Lesson D1

Guidelines and Standards for Wastewater Reuse

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Overview and summary

Due to water shortage, wastewater reuse has gained great importance in many parts of the world. Wastewater reuse practices have become valuable source in water resources management. As an independent source of water, reclaimed water can increase the reliability of water supply. Reclaimed wastewater requires effective measures to protect public health and the environment. Strong wastewater reuse guidelines and regulations are developed for the purpose. It is difficult to establish wastewater guidelines and regulations that can suit all regions in the world. Among the broad reasons for this as limiting factors, are economics of countries relating chosen treatment technologies and additionally, the local context of a region must be taken into consideration in settings. Almost all wastewater reuse guidelines and regulations are bacteriological-based. Some of them consider biochemical parameters.

In this lesson you will comprehend the importance as well as the necessity of setting wastewater reuse guidelines and regulations. You will be aware of arising problems for getting universal valid standards. You will get an overview of guidelines and regulations existing worldwide and regionally.

1. Introduction

The reuse of wastewater is one of the main options being considered as a new source of water in regions where water is scarce. However wastewater reuse can also be linked with human health risks – for farmers as well as for crop consumers - as wastewater can contain enteric viruses, pathogenic bacteria and protozoa. Some chemical wastewater components, such as nitrogen, and phosphorus, may have both positive and negative effects on plant growth, crop yields, and the environment. Others, such as suspended solids, high salt levels loads, can be disadvantageous for agricultural soils and irrigation infrastructure. In order to reduce negative impacts, many countries have adopted standards and guidelines, that regulate wastewater reuse in agriculture.

In the planning and implementation of water reclamation and reuse, the intended water reuse applications dictate the extent of wastewater treatment required, the quality of the reclaimed water, and the method of water distribution and application. Regulations issued for wastewater reuse in agriculture focus principally on sanitary and environmental protection, and usually refer to: wastewater treatment technology, reclaimed wastewater quality, irrigation practices, and control of areas or crop types where reclaimed water is used. The requirements are based primarily on defining the extent of needed treatment of wastewater together with numerical limits on bacteriological quality, turbidity and suspended solids.

However, the standards required for the safe use of wastewater and the amount and type of wastewater treatment needed are contentious. The cost of treating wastewater to conform to high microbiological standards can be so prohibitive that in many developing countries the use of untreated wastewater is effectively unregulated. Therefore, the health and environmental protection measures need to be tailored to suit the local balance between affordability and risk.

They should be:

- realistic in relation to local conditions (epidemiological, socio-cultural and environmental factors),
- affordable, and
- enforceable.

Where economic constraints limit the level of wastewater treatment that can be provided, a disease-control approach has been suggested, potentially using less strict microbiological guidelines and more management measures for health protection. A range of *health protection measures* including crop restriction, irrigation technique, human exposure control and chemotherapeutic intervention should all be considered in conjunction with partial wastewater treatment. In some cases, community interventions using health promotion programs and/or regular chemotherapy programs could be considered, in particular where no wastewater treatment is provided or where there is a time delay before treatment plants can be built.

Bahri 2002 has suggested that countries with substantial problems in treating wastewater in an adequate manner should undertake intermediate steps to mitigate the negative impacts:

- Introduce crop restrictions and standards for effluent reused for irrigation and other uses
- Apply source control of contaminants
- Apply appropriate irrigation, agricultural, harvest and public health practices that limit risks
- Improve extension and outreach activities to all stakeholders
- Upgrade the effluent quality from treatment plants
- On-farm use of storage and stabilization ponds
- The medium-term goal should be prohibition of all irrigation use of untreated wastewater.

2. Important Criteria

The most important criteria for evaluation of suitability of treated wastewater for irrigational use are as follows:

- Health aspects
- Salinity (especially important in arid zones)
- Heavy metals and harmful organic substances

In addition to standards regarding biological and chemical loads of wastewater, regulations can include best practices for wastewater treatment and irrigation techniques as well as regarding crops and areas to be irrigated.

2.1 Health parameters

Predominantly with domestic sewage the issue of contamination with bacteria or viruses is extremely important. However, also with industrial wastewater pathogens might occur and should at least once in the beginning be analyzed. Total coliform and fecal coliform organisms are often used as indicators for microbiological contamination of wastewater. Nematode eggs are used as an indicator for parasite microbiological standards for wastewater reuse in agriculture (see table 1). They are often set in conjunction with specified requirements for treating wastewater. There are currently several alternative approaches to establishing microbiological guidelines for reusing wastewater (see textbox below). These have different outcomes as their objectives: the absence of fecal indicator bacteria in the wastewater, the absence of excess cases of enteric disease in the exposed population and a model generated risk which is below a defined acceptable risk.

Table 1: Different approaches to set microbiological standards for wastewater reuse

The absence of fecal indicator bacteria in the wastewater	This approach has led to guidelines that require zero fecal coliform bacteria/100 ml for water used to irrigate crops that are eaten raw in addition to a requirement for secondary treatment, filtration and disinfection. The United States Environmental Protection Agency (US EPA) and the US Agency for International Development (USAID) have taken this approach, and consequently have recommended strict guidelines for wastewater use .
No measurable excess cases in the exposed population: epidemiological perspective	The objective of this approach is that there should be no actual risk of infection—that is, there should be no measurable excess risk of infection attributable to the reuse of wastewater as evaluated using scientific evidence, especially from epidemiological studies. This was the approach adopted in the 1989 WHO guidelines, for which epidemiological evidence was used (when available); However, results from any given study are generally specific to the time and place of that study. Extrapolation of the results to other times and other locations — as is necessary when they are used for regulation—depends on making assumptions about the changes to variables, such as contact with wastewater, which might affect the outcome. In scientific terms, assessment of actual health risks continues to be a controversial matter; there are either too few epidemiological studies available to permit any precise weighting of risks or the studies are not sufficiently practice-orientated to permit the results to be translated into concrete policy.
A model-generated risk that is below a defined acceptable risk	In this approach an acceptable risk of infection is first defined — for example, for the microbial contamination of drinking-water supplies. The US EPA has set annual risk of 10^{-4} per person. Once the acceptable annual risk has been established by the regulator, a quantitative microbial risk assessment (QMRA) model is used to generate an estimated annual risk of infection. A microbiological quality guideline limit would then be set so that the model produces an estimate of an annual risk which is below the regulator's acceptable annual risk.

Presently, researchers are divided between two schools of thought on the question of the appropriate level of nematodes and fecal coliform in wastewater that should be used for irrigation. The two schools of thought are: the less stringent epidemiological evidence school led by the WHO and the "no risk school" led by the US. The "no risk" philosophy cannot be adopted by many countries, especially developing countries, which cannot find financial resources for expensive treatment systems, but badly require wastewater for irrigation. Under the "no risk" scenario, the only options left for these countries would be, either no wastewater reuse or wastewater reuse (illegal) without any regard for the tough (and thus impractical) guidelines.

Differentiating between the potential risk and actual risk of contracting a disease is another issue in developing appropriate guidelines. The actual health risk depends on three more factors namely:

- time of survival of pathogens in water or soil,
- infective dose, and
- host immunity.

The risks to populations are dependent on the irrigation method used. Health risks from irrigated crops are greatest when spray or sprinkler irrigation is used, and the risk to field workers is greatest when flood or furrow irrigation is used. However, other potential sources of crop contamination should also be considered such as crop handling, transportation and the sale of products in unhygienic markets. Consumers can themselves make an important contribution to minimizing risks by, for instance, complying with sanitary standards in processing and using wastewater, i.e. by handling it on the basis of the information available. (Also see chapter 3.3)

2.2 Chemical parameters

In addition to biological parameters, regulations often include chemical parameters in order to protect human and environmental health, but also to provide for long-term soil productivity and functioning of irrigation schemes. Table 2 gives some examples of wastewater components' impacts in irrigational use.

In developing countries, salinity is usually the dividing line between water suited or unsuited for irrigation uses. High salt concentrations are an indication of highly concentrated wastewater, a factor typical for arid countries. Heavy metal concentrations are as a rule still relatively low in developing countries and are not yet responsible for any major problems. High salt concentrations in irrigation water hamper the water intake of crops and lead to yield losses for many crops. In addition, high sodium contents in loamy soils lower their permeability for water, which results in lower soil aeration. The consequences of these effects are also yield losses. In the case of high subsoil permeability, there is an additional risk of groundwater salinisation.

Another important aspect is wastewater nutrient content. Raw wastewater contains nitrogen, phosphate, and potassium in concentrations sufficient to cover or even exceed overall plant fertilization needs. The presence of trace elements and organic matter also favors plant growth and raises soil humus levels. These substantial advantages for farmers are offset in part by environmental risks consisting in the danger of nitrate-leaching. Other agro-biological risks are bound up with the fact that nitrogen can, in later phases of growth, have negative effects on plant growth. The nitrogen, however, stimulates undesirable algae growth on cultivated soils. Appropriate management methods are called for here. In table 2 the most important water quality parameters and their significance are listed.

Table 2: Physico-chemical parameters, their significance and approximate ranges for treated wastewater [SAR= Sodium adsorption ratio]

Parameter	**Significance**	**Approximate Range in Treated Wastewater**
Total Suspended Solids (TSS)	TSS can lead to sludge deposits and anaerobic conditions. Excessive amounts cause clogging of irrigation systems Measures of particles in wastewater can be related to microbial contamination, turbidity. Can interfere with disinfection effectiveness	< 1 to 30 mg/l
Organic indicators TOC Degradable Organics (COD, BOD)	Measure of organic carbon Their biological decomposition can lead to depletion of oxygen. For irrigation only excessive amounts cause problems. Low to moderate concentrations are beneficial.	1 – 20 mg/l 10 – 30 mg/l
Nutrients N,P,K	When discharged into the aquatic environment they lead to eutrophication. In irrigation they are beneficial, nutrient source. Nitrate in excessive amounts, however, may lead to groundwater contamination.	N: 10 to 30 mg/l P: 0.1 to 30 mg/l
Stable organics (e.g. phenols, pesticides, chlorinated hydrocarbons)	Some are toxic in the environment, accumulation processes in the soil.	
pH	Affects metal solubility and alkalinity and structure of soil, and plant growth.	
Heavy metals (Cd, Zn, Ni, etc.)	Accumulation processes in the soil, toxicity for plants	
Dissolved inorganics (TDS, EC, SAR)	Excessive salinity may damage crops. Chloride, Sodium and Boron are toxic to some crops, extensive sodium may cause permeability problems	

2.3 Restriction according to origin and use of wastewater

Apart from biological and chemical parameters, irrigation practice guidelines are used to minimize negative impacts of wastewater reuse in agriculture.

2.3.1 Crop restriction

Crop restriction is often practiced in conjunction with wastewater treatment so that lower quality effluents can be used to irrigate non-vegetable crops (see table 3).

Although this appears straightforward, in practice it is often difficult to enforce. It can only be done effectively where a public body controls the use of wastewater and laws providing for crop restricted are strictly enforced, where there is adequate demand for the crops allowed under crop restrictions and where there is little market pressure in favor of excluded crops (i.e. salad and other crops eaten uncooked). Crop restriction requires much less costly wastewater treatment and may be favored for this reason alone (but wastewater treatment engineers need to discuss this clearly with the appropriate regulatory agency and local farmers).

2.3.2 The irrigation technique

The irrigation technique can be chosen to reduce the amount of human exposure to the wastewater. In general, health risks are greatest when spray/sprinkler irrigation is used, as this distributes contamination over the surface of crops and exposes nearby population groups to aerosols containing bacteria and viruses (the opposite occurs with nematode eggs, which tend to be washed off during spray irrigation). This technique should be avoided where possible, and if used, stricter effluent standards apply (see table 3). Flood and furrow irrigation exposes field workers to the greatest risk, especially if earth moving is done by hand and without protection. Localized irrigation (inc. drip, trickle and bubbler irrigation) can give the greatest degree of health protection by reducing the exposure of workers to the wastewater. A period without irrigation before harvest (1-2 weeks) can allow die-off of bacteria and viruses such that the quality of irrigated crops improves to levels seen in crops irrigated with fresh water, as shown by Vaz da Costas Vargas et al. (1996). However, it is not practical in unregulated circumstances since farmers will probably not stop irrigation of leafy salad crops 5 days or more before harvest. Replacing partially-treated wastewater with fresh water for a week or so before harvest is not a reliable way of improving crop quality since re-contamination of the crops from the soil has been found to occur. Use of ending of irrigation before harvest is more feasible with fodder crops which do not need to be harvested at their freshest, and could enable the use of lower quality effluents.

Table 3: 1989 WHO guidelines for using treated wastewater in agriculture [a]

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

a In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.
b Ascaris and Trichuris species and hookworms.
c During the irrigation period.
d A more stringent guideline limit (□ 200 fecal coliforms/100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
e In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

2.3.3 Human exposure control

The groups potentially most at risk from wastewater reuse in agriculture are the farm workers, their families, crop handlers, consumers of crops, and those living near wastewater-irrigated areas. The approach required to minimize exposure depends on the target group. Farm workers and their families have higher potential risks of parasitic infections. Protection can be achieved by low-contaminating irrigation techniques, together with wearing protective clothing (e.g. footwear for farmers and gloves for crop handlers) and improving levels of hygiene both occupationally and in the home can help to control human exposure. Provision of adequate water supplies for consumption (to avoid consumption of wastewater) and for hygiene purposes (e.g. for hand washing) is important. Consumers can be protected by cooking vegetables, and by high standards of personal and food hygiene.

3. International Experiences in Formulating Guidelines

A comparison of international standards might help to develop guidelines for the reference area within each particular project. In many countries like USA and Spain only regional standards exist. A very limited number of European countries have guidelines or regulations on wastewater reclamation and reuse because first they usually do not need to reuse water and second their rivers have a sufficient dilution factor.

The US and Saudi Arabia have, in the context of their technical standards, set a number of individual limit values for microorganisms and chemicals. This type of differentiation was pioneered by California, which as early as 1918 undertook some initial efforts concerning the reuse of wastewater; and later, with the growth of technical potentials, the US further differentiated and tightened up these regulations, the final outcome being extremely low limit values (California State Water Code). These strict limit values have no grounds in medical science and take considerable effort to monitor and enforce. The 1989 WHO guidelines (see chapter 3.1) reflect this view.

Many developing countries focus on use restrictions in their legislation. Often, for example, such regulations ban wastewater irrigation for vegetables that can be eaten raw, or for edible plant parts in general, and require a minimum time interval between irrigation and crop harvest. The main problem with such use restrictions is that they cannot be monitored without functioning oversight agencies. The serious problems involved in monitoring use restrictions have led several countries, including Mexico (see chapter 3.4) and Tunisia (see chapter 4.1), to combine these two approaches: use restrictions plus easy-to-measure limit values for chemical and biological sum parameters (BOD_5 and COD) and micro-organisms, a practice that has given rise to a comprehensive and yet uncomplicated approach that, while doing justice to minimum safety needs, is still comprehensive enough to be generally conducive to the strategy of wastewater reuse.

3.1 WHO (1989)

The World Health Organization (WHO) has recognized both the potential and risk of untreated wastewater use and so has developed guidelines for policy makers attempting to legislate permission for the safe use of wastewater. In the 1989 guidelines (see table 4), the WHO acknowledged that most previous standards were unnecessarily high for public health protection and do not reflect reality of wastewater use on the ground. The WHO is currently revising their guidelines on wastewater reuse. Publication of the revised version is expected in 2004.

The main features of the 1989 WHO guidelines for wastewater reuse in agriculture are as follows:

- Wastewater is considered as a resource to be used, but used safely.
- The aim of the guidelines is to protect against excess infection in exposed populations (consumers, farm workers, populations living near irrigated fields).
- Fecal coliforms and intestinal nematode eggs are used as pathogen indicators.
- Measures comprising good reuse management practice are proposed alongside wastewater quality and treatment goals; restrictions on crops to be irrigated with wastewater; selection of irrigation methods providing increased health protection, and observation of good personal hygiene (including the use of protective clothing).
- The feasibility of achieving the guidelines is considered alongside desirable standards of health protection.

Many countries have welcomed the guidance from WHO standards and guidelines. France, for example, used a similar approach in setting guidelines, which were published in 1991. These are similar to those of WHO in defining analogous water categories (called A, B and C in the WHO guidelines; table 4) and microbiological limits, but complement them with strict rules of application. For example, for category A in the French guidelines, the quality requirement must be complemented by the use of irrigation techniques that avoid wetting fruit and vegetables, and for irrigation of golf courses and open landscaped areas, spray irrigation must be performed outside public opening hours.

As noted above, the WHO guidelines continue to be the benchmark target for decision makers in developing the wastewater recycling sector, however, as demonstrated, goals need to be in line with the capabilities of the country in question. Some countries have modified the microbiological criteria to suit local epidemiological and economic circumstances, as, for example, Mexico (see chapter 3.4)

3.2 FAO Guidelines for agricultural use (1985)

In contrast to the WHO guidelines that focus mainly on the protection of human and public health, the FAO has developed a field guide for evaluating the suitability of water for irrigation. Guideline values given identify potential problem water based on possible restrictions in use related to 1) salinity, 2) rate of water infiltration into the soil, 3) specific ion toxicity, or 4) to some other miscellaneous effects. The guide is intended to provide guidance to farm and project managers, consultants and engineers in evaluating and identifying potential problems related to water quality. It discusses possible restrictions on the use of the water and presents management options which may assist in farm or project management, planning and operation. Guiding values for salinity and other characteristics of wastewater are given in table 4. However, the FAO guidelines must be seen as orientation values that are in no way intended to replace case-to-case assessments.

Table 4: Guidelines for Interpretations of Water Quality for Irrigation *(adapted from University of California Committee of Consultants 1974)*

Potential Irrigation Problem				**Units**	**Degree of Restriction on Use**		
					None	**Slight to Moderate**	**Sever-e**
Salinity *(affects crop water availability)*[2]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]							
SAR	= 0 – 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)[4]						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)[5]			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5
	pH				**Normal Range 6.5 – 8.4**		

[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).
[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw. Adapted from Rhoades 1977 and Oster and Schroer 1979.
[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride.
[5] NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

me/l = milli equivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 milli mol/litre adjusted for electron charge. mg/l = milligram per litre ≈ parts per million (ppm).

3.3 US EPA (1992)

The US-Environmental Protection Agency (US-EPA) in their 1992 guidelines has recommended the use of much stricter standards for wastewater use in the USA, than those recommended by the WHO. The main guideline is that fecal coliforms should not exceed 14 MPN/100 ml in any sample, which in practice means not detectable. Secondary treatment should be used followed by filtration (with prior coagulant and/or polymer addition) and disinfection. In addition, the US-EPA guidelines set standards indicating the type of treatment required, the resultant water quality specifications, and the appropriate setback distances. The elements of the guidelines applicable to reuse in agriculture are summarized in table 5.

Table 5: US-EPA/USAID Guidelines for agricultural reuse of wastewater (adapted from suggested guidelines for water reuse *(US-EPA/USAID, 1992) [Source: EPA, Process Design Manual: Guidelines for Water Reuse, Cincinnati, Ohio, 1992: Report No. EPA-625/R-92-004]* [1]

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring
Urban Reuse All types of landscape irrigation (e.g. golf courses, parks, cemeteries).	• Secondary [2] • Filtration • Disinfection	• pH = 6-9 • ≤ 10 mg/l BOD • ≤ 2 NTU • No detectable FC/100 ml [3] • 1 mg/l Cl_2 residual (min.)	• pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl_2 residual -continuous
Agricultural Reuse – Food Crops Not Commercially Processed Surface or spray irrigation of any food crop, including crops eaten raw	• Secondary [2] • Filtration • Disinfection	• pH = 6-9 • ≤ 10 mg/l BOD • ≤ 2 NTU • No detectable FC/100 ml [3] • 1 mg/l Cl_2 residual (min.)	• pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl_2 residual -continuous
Agricultural Reuse – Food Crops Commercially Processed	• Secondary [2] • Disinfection	• pH = 6-9 • ≤ 30 mg/l BOD • ≤ 30 mg/l SS • ≤ 200 FC/100 ml [4] • 1 mg/l Cl_2 residual (min.)	• pH - weekly • BOD - weekly • SS - daily • Coliform - daily • Cl_2 residual -continuous
Types of Reuse	**Treatment**	**Reclaimed Water Quality**	**Reclaimed Water Monitoring**
Agricultural Reuse – Non Food Crops Pasture for milking animals; fodder, fiber and seed crops	• Secondary [2] • Disinfection	• pH = 6-9 • ≤ 30 mg/l BOD • ≤ 30 mg/l SS • ≤ 200 FC/100 ml [4] • 1 mg/l Cl_2 residual (min.)	• pH - weekly • BOD - weekly • SS - daily • Coliform - daily • Cl_2 residual -continuous

Legend: SS= suspended solids; FC= fecal coliforms

Footnotes:

1 These guidelines are based on water reclamation and reuse practices in the U.S., and they are especially directed at states that have not developed their own regulations or guidelines. While the guidelines should be useful in many areas outside the U.S., local conditions may limit the applicability of the guidelines in some countries.

2 Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and many stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and SS do not exceed 30 mg/l.

3 The number of fecal coliform organisms should not exceed 14/100 ml in any sample.

4 The number of fecal coliform organisms should not exceed 800/100 ml in any sample. Some stabilization pond systems may be able to meet this coliform limit without disinfection.

For irrigation of crops likely to be eaten uncooked, no detectable fecal coliforms/100 ml are allowed (compared to ≤ 1000 FC/100 ml for WHO), and for irrigation of commercially processed crops, fodder crops, etc, the guideline sets ≤ 200 FC/100 ml (where only a nematode egg guideline is set by WHO). No nematode egg guideline is specified by US-EPA. Actual standard setting is the responsibility of individual states in the USA, and different US-States take different approaches (some specify treatment processes, others specify water quality standards) and a range of standards are in use. Standards in several countries have been influenced by American standards, especially the Californian standards.

3.4 Mexico (1996)

In Mexico, microbiological and chemical standards for wastewater reuse in agriculture have developed considerably over the last 15 years. Existing guidelines were reviewed in 1991, 1993, and again in 1996. Particular attention was paid to (1) the cultivation of vegetables and other crops eaten raw, (2) the importance of wastewater reuse in agriculture as a form of wastewater treatment and disposal, and (3) the diversity of treatment processes available to achieve the guidelines.

The final revision of the microbiological standards occurred in 1996, resulting in the introduction of NOM-001-ECOL-1996 (see table 6) "that establishes the maximum permissible limits of contaminants in wastewater to be discharged into national waters and onto national soil". As in the WHO guidelines, fecal coliforms are used as the indicator to determine pathogenic contamination. The maximum allowable limit in wastewater discharges to national water or property, as well as wastewater application to soils (for agricultural irrigation) is 1,000 and 2,000 (most probable number, MPN) of fecal coliforms per 100 ml, for monthly average and daily average, respectively. To determine parasitic contamination, helminth eggs are used as the indicator. The maximum allowable limit in wastewater application to soils (for agricultural irrigation) is one helminth egg per liter for restricted irrigation, and five helminth eggs per liter for unrestricted irrigation, following the technique established in annex 1 of these regulations.

Table 6: Mexican Standard NOM-001-ECOL-1996 governing wastewater reuse in Agriculture

Irrigation	Fecal Coliforms /100 ml (MPN)	Helminth eggs/liter
Restricted	1000_{m} - 2000_{d}	≤ 5
Unrestricted	1000_{m} - 2000_{d}	≤ 1

(m=monthly mean, d=daily mean, MPN=most probable number)
Note: Unrestricted irrigation is defined as permitting irrigation of all crops, whilst restricted irrigation excludes salad crops and vegetables that are eaten raw.

The new standard, with a single set of parameter limits regardless of the discharge source, was designed to be achievable with the technology and resources available at present and in the near future in Mexico and to be more realistically policed, by reducing the amount of monitoring required. The limits imposed within the standard were designed to be sufficient to protect "at-risk" groups according to currently available literature. Revision of many of the possible treatment processes resulted in the proposed microbiological standards. A stricter helminth standard would have required conventional treatment plants to use filters and this would have carried significant financial implications.

The concentration of basic contaminants, heavy metals and cyanides in wastewater discharges to national water or property, may not exceed the value indicated as the maximum allowable limit in annex tables 2 and 3 of these regulations. The allowable range for pH is 5 to 10 units.

3.5 Recommendations to review WHO standards (2000)

Blumenthal et al. recommend a review of the current WHO guidelines. They base their recommendation on their appraisal of recent research evidence based on a combined approach using empirical epidemiological studies supplemented by microbiological studies of the transmission of pathogens in conjunction with a model-based quantitative risk assessment for selected pathogens.

Their research leads to the conclusion that for unrestricted irrigation, there is no evidence to suggest a need to revise the fecal coliform guideline limit of ≤ 1000 fecal coliform bacteria/100 ml. However, there is epidemiological evidence that the guideline limit for nematode eggs (≤ 1 egg/l) is not adequate in conditions that favor the survival of nematode eggs (lower mean temperatures and the use of surface irrigation), and it needs to be revised to ≤ 0.1 egg/l in these conditions. For restricted irrigation, there is evidence to support the need for a guideline limit for exposure to fecal coliform bacteria to protect farm workers, their children and nearby populations from enteric viral and bacterial infections. The appropriate guideline limit will depend on which irrigation method is used and who is exposed. For example, if adult farm workers are exposed to spray or sprinkler irrigation, a guideline limit of ≤ 10^5 fecal coliform bacteria/ 100 ml is necessary. A reduced guideline limit of ≤ 10^3 fecal coliform bacteria/100 ml is warranted when adult farm workers are engaged in flood or furrow irrigation and when children under age 15 are regularly exposed through work or play. Where there are insufficient resources to meet this stricter guideline limit, a guideline limit of ≤ 10^5 fecal coliform bacteria/100 ml should be supplemented by other health protection measures. The guideline limit for nematode eggs (≤ 1 egg/l) is adequate if no children are exposed, but a revised guideline limit of ≤ 0.1 egg/l is recommended if children are in contact with wastewater or soil through irrigation or play. The evidence reviewed does not support the need for a separate specific guideline limit to protect against viral infections, and there was insufficient evidence to support the need for a specific guideline limit for parasitic protozoa.

Therefore, Blumenthal et al. suggest revised microbiological guidelines for treated wastewater use in agriculture as shown in table 7.

Table 7: Recommended revised microbiological guidelines for treated wastewater use in agriculture [a]

Category	Reuse Conditions	Exposed group	Irrigation technique	Intestinal nematodes [b] (arithmetic mean no of eggs per liter [c])	Fecal coliforms (geometric mean no per 100 ml [d])	Wastewater treatment expected to achieve required microbiological quality
A	*Unrestricted irrigation* A1 Vegetable and salad crops eaten uncooked, sports fields, public parks [e]	Workers, consumers, public	Any	≤ 0.1[f]	≤ 10^3	Well designed series of waste stabilization ponds (WSP), sequential batch-fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration and disinfection)
B	*Restricted irrigation* Cereal crops, industrial crops, fodder crops, pasture and trees [g]	B1 Workers (but no children <15 years), nearby communities	(a) Spray/ sprinkler	≤ 1	≤ 10^5	Retention in WSP series inc. one maturation pond or in sequential WSTR or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration)
		B2 As B1	(b) Flood/ furrow	≤ 1	≤ 10^3	As for Category A
		B3 Workers including children < 15 years, nearby communities	Any	≤ 0.1	≤ 10^3	As for Category A
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Trickle, drip or bubbler	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.

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

[b] Ascaris and Trichurisspecies and hookworms; the guideline limit is also intended to protect against risks from parasitic protozoa.

[c] During the irrigation season (if the wastewater is treated in WSP or WSTR which have been designed to achieve these egg numbers, then routine effluent quality monitoring is not required).

[d] During the irrigation season (feca coliform counts should preferably be done weekly, but at least monthly).

[e] A more stringent guideline limit (4200 fecal coliforms/100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

[f] This guideline limit can be increased to 41 egg/l if (i) conditions are hot and dry and surface irrigation is not used or (ii) if wastewater treatment is supplemented with anthelmintic chemotherapy campaigns in areas of wastewater reuse.

[g] In the case of fruit trees, irrigation should stop two weeks before fruit is picked, and no fruit should be picked off the ground. Spray/sprinkler irrigation should not be used.

Wastewater treatment technologies suitable for meeting the revised microbiological guidelines for agriculture include the use of waste stabilization ponds (WSP), wastewater storage and treatment reservoirs (WSTR), or conventional treatment processes. When using WSP, the revised guidelines usually require the use of 1 or more maturation ponds after the anaerobic and facultative ponds. Use of sequential batch-fed storage and treatment reservoirs can be designed to meet the guidelines for unrestricted and restricted irrigation. When conventional treatment processes are used secondary treatment, filtration and disinfection are often needed to meet the revised guidelines. The cost and difficulty in operating and maintaining conventional treatment plants to the level needed to meet the guidelines means that they are not recommended where WSP and WSTR can be used.

4. Regional Experiences in Formulating Guidelines

In most of the countries of the Mediterranean region, wastewater is widely reused at different extents within planned or unplanned systems. However, only few Mediterranean countries (such as Cyprus, Jordan, and Tunisia) have included water reuse in their water resources planning and have official policies calling for water reuse. Regarding the EM-Water countries, legal standards for wastewater reuse have only been adopted in Jordan and Turkey. The Palestinian Water Authority has developed guidelines for wastewater reuse, but these have not yet been enforced. In Lebanon, no specific guidelines for the reuse of wastewater have yet been developed, but are envisaged for the future. This delay can be explained by the fact that Lebanon is not as much suffering from water shortage as are other MEDA countries.

4.1 Tunisia (1989)

Irrigation with recycled wastewater is well established in Tunisia. The Tunisian government is pursuing wastewater reuse in agriculture as a strategic objective and is translating the objective into systematic practice. A wastewater reuse policy was launched at the beginning of the eighties.

Wastewater reuse in agriculture is regulated by the 1975 Water Code (law No. 75-16 of 31 March 1975), by the 1989 Decree No. 89-1047 (28 July 1989), by the Tunisian standard for the use of treated wastewater in agriculture (NT 106- 003 of 18 May 1989), by the list of crops than can be irrigated with treated wastewater (Decision of the Minister of Agriculture of 21 June 1994) and by the list of requirements for agricultural wastewater reuse projects (Decision of 28 September 1995). They prohibit the irrigation of vegetables that might be consumed raw. Therefore, most of the recycled wastewater is used to irrigate vineyards, citrus and other trees (olives, peaches, pears, apples, pomegranates, etc.), fodder crops (alfalfa, sorghum, etc), industrial crops (cotton, tobacco, sugar beet, etc), cereals, and golf courses (Tunis, Hammamet, Sousse, and Monastir). Some hotel gardens in Jerba and Zarzis are also irrigated with recycled wastewater.

In Tunisia, regulation of wastewater reuse in agriculture mainly relies on use restrictions. For instance, it has banned irrigation with wastewater (treated or untreated) for vegetables that are eaten uncooked. The same applies for heavily used pastures. These restrictions on allowed uses are supplemented by biological and chemical sum limit values (BOD5, COD, organic substances) and limit values for nematode eggs. Tunisia continues to permit wastewater irrigation for golf links, public parks, and the like, i.e. mainly for areas and crop types that pose little risk to consumers since the plants in question are not consumed or the crops do not come into direct contact with the wastewater used.

The 1989 decree stipulates that the use of recycled wastewater must be authorized by the Minister of Agriculture, in agreement with the Minister of Environment and Land Use Planning, and the Minister of Public Health. It sets out the precautions required to protect the health of farmers and consumers, and the environment. Monitoring the physical-chemical and biological quality of recycled wastewater and of the irrigated crops is planned: analyses of a set of physical-chemical parameters once a month, of trace elements once every 6 months, and of helminth eggs every two weeks on 24h composite samples, etc. In areas where sprinklers are used, buffer areas must be created. Direct grazing is prohibited on fields irrigated with wastewater.

Specifications determining the terms and general conditions of recycled wastewater reuse, such as the precautions that must be taken in order to prevent any contamination (workers, residential areas, consumers, etc.), have been published. The Ministries of Interior, Environment and Land Planning, Agriculture, Economy and Public Health are in charge of the implementation and enforcement of this decree. It is interesting to note that in Tunisia, the farmers pay for the treated wastewater they use to irrigate their fields.

However, in Tunisia, where the legal, technical, and political framework for reuse is relatively favorable, only 20% of treatment plant outflows are reused. The low motivation of farmers to reuse wastewater is in fact reported to be the main obstacle to increasing the current level of reused water. One of the most important reasons for this is the legal restriction concerning the use of wastewater to irrigate vegetables. Since vegetables are the most profitable and most easy-to-market crops in Tunisia, this legal restriction is sufficient to explain the slow rate of adoption by farmers.

4.2 Turkey (1991)

Water reuse was officially legitimized in 1991 through the regulation for irrigational wastewater reuse issued in by the Ministry of Environment. According to the "Water Pollution Control Regulations", in order to use treated wastewater in irrigation, a written permission from concerned government organisations must be obtained. A commission organized by the State Water Organisation, İller Bank and Agriculture Ministry and Environmental and Forest Ministry will decide whether the effluent can be used in irrigation or not.

The effluent quality criteria for irrigation according to the Turkish Water Pollution Control Regulations are given in the following tables. In general, the WHO standards have been adopted except the limits for the intestinal nematodes and the residual chlorine. Concerning the microbiological standards, the Turkish regulation seems unsufficient and needs to be revised according to the actual discussions (as mentioned before).

Boron concentrations are particularly important for Turkish conditions because Turkey is rich in terms of boron sources. Therefore water for irrigation is separately classified with respect to their boron concentrations which is not named expressively here.

Table 8: Maximum Concentrations of Toxic Elements in Effluents for Irrigation

Elements	**Max. Concentration (mg/l)**	**Elements**	**Max. Concentration (mg/l)**
Aluminium (Al)	5.0	Lead (Pb)	5.0
Arsenic (As)	0.1	Lithium (Li)	2.5
Beryllium (Be)	0.1	Manganese (Mn)	0.2
Cadmium (Cd)	0.01	Molybdenum (Mo)	0.01
Chromium (Cr)	0.1	Nickel (Ni)	0.2
Cobalt (Co)	0.05	Selenium (Se)	0.02
Copper (Cu)	0.2	Vanadium (V)	0.1
Fluorine (F)	1.0	Zinc (Zn)	2.0
Iron (Fe)	5.0		

Table 9: Effluent Quality Criteria for Irrigation

Effluent quality criteria	First class effluent (very good)	Second class effluent (good)	Third class effluent (usable)	Fourth class effluent (usable by care)	Fifth class effluent (can not be used)
EC25 * 10^6 (umhos/cm)	0.250	250-750	750-2000	2000-3000	>3000
Sodium percent (Na%)	<20	20-40	40-60	60-80	>80
Sodium absorption range	<10	10-18	18-26	<26	
Sodium carbonate residual					
meq/l	<1.25	1.25-2.5	>2.5	12-20	
mg/l	<66	66-133	>133	625-710	
Chloride (Cl)					
meq/l	0-4	4-7	7-12	12-20	>20
mg/l	0-142	142-249	249-426	626-710	>710
Sulfide (SO_4)					
meq/l	0-4	4-7	7-12	12-20	>20
mg/l	0-192	192-336	336-575	576-960	>960
Total salts mg/l	0-175	175-525	525-1400	1400-2100	>2100
Boron[1] concentration mg/l	0-0.5	0.5-1.12	1.12-2.0	2.0	-
NO_3 or NH^+_4	0-5	5-10	10-30	30-50	>50
Fecal coliforms (in 100 ml)	0-2	2-20	20-102	102-103	>103
BOD_5 (mg/l)	0-25	25-50	50-100	100-200	>200
Suspended solids mg/l	20	30	45	60	>100
pH	6.5-8.5	6.5-8.5	6.5-8.5	6-9	<6 or >9
Temperature ºC	30	30	35	40	>40

[1] With respect to Boron concentration there is even a more detailed classification of irrigation waters

4.3 Jordan (2002)

The key policy objectives of the Jordan water reuse management plan are to use reclaimed water, where practical, in exchange for present and future use of freshwater and to maximize the returns from reclaimed water resources. Therefore, the Government of Jordan has imposed that all new wastewater treatment projects must include feasibility aspects for wastewater reuse and has set standards for treated domestic wastewater effluent (Jordanian Standards JS 893/1995 revised in 2002).

Table 10: Allowable Limit for properties and criteria for reuse in irrigation

Allowable limits per end use				
Parameter	**Unit**	**Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits**	**Fruit Trees, Sides of Roads outside city limits, and landscape**	**Field Crops, Industrial Crops and Forest Trees**
		A	B	C
Biological Oxygen Demand	mg/l	30	200	300
Chemical Oxygen Demand	mg/l	100	500	500
Dissolved Oxygen	mg/l	>2	-	-
Total suspended solids	mg/l	50	150	150
pH	unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70
Escherishia Coli	Most probable number or colony forming unit/ 100ml	100	1000	-
Intestinal Helminthes Eggs	Egg/l	< or =1	< or =1	< or =1

Standard: http://www.mwi.gov.jo/main%20topics/Standards/js893-master.htm

The Jordanian standards for wastewater reuse are based on reuse categories depending on crops/ areas to be irrigated. The standard prohibits using reclaimed water for irrigating vegetables that are eaten uncooked (raw). Further, it is prohibited to use sprinkler irrigation except for irrigating golf courses. In the latter case, irrigation should take place at night and sprinklers must be movable and not accessible for day use. When using reclaimed water for irrigating fruit trees, irrigation must be stopped two weeks prior to fruits harvesting and any falling fruits in contact with the soil must be removed.

In addition, the Jordanian standards provide values for a range of chemical wastewater components that are considered for guidance only. In case of exceeding these values, the end user must carry out scientific studies to verify the effect of that water on public health and the environment and suggest ways and means to prevent damage to either.

Table 11: Guidelines for Reuse in Irrigation

Fat And grease	FOG	mg/l	8
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	100
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	$T\text{-}PO_4$	mg/l	30
Chloride	Cl	mg/l	400
Sulfate	SO_4	mg/l	500
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	230
Magnesium	Mg	mg/l	100
Calcium	Ca	mg/l	230
Sodium Adsorption Ration	SAR	-	9
Aluminum	Al	mg/l	5
Arsenic	As	mg/l	0.1
Beryllium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2
Fluoride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5(0. 075 for citrus crops)
Manganese	Mn	mg/l	0.2
Molybdenum	Mo	mg/l	0.01
Nickel	Ni	mg/l	0.2
Lead	Pb	mg/l	5.0
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.1
Mercury	Hg	mg/l	0.002
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

4.4 Recommended for Gaza (2002)

Although reclaimed wastewater reuse for agriculture is increasingly being recognized as an essential component in the management strategy for water shortage in the neighboring countries, such practice is still not officially followed for agriculture in Gaza Strip. There is now a master plan introduced by donor countries to construct three new WWTPs in Gaza Strip to replace the existing ones by the year 2020. Most of the reclaimed wastewater produced from these plants would be suitably managed for use in irrigation.

Environmental Limit Values for reuse of wastewater have been prepared by the Palestinian Standards Institute and the Palestinian Water Authority. However, these limit values have not been enforced so far. The draft Palestinian standards include quality standards for reuse of treated wastewater depending on the crops and areas to be irrigated. They further stipulate that some best practices have to be adopted when reusing wastewater. These include:

- Irrigation has to be stopped two weeks before harvesting period when treated wastewater used for productive crops and field crops, for animal feeding crops before grazing and falling products or that close to the ground has to be excluded.
- Sprinkler irrigation is prohibited.
- Use of treated wastewater is forbidden for irrigation of all vegetables
- Closed pipes have to be used when wastewater transported in areas with high soil permeability, which can affect the aquifer or surface water, used for drinking.
- Dilution of treated water, to meet the requested quality by mixing with fresh water in the treatment plant is forbidden.

Table 12: Recommended Guidelines by the Palestinian Standards Institute for Treated Wastewater Characteristics according to different applications

Quality Parameter (mg/l except otherwise indicated)	Fodder Irrigation		Gardens, Playgrounds, Recreational	Industrial Crops	Groundwater Recharge	Seawater Outfall	Landscapes	Trees	
	Dry	Wet						Citrus	Olive
BOD_5	60	45	40	60	40	60	60	45	45
COD	200	150	150	200	150	200	200	150	150
DO	> 0.5	> 0.5	> 0.5	> 0.5	> 1.0	> 1.0	> 0.5	> 0.5	> 0.5
TDS	1500	1500	1200	1500	1500	-	1500	1500	500
TSS	50	40	30	50	50	60	50	40	40
pH	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Color (PCU)	Free	Free	Free	Free	Free of colored matter	Free of colored matter	Free	Free	Free
FOG	5	5	5	5	0	10	5	5	5
Phenol	0.002	0.002	0.002	0.002	0.002	1	0.002	0.002	0.002
MBAS	15	15	15	15	5	25	15	15	15
NO_3-N	50	50	50	50	15	25	50	50	50
NH_4-N	-	-	50	-	10	5	-	-	-
O.Kj-N	50	50	50	50	10	10	50	50	50
PO_4-P	30	30	30	30	15	5	30	30	30
Cl	500	500	350	500	600	-	500	400	400
SO_4	500	500	500	500	1000	1000	500	500	500
Na	200	200	200	200	230	-	200	200	200
Mg	60	60	60	60	150	-	60	60	60
Ca	400	400	400	400	400	-	400	400	400
SAR	9	9	10	9	9	-	9	9	9
Residual Cl_2	-	-	-	-	-	-	-	-	-

Table 12 (continued):

Quality Parameter (mg/l except otherwise indicated)	**Fodder Irrigation**		**Gardens, Playgrounds, Recreational**	**Industrial Crops**	**Groundwater Recharge**	**Seawater Outfall**	**Landscapes**	**Trees**	
	Dry	**Wet**						**Citrus**	**Olive**
Al	5	5	5	5	1	5	5	5	5
Ar	0.1	0.1	0.1	0.1	0.05	0.05	0.01	0.01	0.01
Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
F	1	1	1	1	1.5	-	1	1	1
Fe	5	5	5	5	2	2	5	5	5
Mn	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pb	1	1	0.1	1	0.1	0.1	1	1	1
Se	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	2.0	2.0	2.0	2.0	5.0	5.0	2.0	2.0	2.0
CN	0.05	0.05	0.05	0.05	0.1	0.1	0.05	0.05	0.05
Cr	0.1	0.1	0.1	0.1	0.05	0.5	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Co	0.05	0.05	0.05	0.05	0.05	1.0	0.05	0.05	0.05
B	0.7	0.7	0.7	0.7	1.0	2.0	0.7	0.7	0.7
FC (CFU/100 ml)	1000	1000	200	1000	1000	50000	1000	1000	1000
Pathogens	Free	Free	Free	Free	Free	Free	Free	Free	Free
Amoeba & Gardia (Cyst/L)	-	-	Free	-	Free	Free	-	-	-
Nematodes (Eggs/L)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

(-) Undefined

4.5 Recommended Mediterranean (2003)

Common guidelines on water reuse in all Mediterranean countries have been proposed by Bahri and Brissaud (2002). These guidelines have been developed under a project funded by UNEP/WHO and have been presented in various meetings. These are based on the consideration that: (a) an agricultural Mediterranean market is developing with large amounts of agricultural products (vegetables, fruits, etc) imported and exported among Europe and other Mediterranean countries; (b) tourism is an essential part of the economic activity of the region; its development might be jeopardized in the long term by disease outbreaks linked to wastewater mismanagement; (c) there is a growing concern of consumers about the food quality and health hazards; (d) unfair competition among farmers should be avoided. These guidelines have been prepared making a large use of the results of the recent assessment of the WHO guidelines by Blumenthal et al., (2000).

However, contemplating to set up Mediterranean guidelines raises three questions:

(a) how to derive health guidelines for water reuse, which would be applicable in many different settings of the Mediterranean Region, in economically less developed countries as well as in industrialized ones?
(b) can uniform water reuse guidelines be realistically enforced in every country of the region ?
(c) does the actual knowledge allow a definitive position regarding the limits to be set up?

In addition, it should be noticed that:

(a) populations of the North and South banks are both exposed to contamination of food and the environment,
(b) guidelines provide a reasonable health protection defined through either the concept of "no measurable excess risk of infection attributable to wastewater reuse" or an acceptable maximum annual risk, and
(c) guidelines are not unnecessarily too stringent, i.e. too costly with regard to the risk reduction.

As non potable reuse will long remain the goal of the large majority of the reuse projects, these draft guidelines for domestic water reuse for the Mediterranean Region are focused on the microbiological hazards. Four categories of recycled water uses are considered (see table 13):

Category I: urban and residential reuses, landscape and recreational impoundments.
Category II: unrestricted irrigation, landscape impoundments (contact with water not allowed), and industrial reuses.
Category III: restricted agricultural irrigation.

Category IV: irrigation with recycled water application systems or methods (drip, subsurface, etc) providing a high degree of protection against contamination and using water more efficiently.

Table 13: Proposed Mediterranean guidelines

	Quality criteria			
	Microbiological			
Water category	**Intestinal nematode (a) (No. eggs per liter)**	**FC or *E. coli* (b) (cfu/ 100 ml)**	**Physical-chemical SS (c)) (mg/L)**	**Wastewater treatment expected to meet the criteria**
Category I				
a) Residential reuse: private garden watering, toilet flushing, and vehicle washing. b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, fire-fighting, fountains, and other recreational places. c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).	≤0.1(h)	≤200 (d)	≤10	Secondary treatment + filtration + disinfection
Category II				
a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed. c) Industrial reuse (except for food industry).	≤0.1(h)	≤1000 (d)	≤20 ≤150 (f)	Secondary treatment or equivalent (g)+ filtration + disinfection or Secondary treatment or equivalent (g)+ either storage or well-designed series of maturation ponds or infiltration percolation

Table 12 (continued):

	Quality criteria			
	Microbiological			
Water category	**Intestinal nematode (a) (No. eggs per liter)**	**FC or *E. coli* (b) (cfu/ 100 ml**	**Physical-chemical SS (c)) (mg/L)**	**Wastewater treatment expected to meet the criteria**
Category III				
Irrigation of cereals and oleaginous seeds, fiber, & seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated)(e), plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.	≤1	None required	≤35 ≤150 (f)	Secondary treatment or equivalent (g)+ a few days storage or Oxidation pond systems
Category IV				
a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practices (such as plastic mulching, support, etc.) guaranteeing absence of contact between reclaimed water and edible part of vegetables. b) Irrigation of crops in category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface). c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public. d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.	None required	None required	Pretreatment as required by the irrigation technology, but not less than primary sedimentation	

The proposed Mediterranean guidelines are minimum requirements which should constitute the basis of water reuse regulations in every country of the region. Wealthy countries might wish higher protection. Due to late development of wastewater treatment in several countries, all of them cannot be expected to comply with the guidelines within the same delay. However, every country could commit itself to reach the guidelines within a delay depending on its current equipment and financial capacities.

5. Guiding questions

When wastewater reuse guidelines are formulated, the local conditions always have to be considered (existing treatment facilities, agricultural practices, hygienic standards, climate, etc.).

Please discuss the following questions **in the Forum**, important for the formulation of regional wastewater reuse guidelines in the Mediterranean.

- Is wastewater reuse already common practice in your country?
- Which are the main obstacles against wastewater reuse?
- What types of wastewater reuse are most relevant / mainly applied in your country?
- How is the wastewater usually treated before reuse?
- Which crops are mainly irrigated with reclaimed water?
- If wastewater reuse guidelines exist in your country, is the common practice inline with these guidelines, and how is the compliance monitored?
- For the policy for wastewater reuse in irrigation, there are two different possibilities:
    (a) To choose different categories such as restricted or unrestricted irrigation, crops eaten raw or not, sport fields etc., with different water quality requirements. The control of the water quality is then more difficult and misuse not easy to discover.
    (b) To have restrictive standards, so that the treated wastewater can be used for irrigation everywhere. If quality requirements are not stringent enough, irrigation methods should be prescribed, which don't produce aerosols, and irrigation with treated wastewater has to be stopped for a determined period before harvesting.
- Which option do you regard as more appropriate for the Mediterranean region?
- What parameters do you consider most important to be reflected / regulated in Mediterranean wastewater reuse guidelines?
- What standards are economically and administratively enforceable in your country?

6. References

This lesson mainly draws on four Country Studies (Jordan, Palestine, Lebanon and Turkey) compiled within the EMWater project and the following literature:

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