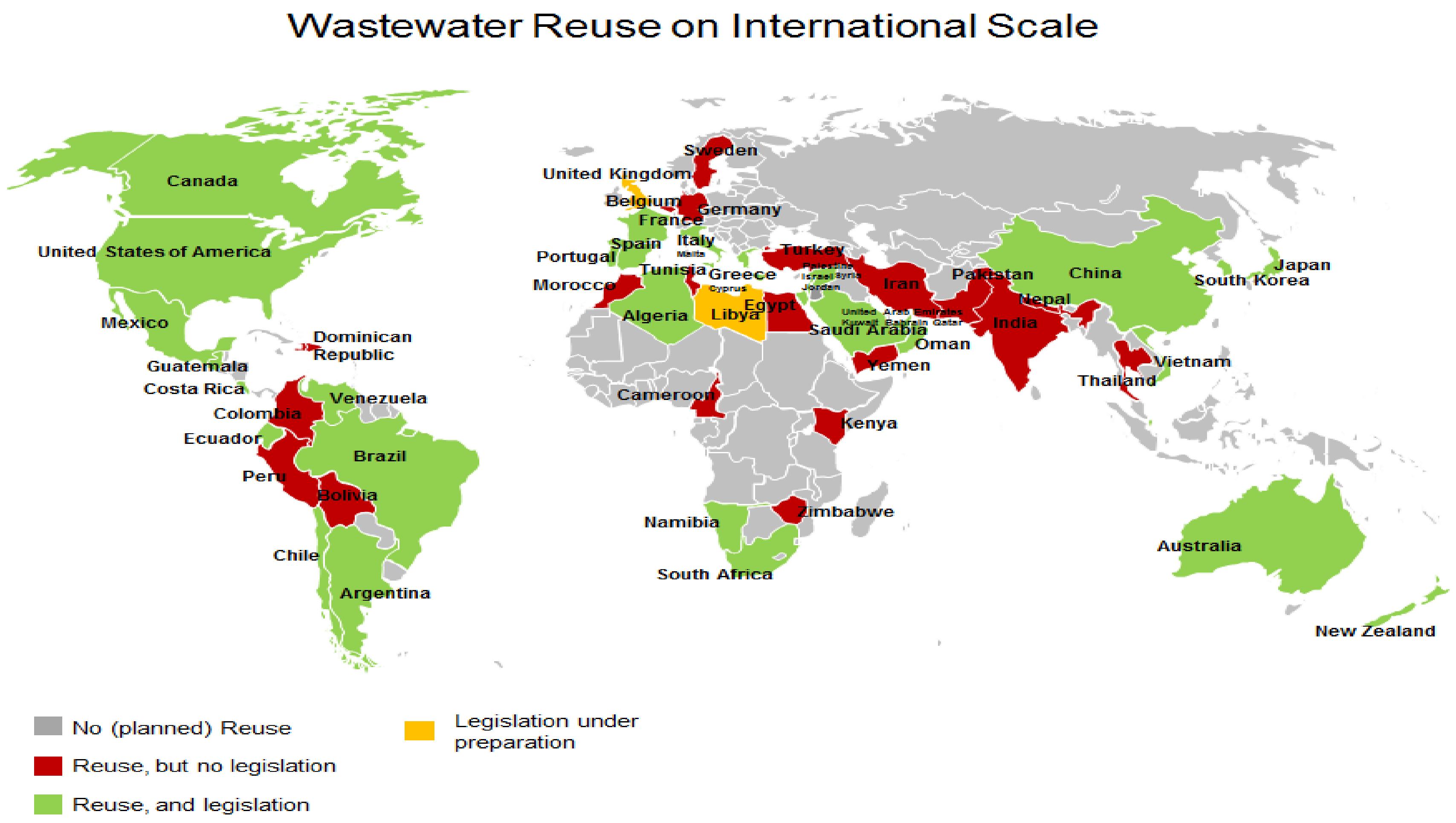

Figure 11: Wastewater reuse on a worldwide scale

6.1 Results

After reviewing the main benchmark standards and their water quality parameters for agriculture, the results are presented in Table 7: Matrix of parameters for the benchmark standards. Their importance and their values in the different benchmark standards are summarized below:

pH

pH indicates the acidity or basicity of water. If the value of pH is abnormal, it means that the water needs further evaluation to determine the reason of the pH level. In irrigation water, the reason can be the presence of a toxic ion (FAO, 1992).

PH is a parameter present in all the reviewed guidelines. The recommended values of the pH lie between 6 and 9, with Australia, WHO, FAO, and ISO having a recommendation of 6 to 8.5.

BOD

BOD measures how much organic material is in the treated wastewater, based on the amount of oxygen needed by the microorganisms in the oxidation process.

A recommended value for BOD is present in US-EPA and the Australian Guidelines, but not in the others. In both guidelines, the recommended value for food crops is equal or less than 10 mg/l, for processed food crops and non-food crops is equal or less than 30 mg/l.

Intestinal nematodes

Infections resulting from intestinal nematodes are one of the main risks associated with the practice of wastewater reuse, particularly in developing countries where they mainly affect children (WHO, 2006).

Intestinal nematode is a parameter recommended from WHO, FAO, and ISO, which set a limit of 1 egg/l for all types of crops. There is no recommended value for California 22, US-EPA, and Australia.

Helminth eggs

Helminth eggs are parasites of concern in agricultural irrigation, causing diarrheic diseases such as Helminthiasis. Helminthiasis is a major concern especially in countries with poor sanitation (WHO, 2006)

The only guidelines that has a limit for helminth eggs are FAO and WHO which recommend a maximum of 1 egg/l for crops that are eaten raw, cereal crops, industrial crops, fodder crops, pasture, and trees is there is exposure of workers. The limit for Helminth eggs was added in the latest edition of the WHO standards, and was labelled there as 'one of the main pollutants for developing countries' (WHO, 2006). The other guidelines do not have a limit.

Turbidity

Turbidity measures the relative clarity of water through the level of presence of particulate matter that scatter light making water appear cloudy. Turbidity does not have a direct health impact, but it often indicates the presence of pathogens such as protozoa (WHO, 2006). Its unit is Nephelometric Turbidity Unit (NTU).

Turbidity is a parameter found in the California 22, US_EPA, and Australia, which have a limit of max 2 NTU in the case of irrigation of food crops. Additionally, California 22 requires that the influent does not exceed 5 NTU for more than 1 minute and that it should never exceed 10 NTU.

TSS

Total Suspended Solids (TSS) is related to turbidity, and microbial contamination.

It is a parameter found in the US-EPA and the WHO guidelines, which require a maximum of 30mg/l for restricted use. The parameter is not regulated in the other guidelines.

Faecal coliform

The predominant faecal coliform is Escherichia coli, and according to FAO "is the most satisfactory indicator parameter for wastewater use in agriculture" (FAO, 1992).

It is one of the main parameters that are regulated. It is present in US-EPA, Australia, FAO, and WHO. The US-EPA has the most stringent requirement, with no detectible faecal coliforms in 100 ml for food crops. Australia requires less than 100 CFU/100 ml and WHO has a basic requirement of less than 100 MPN/l.

Total coliform

Total coliform includes faecal coliforms and other non-faecal coliforms (FAO, 1992). The parameter is used in the California 22 standards, which require MPN2.2/100ml. the parameter is not to be found in any other guidelines.

Chlorine residual

High Chlorine residual can have adverse impacts on crops. A limit value is present in the US-EPA, Australia and FAO Guidelines. All of them require l mg/l min.

Trace metals

Trace elements can damage and limit crop production in the long term, if their presence is relatively high for a long time so it can build-up. Moreover, some heavy metals such as arsenic (As), cadmium (Cd), lead (Pb), etc. have also negative health effects (Jimenez & Asano, 1998).

Regarding trace metals, the table of the limits of the main 12 trace metals is identical in all the guidelines and taken from the WHO recommendations. The suggested levels prevent the build-up, which can cause the negative effects on the long term for both crops and human health (Jimenez & Asano, 1998).

The values for each of the trace metals in all the guidelines are summarized in Table 8: Table for parameters for trace metals

Table 7: Matrix of parameters for the benchmark standards

	California 22			US-EPA			Australia				WHO		FAO			ISO	
	(a) Irrigation of Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop	(b) Recycled water used for the surface irrigation of food crops where the edible portion is produced above ground and not contacted by the recycled water	(c) Surface irrigation of Pasture for animals producing milk for human consumption	Food crops	Processed Food crops	Non-food crops	A	B	C	C	Restricted use	Unrestricted use	Irrigation of crops likely to be eaten uncooked	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Localized irrigation of crops in category B if exposure of workers and the public does not occur	Unrestricted irrigation of agricultural crops	Restricted irrigation of agricultural crops
pH	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0-8.5	6.0-8.5	6.0-8.5	6.0-8.5		6.5-8.5	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0
BOD				≤ 10 mg/l	≤ 30 mg/l	≤ 30 mg/l	≤ 10/5 mg/l	≤ 20/30 mg/l	≤ 20/30 mg/l	≤ 20/30 mg/l							

	California 22			US-EPA			Australia				WHO		FAO			ISO	
Intestinal nematodes											max 1 eggs/ l	max 1 eggs/ l	1 eggs / l	1 eggs / l	Not applicable	1 eggs / l	1 eggs / l
Helminth eggs													1 eggs/ l	1 eggs / l	Not applicable		
Turbidity	Max 2 NTU, influent does not exceed 5 NTU for more than 1 minute, and never exceeds 10 NTU	Max 2 NTU, influent does not exceed 5 NTU for more than 1 minute, and never exceeds 10 NTU	Max 2 NTU, influent does not exceed 5 NTU for more than 1 minute, and never exceeds 10 NTU	≤ 2			≤ 2(5)										
TSS					≤ 30 mg/l	≤ 30 mg/l					30 mg/l						
Faecal Coliform				no detectable/100ml	≤ 200 faecal coli/100 ml	≤ 200 faecal coli/100 ml	<10 CFU /100	<100 CFU /100 ml	<1000 CFU /100 ml	<10000 CFU /100 ml	< 1000 MPN/l	< 1000 MPN/l	1000 geometric mean no. per 200 ml		None		

	California 22			US-EPA			Australia				WHO		FAO			ISO	
							ml										
Total Coliform	MPN 2.2/100ml (7 days) and 23 MPN/ 100ml in more than 1 sample in any 30 day period. No sample shall exceed 240 MPN / 100 ml	2.2 MPN/100 ml (last 7 days) and 23 MPN/100 ml in more than 1 sample in any 30 day period	23 MPN/100 ml (last 7 days) and 240 MPN/100 ml in more than 1 sample in any 30 day period														
Chlorine Residual				1mg/l min.	1mg/l min.	1mg/l min.	-1	-1					1 mg/l	1 mg/l			

Table 8: Table for parameters for trace metals

Trace Elements (mg/l)	US-EPA	Australia	WHO	FAO	ISO
Aluminium	5.0	5.0	5.0	5.0	5.0
Arsenic	0.10	0.10	0.10	0.10	0.10
Beryllium	0.10	0.10	0.10	0.10	0.10
Boron	0.75	0.75	0.7	0.7	0.7
Cadmium	0.01	0.01	0.01	0.01	0.01
Chromium	0.1	0.1	0.10	0.10	0.10
Cobalt	0.05	0.05	0.05	0.05	0.05
Copper	0.2	0.2	0.20	0.20	0.20
Fluoride	1.0	1.0	1.0	1.0	1.0
Iron	5.0	5.0	5.0	5.0	5.0
Lead	5.0	5.0	5.0	5.0	5.0
Lithium	2.5	2.5	2.5	2.5	2.5
Manganese	0.2	0.2	0.20	0.20	0.20
Molybdenum	0.01	0.01	0.01	0.01	0.01
Nickel	0.2	0.2	0.20	0.20	0.20
Selenium	0.02	0.02	0.02	0.02	0.02
Tin, Tungsten, Titanium	-	-	-	-	-
Vanadium	0.1	0.1	0.10	0.10	0.10
Zinc	2.0	2.0	2.0	2.0	2.0

6.2 Summary

After reviewing the reuse schemes of each of the main guidelines for wastewater reuse, this chapter took the analysis at a parameter level, to draw conclusions on the different parameter sets for treated wastewater use in agriculture.

Table 7: Matrix of parameters for the benchmark standards shows that there are similarities both in the parameters and the numerical values between all the guidelines, although there is a clear difference between the more stringent California and Australia standards and the more lenient WHO recommendations. The most common parameters used are faecal coliforms, BOD, intestinal nematodes, and chlorine residual. The values for each of them are similar and do not show major differences. It is also important to note that the parameters for trace metals are the same in all the guidelines, and all taken from the WHO recommendations. The choice of the parameters is based on the effects of each of them for human health, and also for the crop production. The three main categories can be summarized as:

- General parameters, such as pH, TSS, and turbidity
- Biological parameters, such as fecal coliforms, total coliforms, helminth eggs, and intestinal nematodes
- Chemical parameters such as trace metals (inorganic) and BOD (organic) (Jimenez & Asano, 1998)

Finally, the WHO, FAO, and ISO recommendations show stronger similarities among each other. Most of the recommended values of FAO and ISO are taken from the WHO recommendations, and represent the minimal requirements for the protection of human health that can be applied in both developed and developing countries.

7. Conclusion

Water scarcity is a major problem of today’s world; the tackling of this issue through the use of non-conventional water resources is at the center of the policy agenda at international , regional and national levels. Wastewater reuse is an increasing practice worldwide as an adaptive measure to the current water situation and increasing water demand. However, the use of treated wastewater faces several challenges, the main one being health concerns related to the presence of certain chemical and microbial agents. For this reason, guidelines have been developed at both an international and national level. However, many countries still do not have legislation in place that regulates wastewater reuse. Additionally, the various existing guidelines are not harmonized. This is problematic, especially in the context of globalization and common markets.

This survey looked at the wastewater reuse practice in 193 UN countries and the legislation in place in each of them. The survey focused on the reuse schemes and the parameter sets of the main six guidelines: Australia, US-EPA, California 22, FAO, ISO, and WHO. These 6 guidelines have been used as the basis for the development of subsequent national guidelines and represent different approaches to the wastewater treatment issue. The comparison shows that WHO, FAO, and ISO show strong similarities among each other. Their approach in formulating reuse schemes and parameter requirements consists of the establishment of basic requirements that can be used as a reference for both developed and developing countries. On the other hand, guidelines such as Australia, US-EPA, and most prominently California 22 have much more elaborate and stringent standards based on a 'safety first' approach.

The results of the survey show that wastewater reuse is a common practice mostly in arid areas, where demand for water has led to the development of wastewater reuse and linked legislation. There is a difference between developed and developing countries. On one hand, developed countries that do have the option to apply advanced wastewater treatment have guidelines that are based on the California 22 standards. This is the case of countries in the Middle East and North Africa region such as Bahrain, Israel, and Qatar. On the other hand, developing countries that lack infrastructure and economic resources mostly base their recommendations on the more lenient WHO guidelines. This is the case of many countries in Asia and Latin America and the Caribbean. In the European Union, countries that have established practice and legislation have mostly developed their own guidelines which are somewhere between the WHO and California 22 standards. It is also worth noting that in developed countries that do not suffer from water scarcity, wastewater practice is also an established practice for the purpose of environmental protection. Examples are Canada, New Zealand, and countries in Northern Europe. Namibia and Singapore are pioneers in wastewater reuse practice, and both use treated wastewater as potable water. After undergoing advanced treatment, the quality of the water even exceeds the WHO standards.

On a parameter level, the analysis shows that the major guidelines have similar specifications for the water quality used in agriculture both in terms of parameters chosen and the numerical values for each parameter. However, even at a parameter level it is clear that there is a gap between the WHO and the California 22 guidelines.

The results can help draw recommendations on the possibility of developing of common and harmonized regional guidelines such as for example in the EU. The results of the survey show that due to the increasing appeal of the practice of wastewater reuse especially in sectors with high water requirement and high impact on human health such as agriculture, there is a need to revisit the existing guidelines, and consider the harmonization of the existing legislation at a national and regional level to ensure that a minimum water quality standard is met. This is of greater importance in the European Union, which does not have a common legislation on wastewater reuse in agriculture, despite having a common market for agricultural goods. The existing major guidelines show a clear gap between the more lenient WHO guidelines, and the more stringent California 22 guidelines. The California approach puts safety first. These guidelines can be adhered to by developed countries with the capacity to implement the required treatment level and cover the costs involved. However, if we consider developing countries that still have issues with basic sanitation and wastewater treatment, achieving these standards is unrealistic. For regions such as the European Union, with differing levels of economic development and water availability which lead to different levels of prioritization of wastewater reuse, a “third way” might be the best option. This would ensure meeting requirements for water quality that put human health first, without running the risk that the costs of implementation would discourage countries from applying wastewater reuse.

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