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Protection of Jeita Spring

SPECIAL REPORT NO. 4

**Proposed National Standard
for Treated Domestic Wastewater Reuse
for Irrigation**

Ballouneh
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Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation

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Abbreviations

AOX	organic halogen compounds
BOD	biological oxygen demand
cfu	colony forming units
COD	chemical oxygen demand
DALY	disability-adjusted life years
DO	dissolved oxygen
DW	dry weight
EDC	endocrine disrupting compound
FC	faecal coliforms
FOG	Fat, oil and grease
HACCP	hazard analysis critical control point
MPN	most probable number
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenols
PCDD/F	polychlorinated dibenzodioxins and – furans
PE	person equivalents
PhAC	pharmaceutically active compound
SAR	sodium adsorption ratio
SAT	soil aquifer treatment
TC	total coliforms
TDS	total dissolved solids
TEq	TCDD (tetrachlorinated dibenzodioxin) equivalents
TOC	total organic carbon
TSS	total suspended solids
WFD	water framework directive (EU)
WWTP	wastewater treatment plant

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Executive Summary

Water resources protection is the main aim for the establishment of wastewater facilities. However, in many cases the planning of wastewater facilities does not sufficiently integrate all geoscientific aspects relevant for their protection. In karst areas, such as prevalent in Lebanon, regulations concerning wastewater treatment and reuse need to be much more stringent than in other areas because of the high risk of groundwater contamination.

The proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation specifically addresses those issues, which have to be considered for the protection of karst aquifers when applying treated wastewater reuse.

A Best Management Practice Guideline for Wastewater Facilities in Karstic Areas of Lebanon had been prepared in the framework of the German-Lebanese Technical Cooperation Project *Protection of Jeita Spring* in March 2011 (STEINEL & MARGANE, 2011). This document gives recommendations concerning the potential impact of wastewater facilities on water resources with regards to:

- site selection and design process for wastewater treatment plants, collector lines and effluent discharge points
- selection of the optimal treatment method
- criteria for wastewater reuse
- criteria for sludge management
- monitoring of the treated wastewater effluent, sludge quality and effects of wastewater reuse and sludge application

The above mentioned report contains a comparison of international and regional guidelines and technical details concerning treated wastewater reuse.

Simultaneously a draft guideline for wastewater reuse and sludge reuse had been prepared by the Ministry of Energy and Water within the framework of technical support by FAO (2010). However, this document was based mainly on aspects related to safe agricultural production without taking into account the specific conditions in Lebanon, especially the high pollution risk and the fast transfer of pollution in karst aquifers currently mainly originating from infiltration of untreated wastewater into the groundwater.

Under the conditions prevailing in Lebanon it is recommended to allow the application of treated domestic wastewater reuse for irrigation only in areas where the vulnerability of the aquifer to pollution is low so that treated wastewater would not directly or indirectly infiltrate into the groundwater and cause pollution. Moreover treated domestic wastewater reuse depends on the type and characteristics of the soil. If treated domestic wastewater is applied in large quantities, soil salinity may increase and cause a massive reduction in soil fertility.

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For this reason the herewith proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation had to bring together both proposals and includes the following recommendations:

- Treated industrial wastewater and treated domestic wastewater containing a large share (> 10%) of industrial or commercial wastewater, should not be reused for irrigation.
- Domestic wastewater reuse classes should not only, as proposed by FAO, be based on health concerns, but also on the hydrogeological and soil characteristics of the area. Wastewater reuse application in karst areas (Mount Lebanon and Anti-Lebanon mountain ranges) bears a severe pollution risk while the Bekaa Valley (as a non-karstic area) is generally more suitable for reuse. Detailed groundwater vulnerability maps are needed for Lebanon, which should form the basis for reuse decisions. Over the past few decades vast experience with such maps has been gained in the region (MARGANE, 2003).
- Establishment of wastewater treatment facilities is still in the beginning in Lebanon. A large number of wastewater facilities are currently in planning. However, in order to achieve the optimum protection of the water resources in Lebanon, the option of treated wastewater reuse must be agreed upon with the potential users before the planning of a wastewater facility starts. Its must be known already during the design phase of a wastewater treatment facility which treatment level needs to be achieved in order to be able to reuse reclaimed water safely. Treated wastewater will often have to be pumped to the irrigation area so that treatment for reuse in agriculture will be significantly more costly.
- Also public awareness at the farmers level is needed in order to provide an agricultural production which is safe for human consumption. Moreover the safety of farm workers and neighbors of farms needs to be taken into consideration.
- The proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation can only become effective when it is truly implemented. The monitoring of treated wastewater quality, regardless whether wastewater will be reused or discharged into rivers or the sea, is very important in order to provide that no pollution will occur. However, this monitoring will require a massive increase in laboratory capacities, which needs to be planned for now.
- The government agency responsible for the operation of the treatment plant should also be responsible for the monitoring of treated wastewater reuse. All impacts of treated domestic wastewater reuse for irrigation on soil, groundwater and humans have to be monitored regularly.

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1 Introduction

Clean water is vital to the survival and growth of all life and all economic and environmental processes. In Lebanon, water demand is bound to increase due to population growth (2.5 %) and increase in living standard. In contrast, water supply is likely to decrease due to climate change, overexploitation and pollution. It is therefore paramount to protect existing water resources from contamination and increase the use of alternative water resources as new conventional water resources will not become available. The main pollution to water resources in Lebanon results from diffuse pollution from wastewater infiltration through cesspools and septic tanks.

Karst aquifers are commonly characterised by high heterogeneity and anisotropy. In mature karst areas, rapid infiltration and high flow velocities are commonplace. Contaminants can easily infiltrate into karst aquifers through sinkholes and other epikarst features and spread rapidly over large distances in the conduit network. Because of the absence of a significant soil cover or low permeability layer covering the karst, the natural attenuation of pollutants is commonly very low. Hence pollution is not treated in the groundwater system but only transferred. These facts make karst aquifers extremely vulnerable to groundwater contamination (Fig. 1).

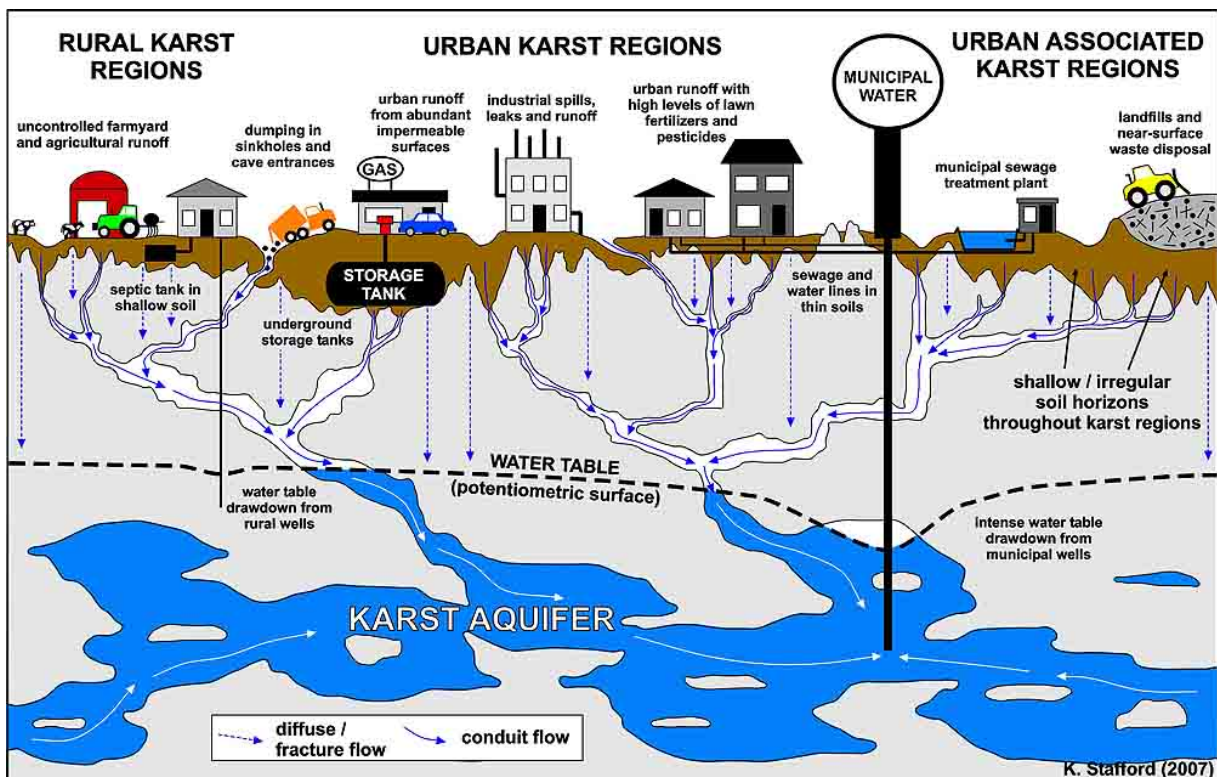


Fig. 1: Potential sources of contamination of groundwater and drinking water supplies due to rural and urban activities (from karstcentral.org).

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Karst aquifers can only effectively be protected by adopting a very restrictive approach in landuse planning. Groundwater vulnerability maps are commonly used to assist decision makers in the landuse planning process and delineation of groundwater protection zones. The establishment of activities potentially hazardous to the groundwater, such as treated wastewater or sludge reuse, should not be allowed in areas where the natural protection of the aquifer is low, i.e. where the groundwater vulnerability is high. On the other hand such activities may be allowed in areas of low groundwater vulnerability.

A variety of methods for groundwater vulnerability mapping has been developed and also applied in the region. Recommendations for application of such methods in the Arab region have been given by Margane (2003). Recommended methods for karst areas are:

- EPIK (SAEFL, 2000),
- PI (Goldscheider, 2002),
- COP (Vias et al., 2002).

It is recommended to use groundwater vulnerability maps to define areas where application of treated wastewater reuse or sludge reuse could be allowed.

2 Risks Associated with Wastewater Constituents

Wastewater can contain a range of contaminants at different levels in relation to the source. **Health risks originating from treated wastewater depend on the level and quality of treatment.** Concerning domestic wastewater, faeces contain high levels of pathogens and should be handled accordingly. Industrial wastewater that contains high levels of heavy metals and/or organic pollutants **should be treated at the industrial site and not mixed with domestic wastewater**, as it will require special treatment and would impair the treatment effectiveness of conventional wastewater treatment plants. Industrial wastewater should not be reused for irrigation. The type and long-term stability of the treatment process significantly influences the quality of the treated wastewater.

Health risks arising from domestic wastewater are related to microorganisms that can lead to diseases by ingestion or contact. Pathogens of concern are classified as virus, bacteria, protozoa and helminth (Table 1):

- Viruses are the smallest pathogens and include highly contagious enteroviruses (polio, echo, coxsackie), hepatitis A and E, and a range of viruses causing diarrhea and gastroenteritis. Due to their small size, they are able to pass filtration devices and can be detected in drinking water, even after disinfection.
- Bacteria are the most common and numerous pathogens including harmless and pathogenic coliforms, salmonella, shigella, and enterococci. They cause classical waterborne diseases like typhoid, dysentery, cholera and other gastrointestinal illnesses.
- Protozoan pathogens are single-celled eukaryotic parasites, which survive as cysts outside their host, the most common being *Giardia lamblia* and *Cryptosporidium*

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parvum. They can be inactivated using UV-radiation but are fairly resistant to chlorination.

- Helminths are common intestinal parasites including nematode, tape worms, hook worms, round worms and whip worms. They produce eggs (ova) that can survive for months in water or soil.

Table 1: Occurrence and survival of pathogens (after Crittenden et al., 2005; Feachem et al., 1983)

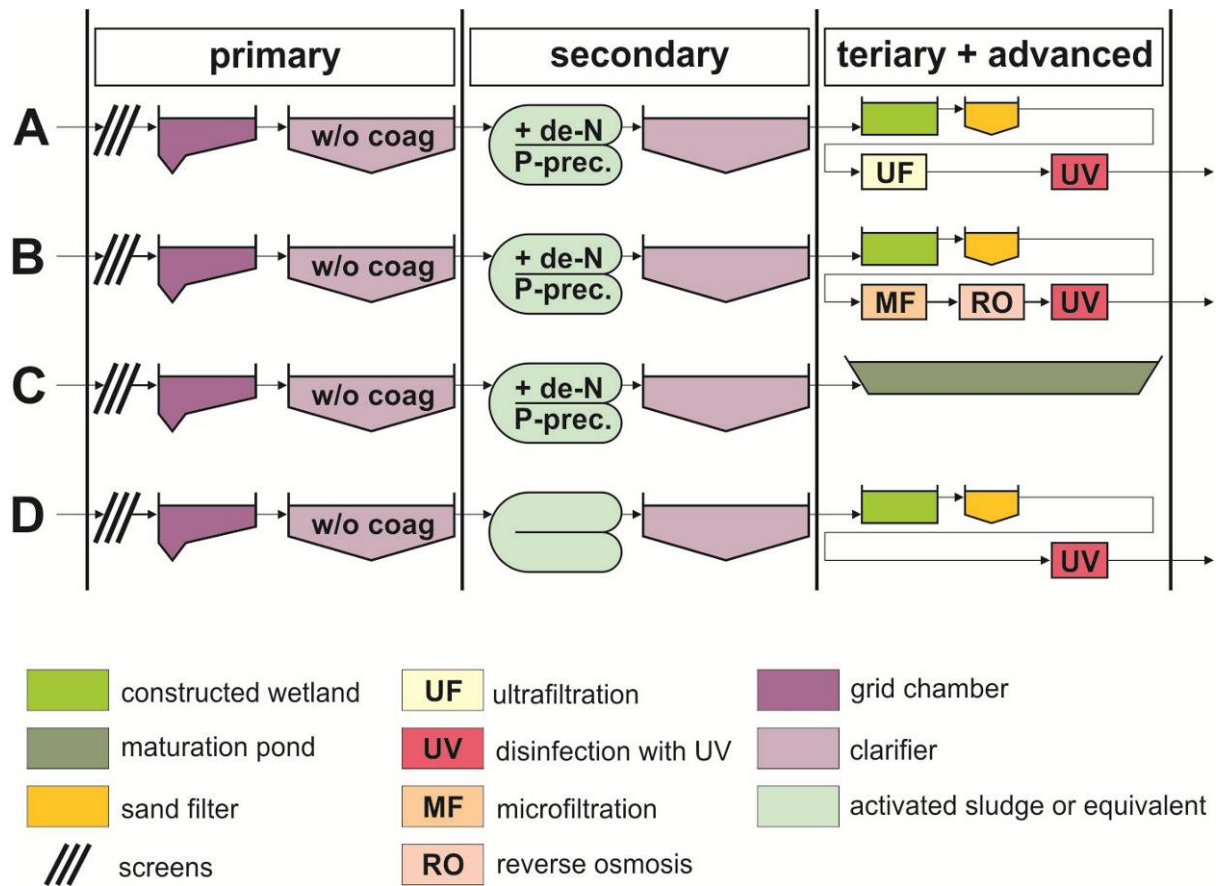
	size [µm]	common conc. in domestic sewage [number/100mL]	infectious dose N ₅₀	usual survival time [days]		
				in sewage	in faeces / sludge	on crops
viruses	0.01 – 0.3	10 ² - 10 ⁴	1 - 10	<50	<20	<15
bacteria	0.2 - 10	10 ⁷ - 10 ¹⁰				
faecal coli.		10 ⁵ – 10 ⁸	10 ⁶ - 10 ¹⁰	<30	<50	<15
salmonella		10 ² – 10 ⁴		<30	<30	<30
shigella		10 ⁰ – 10 ³	10 - 20	<10	<10	<5
protozoa	10-50, cysts: 4 - 6	10 ⁰ – 10 ⁵	1 - 20	<15	<15	<2
helminths	mm-cm, eggs: 35 - 70	10 ⁰ – 10 ³	1-10	months	months	<30

coli. : coliforms bacteria, conc.: concentration

Nitrogen can occur in a number of forms (nitrate NO₃⁻, nitrite NO₂⁻, ammonium NH₄⁺ or ammoniac NH₃, nitrogen gas N₂) and is reported as total-N, organic-N or Kjeldahl-N (organic-N plus ammonium). It can be converted from one form to another through natural processes - many performed by microbes (like nitrification, denitrification, mineralisation). Phosphorus occurs in the form of phosphate (PO₄³⁻). Elevated concentrations of both nutrients lead to eutrophication of aquatic systems.

If reuse for irrigation is considered, anaerobic treatment might be preferred as it retains more nutrients and sludge volumes are lower. If high mineral concentrations exist, these might have to be reduced using advanced treatment to meet irrigation water standards. If effluent is to be discharged into streams, aerobic treatment with high removal rates of organic matter and nutrients is required (Fig. 2). The selection of the right location should also consider possible reuse options, as large distances to reuse schemes and high pumping lifts should be avoided. Agricultural reuse sites should mainly be selected based on the soil characteristics (permeability etc). The wastewater treatment plant should be shielded from any rainwater or inundations (topography) entering the plant. In karst areas, reuse options must consider the risk of contamination for nearby drinking water sources, such as springs and wells, and WWTPs should have a minimum distance to streams, wells or sinkholes, in case spills of raw sewage or half-treated effluent occur or wastewater is bypassed during times of peak flow. WWTPs should frequently be monitoring the effluent water quality and should be fitted with standby power supplies and large enough storage capacities for wastewater in case of peak flows.

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A Industry **B** Groundwater recharge **C** Environmental **D** Agriculture

Fig. 2: Example for possible treatment trains depending on reuse (after AQUAREC, 2006)

Overall, affordability, operability, reliability, suitability and environmental soundness have to be considered for selecting a sustainable wastewater treatment system (Kramer et al., 2007).

To select an appropriate treatment method and system the following factors have to be assessed:

- wastewater quality and volume based on the current and projected population size
- final wastewater destination and required quality (reuse scheme or discharge scenario)
- sludge production and disposal management
- costs of construction, operation and maintenance including the availability of electricity, spare parts and operator skills
- charges to be set and the willingness and ability of the population to pay them and their acceptance/demand for reused water
- land availability, topography, geology, climate and distance to residential and reuse areas
- management structure including public and private obligations

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3 Wastewater reuse

Reuse in agriculture has the added benefit of using the nutrients existing in wastewater and hence reducing the demand on commercial fertiliser. As wastewater effluent is produced continuously but water demands for irrigation vary seasonally, a storage system or a combination with other reuse schemes should be planned. Storage needs to be dimensioned to be able to accommodate about 30 % of the annual effluent. If above ground storage is used, bacterial re-growth and algae growth has to be considered. Limitation on nutrient and pathogen levels might have to be adjusted. Underground storage or closed storage tanks limit algae growth and evaporation losses.

While reuse has a number of advantages, it is not without potential risks mainly related to health and the environment, especially when low-quality water is used. Potential constraints could also be economic feasibility and cultural non-acceptance of reuse, requiring the appropriate choice of treatment and reuse option.

The decision for the most feasible reuse application requires a regional survey of supply of wastewater and (seasonally varying) demand for reuse water to match the source and reuse option. Before the reuse option is included in the design of a wastewater facility, it must be ensured that treated wastewater will in fact be reused by the local farmers. The legal requirements and guidelines for reuse, health standards, and groundwater protection should be compiled. After a review of the geographical, geological and hydrogeological conditions and the marketability of possible crops (including their salinity tolerance), the economic evaluation should be undertaken of treatment, storage and distribution costs compared to a scenario without reuse (including environmental and fertiliser costs). Considerations should also be given to the cultural acceptance and potential consumer confidence in food products based on treated wastewater, as reuse projects often fail, when stakeholders are not consulted, informed and educated. Apart from hygiene education, local socio-cultural conditions and attitudes towards wastewater reuse and environmental protection have to be taken into account, before deciding on the most appropriate reuse option.

Health concerns exist as common secondary treatment techniques are not very effective at removing pathogens, so caution has to be taken to avoid the spread of diseases and wastewater treatment processes should focus more on removing pathogens. Main pathways of agricultural reuse are through direct contact with reclaimed wastewater by farm workers or unplanned access by the public, indirect infections through consumption of contaminated food, spread of contaminated aerosols during irrigation and contamination of downstream freshwater sources through infiltration/runoff into surface or groundwater. Nevertheless, most of these health risks can be managed with low cost measures like appropriate occupational health measures (e.g. protective clothing), crop restrictions (treated wastewater should not be used for crops eaten raw), signage of plots irrigated with reclaimed water, colour-coded dual plumbing systems and restrictions on irrigation method or timing (WHO, 2006). The irrigation method with greatest health concern for consumers is spray/sprinkler irrigation, if

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contaminated crops are eaten uncooked and unwashed. The risk can be reduced through the restriction to crops that are not eaten raw, and through a high level of hygiene at the consumer end. Inhabitants living in the range of sprinkler aerosols could also be affected if the concentration of pathogens is too high and wind conditions are favourable, but results are inconclusive. Furrow irrigation entails the highest contact with reuse water for farm workers; drip irrigation the lowest. For maximum protection a multi barrier approach is suggested (Kramer et al., 2007):

- wastewater treatment: reduce pathogen concentrations
- crop restrictions: only for processed, cooked or fodder crops
- irrigation method: drip/trickle irrigation instead of sprinkler or furrow irrigation (also advisable to avoid salt related leaf damage and salt accumulation in the root zone)
- scheduling of irrigation: restrictions how long before the harvest reuse water can be applied
- location restrictions: buffer strip to dwellings and to surface water and groundwater infiltration features
- human exposure control: protective clothes, hygiene, washing of harvested produce before sale, cooking of crops, clear signage of reclaimed water, immunisation.

It is of utmost importance that the above protection measures are monitored and controlled and clear instructions are given to the users. For disease control it could also be an option to vaccinate farm workers and supply them with prophylactic treatments.

Environmental risks to soil, plants, groundwater and ecosystems can occur and are mostly related to salinity levels, specific toxicity effects to plants and over-nutrication. **Salinity** levels in wastewater can be high and are not reduced without advanced treatment options. On the contrary, salinity is increased through evaporation from treatment ponds and basins, especially in hot climates. Salinity levels are also increased through flood and furrow irrigations where large amounts of water evaporate and salt accumulation occurs on the ridges, where the plants are located. If groundwater tables are high, secondary salinisation can occur through capillary rise of groundwater and sufficient drainage and leaching is needed. High levels of salinity affect the water availability to crops through osmotic pressure. Crops show varying sensitivity to salinity though and more salt tolerant crops (Table 2) could be grown. To limit salinity increase in the groundwater, irrigation should be scheduled right to match plant needs as closely as possible to avoid extensive leaching and irrigation inefficiency. Drip irrigation is most suitable to prevent salinity problems, has the highest water efficiency and the lowest contamination potential, but high capital costs (Table 5). Simplified but detailed methods for calculating irrigation and **fertigation** requirements under drip irrigations have been compiled for different crops for the Jordan Valley (GTZ, 2006b). The water requirements are based on evapotranspiration losses incorporating crop stages, ground coverage, irrigation efficiency and leaching requirements. Scheduling for irrigation is calculated from the net irrigation depth, growth irrigation depth, precipitation, irrigation frequency and irrigation duration. Nutrient management compares the target yield and crop requirement with nutrients in reclaimed wastewater, manure and soil. The sufficiency concept

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takes into consideration the availability of nutrients in the soil depending on soil structure and crop growth stage (GTZ, 2006b).

Table 2: Salt and boron tolerance of plants as experienced in the Jordan Valley (after GTZ, 2006a)

EC ($\mu\text{S}/\text{cm}$)	< 1.7	citrus, carrots, strawberry, onion
	1.7 – 3.0	olive, pepper, cucumber, cauliflower, lettuce, watermelon, cabbage, grapes
	>3.0	asparagus, date palms, barley, wheat, tomato, squash, eggplant, sweet corn, potato, alfalfa, rocket, parsley
B (mg/L)	0.5 – 0.75	lemon
	0.75 - 1	wheat, strawberry
	1 - 2	pepper, carrot, potato, cucumber, lettuce
	4 - 6	alfalfa, parsley, tomato
	6 - 15	asparagus, celery

Apart from total salinity the relation of **sodium** to calcium plus magnesium concentrations (expressed as the sodium adsorption ratio SAR) is an important indicator for irrigation water quality as high sodium concentrations cause dispersion and swelling of clay minerals. This leads to a reduction of soil permeability and infiltration rates, and the formation of hard clay crusts (Rhoades et al., 1992). Some plants, for example fruit trees, are also very sensitive to elevated levels in sodium, chloride or boron. **Boron** originates from bleach in detergents and has low removal rates. While nutrients are essential for high yields of crops, an excess of **nitrogen** can result in yield loss and disease due to luxuriant growth (Morishita, 1988). Grassy and leafy crops are generally better in nutrient uptake. Guidelines at what concentration these parameters could limit the application as irrigation water depending on the sensitivity of the plants are presented in Table 3. Elevated levels of suspended solids will mainly affect the irrigation system through clogging and should be especially low for drip and micro-irrigation systems. If spray irrigation is used, particles deposited on leaves might lower yields due to reduced photosynthesis capacity (GTZ, 2006a).

Increased concentrations of heavy metals can also lead to toxicity in plants (Table 4) and can be transferred through the plant to the consumer, when bioaccumulation is high, e.g. for cadmium (Pescod, 1992). Problems related to heavy metals and organic contaminants can be lowered by reducing turbidity, as these contaminants are largely attached to solids (McBride, 1994).

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Table 3: Guidelines for interpretation of water quality for irrigation (after Ayers and Westcot, 1985)

potential irrigation problem	unit	degree of restriction on use			
		none	slight to moderate	severe	
Salinity (affects crop water availability)					
EC	dS/m	< 0.7	0.7 - 3.0	> 3.0	
TDS	mg/L	< 450	450 - 2000	> 2000	
SAR and EC evaluation (affects infiltration rate)					
SAR = 0 - 3 and EC	dS/m	> 0.7	0.7 - 0.2	< 0.2	
= 3 - 6 and EC	dS/m	> 1.2	1.2 - 0.3	< 0.3	
= 6 - 12 and EC	dS/m	> 1.9	1.9 - 0.5	< 0.5	
= 12 - 20 and EC	dS/m	> 2.9	2.9 - 1.3	< 1.3	
= 20 - 40 and EC	dS/m	> 5.0	5.0 - 2.9	< 2.9	
Specific Ion toxicity (affects sensitive crops)					
Na	Surface irrigation	meq/L	< 3	3 - 9	> 9
Na	Sprinkler irrigation	meq/l	< 3	> 3	
Cl	Surface irrigation	meq/l	< 4	4 - 10	> 10
Cl	Sprinkler irrigation	meq/l	< 3	> 3	
Boron (B)		mg/L	< 0.7	0.7 - 3.0	> 3.0
Nitrogen (NO ₃ -N)		mg/L	< 5	5 - 30	> 30

EC: electrical conductivity in deciSiemens per metre at 25°C, SAR: sodium adsorption ratio, meq/L: milliequivalent per litre

During irrigation portions of the water will percolate down to the groundwater or run off overland into surface waters and can reach drinking water supplies. During the percolation through the soil, attenuation processes generally lower concentrations of nutrients, heavy metals and organic trace contaminants (Katz et al., 2010; 2009). As karst areas are particularly prone to direct infiltration and have only limited capacity to attenuate contaminants, special emphasis should be given to buffer strips (min. 50 m) around sinkholes and along streams. Livestock should also not be allowed in these zones (Currens, 2002). The risk of groundwater contamination can be lowered by choosing fields with appropriate soil thickness and soil properties, by restricting application of reclaimed water in groundwater protection zones and close to streams and by increasing the water quality of reuse water. The consequences of effluent reuse on groundwater quality are often not considered, but should be of special focus in karst regions.

Wastewater reuse requires regular monitoring of reclaimed water quality and also the installation of groundwater monitoring wells to observe any changes to groundwater quality early (EPA SA, 2007a, b). Sampling frequency have to be often enough to allow a statistical interpretation of the data. Clear operational rules on how to sample, how to interpret the results and how to assess compliance with quality standards have to be in place (Kramer et al., 2007). Sampling can either be based on total outflow or on the size of the WWTP and a higher sampling frequency is commonly required for larger WWTPs with higher volume output. Common parameters should be sampled more regular than expensive and less common parameters (Table 5).

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Table 4: Recommended maximum concentration of trace elements for crop production not exceeding a water application rate of 10 000 m³/ha/a for long term use (after Rowe and Abdel-Magid, 1995; Pescod, 1992)

mg/L	long-term use	short term use	Remarks
Al	5.0	20	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As	0.10	2.0	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice.
B	0.75	2.0	Essential to plant growth at a few tenths mg/L; toxic to many sensitive plants (e.g. citrus) at 1 mg/L, most grasses can tolerate 2-10 mg/L
Be	0.10	0.5	Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans.
Cd	0.01	0.05	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/L in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	0.05	5.0	Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	0.10	1.0	Not generally recognised as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	0.20	5.0	Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solutions.
F	1.0	15	Inactivated by neutral and alkaline soils.
Fe	5.0	20	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	2.5	2.5	Tolerated by most crops up to 5 mg/L; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/L). Acts similarly to boron.
Mn	0.20	10	Toxic to a number of crops at a few-tenths to a few mg/L, but usually only in acid soils.
Mo	0.01	0.05	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	0.20	2.0	Toxic to a number of plants at 0.5 mg/L to 1.0 mg/L; reduced toxicity at neutral or alkaline pH.
Pb	5.0	10	Can inhibit plant cell growth at very high concentrations.
Se	0.02	0.02	Toxic to plants at concentrations as low as 0.025 mg/L and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. As essential element to animals but in very low concentrations.
V	0.10	1.0	Toxic to many plants at relatively low concentrations.
Zn	2.0	10	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

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Table 5: Sampling frequency of reclaimed wastewater for reuse in agriculture (modified after Salgot and Huertas, 2006)

	permanently - weekly	1-2 per month	monthly – once a year	once per 1 - 5 years
microbiological analysis	E.coli, Salmonella, bacteriophage		Helminths eggs, Taenia	Legionella, Giardia, Cryptosporidium
physico-chemical, inorganic	ph, EC, turbidity, TSS, COD, BOD, DO, AOX, total N, NH ₄ , residual Cl ₂	SAR, UV 254, DOC, NO ₃ , SO ₄ , Cl, total P	B	
heavy metals			As, Cd, Cr, Cu, Hg, Ni, Pb, Zn	Al, Ba, Be, Co, Fe, Li, Mn, Mo, Se, Sn, Th, V
organic pollutants			surfactants, hydrocarbons	aldehyde, phenols, diuron, 2,4-D, EDTA, benzene, benzo(a)pyrene, PAHs
micropollutants				PhAC, EDC, DBP

UV 254: analysis for concentration of humic acids

Reclaimed wastewater is a valuable source of water that could alleviate stresses on water supplies. It can be used for agricultural irrigation, urban irrigation, industrial reuse or groundwater recharge. One of the main problems is the fact, that wastewater occurs primarily in urban areas away from agricultural areas, which consume about 70 – 80 % of the total demand and hence have the greatest potential for wastewater reuse. Consequently, central WWTPs near urban areas have restricted reuse potential and decentralised WWTPs in rural areas have high reuse potential.

Apart from quantity, quality of effluents determines the possibility and type of reuse. If treated wastewater is going to be reused, treatment levels should be based on environmental and public health impacts in the reuse area. Its must be known already during the design phase of a WWTP which treatment level needs to be achieved in order to be able to reuse reclaimed water safely (Fig. 2). Reclaimed water contains valuable nutrients that are best utilised in agricultural irrigation and quality standards can often be met by extensive systems in rural areas. Reuse on greens with public access or storage in publicly accessible impoundments requires additional pathogen removal.

For agricultural reuse, health risks can largely be eliminated with appropriate irrigation management and human exposure control measures. Unless consumer acceptance is too low and produce is not marketable, health related issues should not be a constraint for reuse and it has been practiced successfully worldwide.

In contrast, environmental impacts to water resources are of concern, especially in mature karst areas found over large areas in Lebanon. Treatment standards need to be high, as

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infiltration to the groundwater is highly likely. A special reuse class for karst areas with more stringent limits for pathogens and nutrients is recommended. Areas, where wastewater reuse can safely be applied have to be selected based on hydrogeological criteria addressing the protection needs of downstream drinking water resources. Restrictions for areas unsuitable for wastewater irrigation (e.g. due to slope, soil thickness or proximity to water courses or infiltration features) have to be in place and enforced. Irrigation management has to be followed more strictly than in other areas and requires additional education of farmers.

4 Comparison of International Guidelines for Treated Wastewater Reuse

Overall, the aim of wastewater reuse guidelines is to protect the population from health risk and the environment from degradation and pollution. Most of the worldwide available guidelines are based on either the US EPA guidelines (US EPA, 2004) or the WHO guidelines (WHO, 1989). These guidelines are suitable for developed countries with anyway high wastewater treatment standards, but should be adjusted in developing countries and account for the end use (Choukr-Allah, 2010). The guideline should include assessment of the irrigation method, exposure scenario and hygiene measures (Blumenthal and Peasey, 2002). Too stringent regulations cannot be enforced and are eventually ignored (Choukr-Allah, 2010). This concept has been accounted for in the newer WHO guidelines (WHO, 2006).

A comprehensive comparison of internationally applied standards for treated wastewater and sludge reuse is listed in Steinel & Margane (2011). Therefore here only the most important guidelines are presented, relevant for the decision which regulation to adopt in Lebanon.

4.1 WHO and UNEP

In 2006, the World Health Organisation (WHO), the United Nations Environment Programme (UNEP) and the Food and Agriculture Organisation (FAO) updated the older guidelines and presented quality standards for reuse of wastewater, faeces and greywater in agriculture and aquaculture based using a unit combining mortality and morbidity called disability-adjusted life years (DALY). Best practice guidelines for reuse management including crop restriction, irrigation techniques, good personal hygiene and produce handling are essential to this concept of reuse (WHO, 2006). The new health-based guidelines of a DALY loss of $\leq 10^{-6}$ per person per year (this is achieved by a 6 - 7 log unit reduction of pathogens) can hence be achieved by a combination of measures (log unit reduction in brackets), e.g. treatment level (0.5 - 7), die-off between irrigation and consumption (1 - 2), drip irrigation (2 - 4), subsurface irrigation (6), washing of produce (1), produce disinfection (2), produce peeling (2), produce cooking (6 - 7). A target of ≤ 1 helminth eggs/L is applicable to irrigation of all crops except for high growing crops (fruit trees, olive trees, date palms etc.). In addition, maximum tolerable soil concentrations based on human health protection for various chemicals are given (Table

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6). Monitoring should be conducted at the point of use or the point of effluent discharge. Urban/rural WWTP should take samples for *E. coli* every two weeks/four weeks and for helminth eggs every months/1-2 months, respectively. Testing of produce for human consumption should include testing for *E. coli*, thermotolerant coliforms, helminth eggs and heavy metals (WHO, 2006).

Table 6: Maximum tolerable soil concentration of selected inorganic and organic compounds based on human health protection (WHO, 2006)

inorganic compounds	soil (mg/kg)	organic compounds	soil (mg/kg)
Ag	3	2,4-D	0.25
As	8	2,4,5-T	3.82
B	1.7	aldrin	0.48
Ba	302	chlordan	3
Be	0.2	dieldrin	0.17
Cd	4	lindane	12
F	635	DDT	1.54
Hg	7	PAHs	16
Mo	0.6	PCDs	0.89
Ni	107	PCDDs	0.00012
Pb	84	benzene	0.14
Sb	36	chlorobenzene	211
Se	6	toluene	12
Tl	0.3	phthalate	13 733
V	47	pyrene	41
		styrene	0.68
		toxaphene	0.0013

The WHO guidelines ensure health safety via a comprehensive risk assessment of all process steps from wastewater production through to produce consumption (Stockholm framework), but no environmental assessment is included. Validation at the beginning of a new system and verification/monitoring afterwards has to be performed to prevent hazards. While this system allows for more flexibility, each reuse project has to be assessed individually, which is of limited practicality for controlling compliance.

The older guidelines set more specific values and have been adopted in similar form by a number of countries worldwide. The helminth egg guideline of ≤ 1 egg/L for unrestricted irrigation was later revised to ≤ 0.1 egg/L and higher quality standards for flood irrigation and children were added (Table 7). The microbiological guidelines can be met through the use of wastewater stabilisation ponds (WSP), wastewater storage and treatment reservoirs (WSTR) or through conventional treatment processes (Blumenthal and Peasey, 2002).

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Table 7: Revised 1989 WHO guidelines for wastewater reuse in agriculture. Grey shaded fields are revised or added compared to original guidelines (after Blumenthal and Peasey, 2002)

	Reuse condition	Exposed group	irrigation method	helminth eggs/L	Faecal coli./100 ml
A	unrestricted: crops eaten uncooked, sports fields, public parks	workers, consumers, public	any	≤ 0.1	≤ 10 ³
B	restricted: cereal crops, industrial crops, fodder crops, pasture and trees	B1 workers >15 years	spray / sprinkler	≤ 1	≤ 10 ⁵
		B2 workers >15 years	flood /furrow	≤ 1	≤ 10 ³
		B3 workers including children, nearby communities	any	≤ 0.1	≤ 10 ³
C	Localised 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

Table 8: Recommended control measures for various problems (after WHO, 2006)

problem	control measure
nitrogen excess	dilute with freshwater; limit the quantity of water applied; remove excess nitrogen through treatment
organic matter	allow time between irrigation for soil to biodegrade it; enhance removal through treatment
salinity	avoid use of water with 500 – 2000 mg/L TDS depending on soil type and drainage; reduce upstream salt use and discharge into wastewater; increase soil washing, improve ground drainage, apply soil amenders; dilute water
chlorides	use water <100 mg/L in sprinklers; use water <350 mg/L for flood irrigation; irrigate at night
toxic organic compounds	pretreat or separate industrial wastewater; promote cleaner production in industries; educate society to use less toxic compounds and dispose of them safely
heavy metals	pretreat or separate industrial wastewater; use only in soils with pH >6.5
TSS	remove solids with treatment; plough soils when clogged; do not use drip irrigation that can get clogged

For groundwater or environmental protection purposes no specific guidelines are given, as local differences make a general guideline challenging. Recommended water quality guidelines for maximum crop production and soil protection are given though Table 3. The WHO guidelines name a number of control measures to reduce environmental impacts (Table 8).

Before the revised WHO guidelines from 2006, the UNEP set guidelines for municipal wastewater reuse in the Mediterranean region and specified microbiological and chemical health risks (UNEP, 2005). They consider four categories of reuse: I: urban and residential

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uses, II: unrestricted irrigation and industrial reuse, III: restricted agricultural irrigation, and IV: irrigation with drip or subsurface irrigation (Table 9).

Table 9: Recommended guidelines for water reuse in the Mediterranean region (after UNEP, 2005)

	helminth eggs/L ^a	faecal coli./100mL ^b	TSS (mg/L)	recommended treatment
I	≤0.1	≤200	≤10	secondary + filtration + disinfection
II	≤0.1	≤10 ⁻³	≤20, ≤150 ^c	secondary + filtration + disinfection or secondary + storage/maturation ponds/ infiltration
III	≤1	≤10 ⁻⁵	≤35, ≤150 ^c	secondary + few days storage or oxidation pond system
IV	none	none	as required by irrigation technology	minimum primary treatment

a: does not require routine monitoring, b: should be monitored weekly, at least monthly, c: when treating with stabilisation ponds

4.2 USA

The use of reclaimed water dates back to the 1960s in California (for urban and agricultural irrigation due to water scarcity) and in Florida (to control discharge into sensitive wetlands). Texas and Arizona also use reclaimed water on a larger scale for irrigation. Many examples for aquifer recharge exist and industrial reuse is also increasing. Generally guidelines are fairly strict requiring coagulation/flocculation, sedimentation, filtration and disinfection, sometimes leading to problems with disinfection by-products (Bougeard, et al., 2010; McQuarrie and Carlson, 2003). The US EPA has issued guidelines on water reuse (Table 10; US EPA, 2004), but the states have developed their own guidelines, the most prominent being the Californian Title 22 guidelines (2000) (Table 11). These guidelines are not based on the risk approach like the WHO guidelines, but are much stricter requiring no detectable faecal coliforms for unrestricted irrigation and are therefore not realistic for developing countries (Kramer et al., 2007). In Texas salinity is a major problem and crop selection, irrigation technique and water quality recommendations similar to Table 3 and Table 4 are given (Fipps, 1996).

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Table 10: Suggested guidelines for water reuse (after US EPA, 2004)

type of reuse	BOD ₅ (mg/L)	TSS (mg/L)	Turbidity (NTU)	FC /100 mL	Cl ₂ residual (mg/L)	setback distance s (m)	treatment required
urban reuse	≤10		≤2	nil	1	15 to A	secondary + filtration + disinfection
restricted access area irrigation	≤30	≤30		≤200	1	90 to A 30 to B	secondary + disinfection
unrestricted agricultural reuse	≤10		≤2	nil	1	15 to A	secondary + filtration + disinfection
restricted agricultural reuse	≤30	≤30		≤200	1	90 to A 30 to B	secondary + disinfection
environmental reuse	≤30	≤30		≤200			secondary + disinfection (min), (+ dechlorination)
groundwater recharge	site specific						minimum: primary for spreading, secondary for injection
indirect potable reuse*	drinking water standards					site- specific	secondary + filtration + disinfection + advanced

A: potable water supply wells, B: areas accessible to the public (if spray irrigation), Note: Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and may include stabilisation pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do not exceed 30 mg/l. Some stabilisation pond systems may be able to meet this coliform limit without disinfection. *Monitoring should include inorganic and organic compounds or classes of compounds, that are known or suspected to be toxic, carcinogenic, teratogenic, or mutagenic and are not included in the drinking water standards.

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Table 11: California water recycling criteria: treatment and quality requirements for non-potable uses of reclaimed water (State of California Title 22 Water Recycling Criteria (2000) (after UNEP, 2005)

Type of use	TC/100 mL ^a	treatment required
Irrigation of fodder, fiber and seed crops, orchards ^b and vineyards ^b , processed food crops, non food bearing trees, ornamental nursery stock ^c , and sod farms ^c ; flushing sanitary sewers	None required	Secondary
Irrigation of pasture for milking animals, landscape areas ^d , ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	≤23 ≤240*	Secondary + Disinfection
Irrigation of food crops ^b ; restricted recreational impoundments; fish hatcheries	≤2.2 ≤23*	Secondary + Disinfection
Irrigation of food crops ^e and open access landscape areas ^f ; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	≤2.2 ≤23* 240 (max)	Secondary + Coagulation ^g + Filtration ^h + Disinfection
Non restricted recreational impoundments	≤2.2 ≤23* 240 (max)	Secondary + Coagulation + Clarification ⁱ + Filtration ^h + Disinfection

a: Based on running 7-day median; b: No contact between reclaimed water and edible portion of crop, c: No irrigation for at least 14 days prior to harvesting, sale, or allowing public access, d: Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas, e: Contact between reclaimed water and edible portion of crop; includes edible root crops, f: Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas, g: Not required if the turbidity of the influent to the filters is continuously measured, does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes, h: The turbidity after filtration through filter media cannot exceed 2 nephelometric turbidity units (NTU) within any 24-hour period, 5 NTU more than 5% of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5% of the time within any 24-hour period and 0.5 NTU at any time, i: Not required if reclaimed water is monitored for enteric viruses, Giardia, and Cryptosporidium. *in more than one sample in any 30-day period, TC: total coliforms

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4.3 Jordan

Due to the increasing water scarcity, many countries in the MENA region are now recycling wastewater with Jordan and Syria leading the way.

Jordan faces serious water scarcity and has made great improvements in sewage collection and treatment coverage. According to the National Water Strategy "Water for Life" (MWI, 2009), the Jordanian Government intends to increase reuse of treated domestic wastewater in agriculture to 220 MCM until 2022, which then would constitute 13% of the available water resources.

Guidelines for various reuse options were issued in 1995 (JS 893/1995). Revised more stringent standards were enacted in 2003 JS 893/2002), prohibiting the irrigation of vegetables eaten raw or recharging aquifers for potable use. The use of sprinklers and irrigation two weeks before harvest are also forbidden. Further revisions (JISM, 2006; Table 12 and Table 13) specify conditions for reclaimed domestic wastewater quality standards when discharged to wadis/streams or used for irrigation and are less strict for BOD, COD and *E.coli* than previous guidelines, but include advice on irrigation practices and human exposure control (Kramer et al., 2007).

Table 12: Current Jordanian standards for wastewater reuse in irrigation and discharge to wadis/streams JS 893/2006 (after JISM, 2006)

Parameter	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	Discharge to wadis or streams
BOD (mg/L)	30	200	300	60
COD (mg/L)	100	500	500	150 (300 WSP)
DO (mg/L)	>2	-	-	>1
TSS (mg/L)	50	200	300	60 (120 WSP)
pH	6-9	6-9	6-9	6-9
Turbidity (NTU)	10	-	-	-
NO ₃ (mg/L)	30	45	70	80 (100 WSP)
Total N (mg/L)	45	70	100	70 (100 WSP)
<i>E.coli</i> /100 mL	<100	<1000	unlimited	1000*
Helminth eggs/L	≤1	≤1	≤1	≤1
FOG (mg/L)	8	8	8	8

FOG: fat, oil and grease; *In WWTP applying WSP (wastewater stabilisation ponds) *E.Coli* levels (1000 CFU) can be exceeded if the wadi or stream water will be stored in a reservoir used for Irrigation.

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Table 13: Further guidelines for reuse in irrigation and discharge to wadis/streams (JS 893/2006) (after JISM, 2006)

parameter (mg/L)	irrigation	discharge to wadis/streams	parameter (mg/L)	irrigation	discharge to wadis/streams
TDS	1500	1500	As	0.1	0.05
total PO ₄	30	15	Be	0.1	0.1
Cl	400	350	Cd	0.01	0.01
SO ₄	500	300	Co	0.05	0.05
HCO ₃	400	400	Cr (total)	0.1	0.02
Na	230	200	Cu	0.2	0.2
Mg	100	60	Hg	0.002	0.002
Ca	230	200	Li	2.5 (0.075 citrus)	2.5
SAR	9	6	Mn	0.2	0.2
CN	0.1	0.1	Mo	0.01	0.01
phenol	<0.002	<0.002	Ni	0.2	0.2
MBAS	100	25	Pb	0.2	0.2
Al	%	2	Se	0.05	0.05
B	1	1	V	0.1	0.1
F	2	1.5	Zn	5	5
Fe	5	5	Residual Cl ₂		≤1

MBAS: methylene blue active substances = anionic surfactants, detergents

5 Existing Standards Related to Water in Lebanon

Concerning standards and regulations for water quality and resources protection Lebanon is trailing far behind most other Arab countries. The following regulations are in place, but are not sufficiently enforced:

- Standards for drinking water (Table 14; Law 444 of 2002) exist only for biological and inorganic parameters, but not for heavy metals or organic contaminants.
- Environmental limit values for wastewater discharge into the environment (Table 15, MoE decision 8/1 of 2001) are existing and pretreatment of industrial wastewater before discharge is required (Decree No. 2761 of 1933) but regulations are commonly not enforced (EMWater, 2004).
- The irrigation with treated wastewater is currently prohibited (Decree 8735 of 1974) and hence no standards for water reuse are established (EMWater, 2004), but as reuse is envisaged for the future, draft wastewater reuse guidelines have already been prepared (Table 16).

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Table 14: Drinking water standards (EMWater, 2004)

Parameter	standard value	Parameter	standard value
Total Coli. (MPN/100 mL)	0	NO ₃ (mg/L)	5 (max 50)
Faecal streptococcus (MPN/100 mL)	0	Cl (mg/L)	25 (max 200)
Faecal Coli. (MPN/100 mL)	0	SO ₄ (mg/L)	25 (max 250)
Sulphate reducing bacteria (MPN/200 mL)	1	Na (mg/L)	20 (max 150)
Thermo tolerant coli. (MPN/100 mL)	0	K (mg/L)	10 (max 12)
Salmonella (MPN/5 L)	0	Mg (mg/L)	30 (max 50)
Pathogenic staphylococci (MPN/100 mL)	0	Ca (mg/L)	100
Bacteriophages (MPN/50 mL)	0	Total Al (mg/L)	0.05 (max 0.2)
Enteroviruses (MPN/10 L)	0	Dry Residues (mg/L)	1500
Temperature (°C)	12 (max 25)	EC (mS/cm)	400
pH	6.5 - 8.5 (max 9)		

Table 15: Environmental limit values for discharge of sewage into the sea, surface waters and sewers (after EMWater, 2004)

Parameter (mg/L)	discharge into			Parameter (mg/L)	discharge into		
	sea	surface waters	sewer		sea	surface waters	sewer
pH	6-9	6-9	6-9	Ag	0.1	0.1	0.1
Temperature (°C)	35	30	35	Al	10	10	10
BOD₅	25	25	125	As	0.1	0.1	0.1
COD	125	125	500	Ba	2	2	2
Total P	10	10	10	Cd	0.2	0.2	0.2
Total N	30	30	60	Co	0.5	0.5	1
TSS	60	60	600	Total Cr	2	2	2
AOX	5	5	5	Cr(VI)	0.5	0.2	0.2
Detergents	3	3		Cu	1.5	0.5	1
E.coli (MPN/100 mL)	2000	2000		Fe	5	5	5
Salmonellae (MPN/L)	nil	nil	nil	Hg	0.05	0.05	0.05
Hydrocarbons	20	20	20	Mn	1	1	1
Phenol index	0.3	0.3	5	Ni	0.5	0.5	2
Oil + grease	30	30	50	Pb	0.5	0.5	1
TOC	75	75	750	Sb	0.3	0.3	0.3
NH ₄	10	10		Sn	2	2	2
Active Cl ₂	1	1		Zn	5	5	10
Cyanides	0.1	0.1	1	SO ₄	1000	1000	1000
F	25	25	15	Sulphide	1	1	1
NO ₃	90	90		PO ₄	5	5	

The draft wastewater reuse guidelines (prepared by the FAO) are based on a multiple barrier approach including wastewater treatment, crop restrictions, irrigation management and human exposure control. The programme CROPWAT is suggested for water management. Nutrient management to avoid excessive nitrogen application, which could lead to poor-quality produce and leaching of nitrate into groundwater supplies, might require the blending of reclaimed water with freshwater and the establishment of a nutrient balance. Soils with low water holding capacity should be irrigated with smaller amounts of water but more often. When using sprinkler irrigation, buffer zones of about 300 m to water bodies and publicly

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accessible areas are proposed. Sampling frequency of treated wastewater for BOD, TSS, total P, total N, pH, temperature, TDS, NO₃, PO₄, E. coli, FC and helminths eggs should be once per months for smaller WWTPs (2000 - 50000 PE) and twice per months for larger WWTP (>50000 person equivalents (PE)). Na, Ca, Mg, K, SO₄, Cl and B are recommended to be measured twice per year and heavy metals once a year (FAO, 2010). It is also stressed that WWTPs need to be operated by skilled personnel and sampling takes place according to a set protocol.

Table 16: Draft Lebanese guideline for wastewater reuse (FAO, 2010)

class	I	II	III
restrictions	produce eaten cooked; irrigation of greens with public access	fruit trees, irrigation of greens and with limited public access; impoundments with no public water contact	cereals, oil plants, fiber and seed crops, canned crops, industrial crops, fruit trees (no sprinkler irrigation); nurseries, greens and wooden areas without public access
proposed treatment	secondary + filtration + disinfection	secondary + storage or maturation ponds or infiltration percolation	secondary + storage /oxidation ponds
BOD ₅ (mg/L)	25	100	100
COD (mg/L)	125	250	250
TSS (mg/L)	60 (200 WSP)	200	200
pH	6 – 9	6 – 9	6 – 9
residual Cl ₂ (mg/L)	0.5-2	0.5	0.5
NO ₃ -N (mg/L)	30	30	30
FC (/100ml)	<200	<1000	none required
Helminth eggs (/1 L)	<1	<1	<1

Note: Irrigation of vegetables eaten raw is not allowed

A National Wastewater Management Plan (NWMP) was initially prepared in 1982, but has not been implemented until recently (UNEP, 2006). In 1995, the National Emergency Rehabilitation Programme (NERP) was launched and comprised two major programmes: (1) the Coastal Pollution Control Programme (CPCP) was set up to fulfil the requirements of the Barcelona Convention and (2) the Water Resources Protection Programme (WRPP) included the rehabilitation of water treatment plants and water sources (springs and wells) and distribution networks (EMWater, 2004). A National Water Master Plan for freshwater management was proposed in 2003 using a number of estimations (JICA, 2003), but was not accepted by the Ministry of Energy and Water. Therefore, it is still lacking, mainly due to a lack of data and a lack of policy (Kronfol and Kaskas, 2007). There is urgent need for a comprehensive Water Code to address water and wastewater management. Reviewing of existing legislation and new regulations for wastewater reuse and sludge management are needed. Without enforcement of existing (and new) laws though, no policy will be successful.

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6 Proposed National Standards for Treated Domestic Wastewater Reuse for Irrigation

The evaluation of wastewater reuse options has to consider primarily supply and demand and additional costs compared to discharge and other water sources. While agricultural reuse schemes commonly assess risks to health and to soil and crops, consequences for surface and groundwater are often ignored. Due to overland flow and percolation, irrigation water will also reach water resources. In areas with thick soils, attenuation of contaminants limits possible pollution, but especially in karst areas, where preferential flowpaths are common, pollution risks have to be assessed and good management practices have to be in place.

Recommendations for reuse in karst areas are:

- In case of reuse for irrigation and aquifer recharge, treated wastewater reuse standards should be similar as for discharge into the environment, because karst aquifers are highly vulnerable and contamination can reach drinking water supplies fast. Less stringent water quality standards should only be used for irrigation where sufficiently thick soils or extensive layers of low hydraulic conductivity are verifiably present to prevent percolation to the groundwater. High water quality also allows for irrigation of sensitive crops like fruit trees that are common in Lebanon. Since effluent quality should be high regardless of discharge or reuse, no additional treatment costs are incurred for reuse.
- Groundwater vulnerability maps should be used as a reference for the decision whether to allow treated wastewater reuse in agriculture. Only in areas of very low and low vulnerability treated wastewater reuse in agriculture should be allowed. Indirect infiltration of treated wastewater reuse in agriculture along river beds, i.e. a transfer to areas of medium or high vulnerability must be avoided.
- Irrigational reuse should not be permitted in groundwater protection zones I and II, e.g. buffer strips around sinkholes and along streams should be respected (minimum 50 m).
- To avoid excess runoff and erosion, slope angle should not be larger than 3, 12 or 20% for flood irrigation, sprinkler irrigation or drip irrigation, respectively.
- Soils need to have a minimum thickness (50 cm), as well as minimum quality to be able to retain water and nutrients long enough for plant uptake and to limit leaching to the groundwater.
- Added nutrients in the reuse water and additional fertiliser should match the demand of the crops, e.g. at the start of the growing season less nutrients should be applied, to avoid leaching of nitrate into the groundwater. Overfertilisation is a common problem in reuse schemes.
- Irrigation management should adjust applied volumes of water to the crops need and the water holding capacity of the soil to prevent excessive leaching into the groundwater.

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- Heavy metals are of limited problematic in karst regions as the high pH in soils generally reduces their mobility.

General recommendations are:

- Health protection measures for farm workers should include protective clothes, good hygiene practices, and possibly immunisations (for example polio, diphtheria, tetanus).
- Health protection measures for consumers should include washing of produce, withholdings times before harvest, and crop restrictions to produce that is peeled or cooked.
- Health protection measures for adjacent population should include the use of drip or trickle irrigation, buffer strips near dwellings and clear signage of reclaimed water.
- Irrigation management should prevent salt accumulation in the root zone and capillary rise of groundwater.
- Crop selection should be adjusted to salinity, lithium and boron levels of the reclaimed water.
- Elevated levels of heavy metals should not be applied to crops for human consumption to avoid bioaccumulation.
- Elevated nitrate levels can lead to yield loss and should only be used on grassy and leafy crops or water has to be blended with freshwater.

A national policy for wastewater reuse should include guidelines for water quality and management measures as outlined above and has to formulate how and by whom these guidelines will be enforced. However, regulations must be realistic and achievable in the national context. It is advisable to increase measures and water quality standards step by step, so they can actually be met. If guidelines are too strict and cannot be enforced, they will most likely be ignored completely (Pescod, 1992). As the use of treated wastewater is certainly safer than the use of untreated wastewater as is practiced in the Bekaa Valley, any improvement on water quality and water resource protection measures is a step in the right direction. It is extremely important that the above protection measures are monitored and controlled and clear instructions are given to the users.

The standard proposed by FAO (2010) is quite similar to that applied in Jordan since many years. There, positive experiences have been made with treated wastewater reuse in agriculture. However the FAO proposal is lacking the conditions in which area treated wastewater is allowed to be reused in agriculture. Because of the high pollution risks in karst aquifers, the potential reuse areas depend on the groundwater vulnerability. Only where groundwater vulnerability is very low or low, i.e. where infiltration into the groundwater is negligible, reuse could be allowed. Indirect infiltration, i.e. transfer to areas of medium or high vulnerability must be avoided. There are a number of methods used for mapping of groundwater vulnerability in karst areas, such as the EPIK, PI and COP methods (Margane, 2003).

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The draft proposal for the National Standard for Treated Wastewater Reuse in Agriculture is laid down in Annex 1.

7 Education and public acceptance

There is clear need for educating the population in general and potential polluters in particular about changes in regulations and their purpose, as each citizen has to take part in environmental protection. The reuse of treated domestic wastewater for irrigation will require awareness raising campaigns to be successfully implemented. These campaigns can be in form of regular newspaper articles, regular TV spots, public seminars, billboard advertisements, leaflets, TV documentaries and stipulation of the foundation of civil organisations that promote environmental awareness from citizen to citizen. For example the Association of the friends of Ibrahim Abd El Al, Greenline, Mubadarat or T.E.R.R.E. Liban are already working towards a more sustainable way of living, some with a focus on water issues. Special courses or workshops should be given to planners, decision makers, farmers and major polluting industrial companies. Environmental education should be made mandatory in the curriculum at schools for all levels, as the education of children will propagate this knowledge to the older generation as well as to the coming generation. It will be important to find well-known sponsors, public figures and celebrities with positive connotations for the campaigns to increase the acceptance of the message.

There is a common lack of knowledge how wastewater treatment is working and the quality that can be achieved. Public perception of treated wastewater is influenced by cultural and social factors and varies from country to country (EMWater, 2004). Many reuse schemes have failed due to overestimation of demand as expectation of higher acceptance in the population for reuse water was assumed. Since wastewater reuse may involve pumping costs, those costs may have to be covered by the farmers. Otherwise it must be clear who else would cover these costs in the future. Therefore, all involved stakeholders (municipalities, Water Establishments, CDR) and potential users have to be consulted as early as possible during the project planning and the selection of the appropriate technology should be based on the demand, user's preference and their economic potential. They have to be educated and advised about the control measures for safe usage. Consumers have to be informed about the safety of the produce and a public authority should regularly control its safety.

Methods and tools for awareness raising programmes for wastewater reuse have been developed and should be used (UNEP/WHO/HABITAT/WSSCC, 2004; Wegelin-Schuringa, 2001; UNICEF, 1999). Participatory approaches should involve stakeholders during the assessment phase, the design phase and the implementation phase in order to promote changes in attitude and advocate the benefits of reuse (Kramer et al., 2007). Positive examples from other people will have the strongest impact on behavioural changes (UNICEF, 1999). It is therefore often successful to start with a small-scale project with local involvement and then upscale to regional projects.

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Greywater, especially if it is from one's household, does not have the 'yuck' factor and reuse of greywater is accepted much more widely (Po et al., 2003). Household and neighbourhood scale greywater treatment systems are available and their installation should be promoted especially in areas that will not be served by centralised systems (McIlwaine and Redwood, 2010; Morel and Diener, 2006).

Many farmers lack basic agricultural training and environmental awareness and need to be trained, so reuse is done in the intended way. Information about the existence and purpose of groundwater protection zones, as well as health and environmental protection measures - as recommended above (Chapter 3) - has to be disseminated. The boundary of groundwater protection zones 1 and 2 have to be visibly marked by signposts, which state what is not allowed in these protection zones and who has to be notified in case of violations thereof. Concerning treated wastewater reuse, an analysis of soil thickness and quality should be undertaken to advise which areas could be irrigated with treated wastewater and where reuse could not be applied. Health protection measures have to be explained to farmers, consumers and the adjacent population, as human behavioural patterns are the main factor for disease transmission (WHO, 2006). All channels, pipes and outlets of reclaimed water have to be clearly marked. Crop selection and irrigation management is an important part of successful reuse implementation. Nutrient requirements have to be assessed to prevent overfertilisation (GTZ, 2006b). It requires the knowledge of nutrient levels in reclaimed water and soil as well as nutrient needs of specific crops. As salinity levels of treated wastewater are commonly higher than ground- or surface water, farmers have also be educated how to prevent salinisation problems and salinity related yield losses.

8 Economic considerations

Financial aspects often constrain the selection of the treatment method. Costs for wastewater treatment and reuse vary widely depending on the costs for land (especially if expropriation is required), topography, the size of the treatment plant and sewer network, the volume of wastewater to be treated, the treatment method, the type of sludge management and the reuse options applied. Apart from the overall costs for construction of a sewer network and treatment plant, the costs for no action and negative effects on the population and the environment have to be considered.

During the design phase the following additional cost factors have to be considered:

- additional costs for treatment to required levels (reuse requires more advanced treatment methods);
- land availability and costs for large enough storage facility for treated wastewater;
- additional costs for monitoring quality of WWTP effluent and treated wastewater in storage facility (quality needs to be controlled more often than if released into surface water or into the sea);

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- operation and maintenance costs for conveyor line for treated wastewater;
- operation and maintenance costs for pumping stations, in case treated wastewater needs to be pumped;
- additional costs for quality control of agricultural produce (food testing needs to be conducted more often than for freshwater);
- costs for awareness campaigns.

On the other hand economic benefits of irrigation with treated wastewater for the farmer are significant (Table 17).

Table 17: Economic benefits of irrigation with wastewater in Morocco (after Soudi et al., 2000)

crops	net benefit from recycled water (€/ha)*	net benefit from fertilising benefits (€/ha)**	total benefits (€/ha)
wheat	75	149	224
grain maize	159	361	514
fodder maize	157	357	514
zucchini	68	155	222
pumpkin	61	122	183
tomato	155	354	510
potato	94	214	308

* calculated on the basis of a 0.02 €/m³ cheaper price compared to other water supply and an irrigation rate of 1000 m³/ha, ** assuming wastewater concentrations of N = 40 kg/ha, P = 11 kg/ha and K = 28 kg/ha

9 Monitoring and control requirements

Monitoring, control and enforcement of regulations are necessary to ensure good groundwater quality. The implementation of treated wastewater reuse for irrigation requires monitoring and regulations should outline the frequency and sampling techniques necessary. Environmental rangers similar to Jordan are probably needed to control and enforce new regulations. There, the rangers are part of the national police force operating in coordination with the Ministry of Environment. They have the right to detain persons who are in violation of the environmental law or the water law and are responsible for implementation of the regulations related to water resources protection, such as protection zones.

Monitoring needs with regards to wastewater treatment are:

- Effluent quality complies with effluent standards according to further use or disposal.
- Sewer networks are inspected for blockages and leakages.
- Control needs with regards to wastewater treatment require checking if:
 - no spillage of untreated sewage occurs
 - all parts of the treatment system are working properly
 - all equipment including emergency equipment is functional

The parameter list and frequency depends on whether reuse is intended (health impact through exposure, impact on crops grown), the potential impact on water resources and

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discharge into river courses or the sea. Samples of the treated wastewater effluent should be taken and analysed for the following parameters at the below mentioned intervals for the below mentioned purposes (Table 18):

Table 18: Recommended sampling frequencies of WWTP effluent.

Parameter	Reuse	Impact on water resources*	Discharge into river courses	Discharge into the sea
EC, pH, temperature, turbidity, DO, in-/outflow	continuously (min.every 500 m ³)	weekly	continuously (min.every 500 m ³)	continuously (min.every 500 m ³)
BOD ₅ , COD, TSS, NO ₃ , total N, total P, TOC, E. Coli, FC	every 5000 m ³	twice per week	every 5000 m ³	every 0.05 Mio m ³
, helminth eggs	every 10000 m ³	weekly	every 10000 m ³	every 0.1 Mio m ³
Thermotolerant Coli, Cryptosporidia, Giardia	every 50000 m ³	monthly	every 50000 m ³	every 0.5 Mio m ³
Na, Ca, Mg, K, Cl, SO ₄ , B, Li	every 50000 m ³	monthly	every 50000 m ³	every 0.5 Mio m ³
Cd, Cr, Cu, Hg, Ni, Pb, Zn	every 50000 m ³	monthly	every 50000 m ³	every 0.5 Mio m ³
Al, As, Be, Co, Fe, Mn, Mo, Se, V	every 0.5 Mio m ³	quarterly	every 0.1 Mio m ³	every 5 Mio m ³
AOX, phenols, FOG	every 1 Mio m ³	monthly	every 50000 m ³	every 10 Mio m ³

* water sampling at drinking water sources (springs/wells); note: a weekly sampling is equivalent to a sampling every 10 000 m³ for a WWTP serving about 10 000 people with a water consumption of 150 L/day

It is emphasised that laboratories in Lebanon are currently not able to deal with such large numbers of samples and with many of these parameters at the required level of accuracy so that laboratory capacities must be developed in order to carry out adequate sampling programs.

Monitoring needs with regards to reuse of treated wastewater are:

- Water quality lies within the guideline limits for the specific use.
- Sampling frequencies of treated wastewater should principally depend on the potential impact and not on the size of the treatment facility. In this sense, it is recommended to analyse indicator parameters, such as BOD₅, total N and *E. Coli* every 10,000 m³. For new WWTPs a higher sampling frequency is recommended over the first two years.
- Fertiliser needs have to be adjusted to nutrients added through reclaimed wastewater depending on crop needs.
- For large-scale irrigation, groundwater monitoring wells should be installed and monitoring for nitrate, salinity and pesticides undertaken.
- Crops intended for human consumption have to be controlled for their safety.

Control needs with regards to reuse of treated wastewater require checking if:

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- Reclaimed water is not used in unsuitable areas or groundwater protection zones I and II
- Irrigation practices comply with management guidelines
- Crop restrictions are respected

Also the environmental and health impacts of treated wastewater reuse need to be monitored. This comprises:

- The effect on soil salinity and fertility;
- The health effects on farmers;
- The effects on the groundwater quality downstream of the reuse area.

The government agency responsible for the operation of the treatment plant should also be responsible for the monitoring of treated wastewater reuse. All related activities should be laid down in a monitoring concept, which should be prepared for each facility, comprising the locations where monitoring is needed, specific parameter lists, time intervals for monitoring and analysis, responsibilities, laboratories, staff and budget. Quality assurance measures will be needed to provide that analysis results are correct.

Overall, the main concern is the lack of enforcement of guidelines. While a number of laws and regulations already exist, the staff and equipment for their enforcement are lacking. Capacity building of environmental rangers, agricultural staff and WWTP operators as well as raising of environmental awareness in the population will be needed.

10 Criteria and Conditions for Treated Domestic Wastewater Reuse for Irrigation

Maximum allowable limits of the related standard for reuse of treated domestic wastewater for irrigation should be based on water resources protection needs (potential impact on water resources) and not only on general crop restrictions and health protection alone.

10.1 Reuse Area

Wastewater reuse should only be allowed in areas where there will be no negative impact on the quality of downstream groundwater or surface water resources. This means that reuse should primarily take place only on **sufficiently thick geological units of low hydraulic permeability**, which act as a **hydrogeological barrier**.

Because of the high pollution risks in karst aquifers, the potential reuse areas must depend on the groundwater vulnerability. Only where groundwater vulnerability is very low or low, i.e.

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where infiltration into the groundwater is negligible, reuse could be allowed. Indirect infiltration, i.e. transfer to areas of medium or high vulnerability must be avoided. There are a number of methods used for mapping of groundwater vulnerability in karst areas, such as the EPIK (SAEFL, 2000), PI (Goldscheider, 2002) and COP (Vias et al., 2006) methods (Margane, 2003).

Areas of very low and low vulnerability are found e.g. in most parts of the Bekaa Valley and smaller areas along the coast, where Tertiary and Quaternary sediments are present. In the Lebanon and Anti-Lebanon mountains where karst predominates, it applies to areas where the geological units J5 (Bhannes Formation; basalt, limestone, marl, claystone) or C1/C2a (Chouf Sandstone Formation/Abieh Formation; sandstone, claystone, lignite, basalt/limestone, marl) crop out. Only where those layers crop out over sufficiently large areas, wastewater reuse will be an option. **Wastewater reuse on outcrops of the geological units J6 (Bikfaya Formation) and J4 (Keserwan Formation) should be ruled out, because of the very high vulnerability of the underlying groundwater to pollution as a consequence of the high karstification.** Groundwater vulnerability maps are urgently needed to delineated suitable wastewater reuse areas.

It is recommended to **allow only class I** treated domestic wastewater **reuse** in karst areas if all other protection measures (e.g. location in groundwater protection zone I+II, thin soils, steep slope, close to streams or infiltration features, etc) are fulfilled. Class II + III should only be allowed in areas with thick soils, for example in the Bekaa Valley.

The application of wastewater reuse requires a careful nutrient management. In order to avoid pollution of the groundwater resources an oversupply of nutrients to the soil should be avoided.

10.2 Health Constraints

Apart from those hydrogeological aspects, health aspect related to the impact on human beings resulting from exposure to the reclaimed water and resulting from the crops grown using reclaimed water have to be considered.

Human exposure to reclaimed wastewater must be monitored and controlled:

- **Reclaimed water sources (pipes, storage tanks, etc.) have to be clearly marked** (commonly different color).
- **Exposure of farmers** to reclaimed water has to be minimized. Good hygiene practices have to be applied so that farmers are protected from potentially negative health impacts. Their good health should be controlled regularly.
- **Exposure of neighbors** of farms where reclaimed water is applied, whether through skin contact or inhalation, to reclaimed water has to be ruled out.
- **Exposure of consumers** must be monitored and controlled.

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10.3 Responsibilities

An agreement between the operator and the local irrigation committee where reuse is intended should be prepared. This agreement should cover the scheduling, approximate amounts and quality of reclaimed water to be reused. It also needs to specify a transfer point of responsibility from the WWTP operator to the local irrigation committee.

The operator of the WWTP must be responsible for maintaining the required quality, specified in the reuse standard at any time. The operator has to conduct a monitoring program for all quality parameters specified in the Standard for Reuse of Treated Domestic Wastewater for Irrigation. The operator must conduct this monitoring through an accredited laboratory. If the standards cannot be met for any reason, the operator must inform the farmers (irrigation committees) using reclaimed water and stop delivery thereof immediately.

A governmental supervising authority must control the validity of the analyses. If results of the operator and the governmental supervising authority do not sufficiently match (difference must be <10 % for any parameter) for more than five samplings, the governmental supervising authority needs to review the sampling and analysis procedure of the operator and suggest changes thereof. This review should be handed over to the Government (Ministry of Energy and Water) and to the operator. If 3 months after this handover there are still differences >10 % in the results of any parameter, the Government would put a certified laboratory of their choice in charge of conducting the sampling and monitoring of reclaimed wastewater quality at the expense of the operator.

The parameters specified in the reuse standard have to be met at the location where reuse of reclaimed water is intended. This means that the design of the treatment process must take into account the processes occurring during the transfer.

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ANNEX 1: Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation

1 Subject

This standard specifies the conditions under which treated wastewater could be reused in agriculture.

2 Definitions

2.1	Domestic wastewater	Domestic wastewater that might include industrial and commercial wastewater that is allowed to be drained to the wastewater networks according to the official connecting conditions of the authorities concerned and where the share of industrial or commercial wastewater is less than 10%.
2.2	Reclaimed water	Treated domestic wastewater which is intended to be reused according to this specification unless this wastewater is mixed with other resources.
2.3	Green areas	Areas that are specified for aesthetic purposes but not for promenade purposes.
2.4	Mechanical treatment systems	Systems that use mechanical methods for treating wastewater such as activated sludge, RBC (Rotating Biological Contactors) and trickling filters.
2.5	Natural treatment systems	Systems that treat wastewater naturally by aerobic, anaerobic or maturation ponds.
2.6	Disinfections	Process which removes or decreases pathogenic microorganisms or pollution that might exist in water, through using disinfectants such as chlorine, ClO ₂ , UV, ozone or any disinfectant adopted by authorities concerned.
2.7	Industrial crops	Crops used for industrial purposes such as wood and olive trees.
2.8	Field products	Products planted in wide areas and harvested yearly which include the following: <ul style="list-style-type: none"> - Fodder Products: products planted for animals feeding purposes such as alfalfa, sweet corn, sudani grass. - Crop Products: products planted for its carbohydrates grains to be used for feeding humans and animals such as: wheat, barley and corn. - Bean Products: products used for their seeds after

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		<p>drying such as lentil, fenugreek and lupine.</p> <ul style="list-style-type: none"> - Fiber products: products planted for their fibers such as cotton and linaceae. Oil products: products planted for their oil such as, sesame and soya beans. - Sugar products: crops planted to extract sugar such as sugar beet and sugar cane
2.9	Cooked vegetables	vegetables usually eaten after cooking which includes: eggplant, zucchini, beans, cauliflower, potato, okra, peas, spinach, and artichoke, turnips, Jew's mallow (mulukhiyah).
2.10	Vegetables eaten raw	include the following vegetables: tomato, cucumber, green pepper, cabbage, onion, carrot, radish, lettuce, mint, rocket, legume, strawberry, water melon muskmelon, parsley and coriander.
2.11	Accredited laboratory	A Lebanese or international laboratory certified by the national authority for standards and norms.
2.12	Groundwater vulnerability	The likelihood of groundwater to become polluted
2.13	Permeability	The capacity of water to flow through sediments and rocks
2.14	Exposure	An event that brings the specified group into contact with elements detrimental to their health
2.15	Karst	Limestone rocks that have been affected by calcite dissolution through weathering processes. Rainwater is infiltrating in karst through connected dissolution paths. Due to commonly fast transfer and lack of attenuation capacities, pollution spreads rapidly in karst aquifers.
2.16	Groundwater protection zone 1 and 2	Areas which have been declared protected zone by the Government of Lebanon through a decree in order to protect the groundwater resources. The landuses not allowed in protection zones are listed in the decree.

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3 General Conditions

- 3.1 Treated industrial or commercial wastewater is not qualified for reuse in irrigation.
- 3.2 In karst areas only category 1 treated domestic wastewater can be applied for all reuse purposes
- 3.3 Treated domestic wastewater reuse is not allowed in groundwater protection zones 1 and 2.
- 3.4 Treated domestic wastewater reuse of categories 2 and 3 can only be applied in areas of very low or low groundwater vulnerability. Groundwater vulnerability maps have to be available in order to decide whether an area qualifies for such reuse. In karst areas only such methods can be used for groundwater vulnerability mapping which are specifically intended for karst areas.
- 3.5 Treated domestic wastewater for irrigation has to conform to all parameters specified below in Tables 1 and 2 and according to the final planned use category when it is being reused at the reuse location. The parameters specified in Tables 1 and 2 have to be met at the location where reuse of reclaimed water is intended. The design of the treatment process must take into account the processes occurring during the transfer.
- 3.6 It is not allowed to dilute reclaimed water by mixing it in the treatment plant with pure water to achieve the stated conditions in this specification.
- 3.7 In case reclaimed water is reused for purposes other than those stated in this standard, a standard concerning such use is to be used or, if not available, to be prepared after appropriate researches carried out bearing in mind health and environmental effects.
- 3.8 Official authorities concerned with operating and designing wastewater treatment plants should always attempt to achieve a treated wastewater quality which is better than listed in the standards in the interest of making best use of reclaimed water and achieving the optimal environmental conservation.

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- 4.1 Requirements consists of two parameter groups:
- General Parameters are those mentioned in Table 1 which oblige the operating agency to be committed to producing water conforming to those standards according to the uses mentioned in the specification.
 - Crop Production Parameters are those values mentioned in Table 2 and considered as threshold values for crop production.

Limits for all above mentioned parameters have to be maintained in order to meet the standard.

- 4.2 Treated wastewater should not be used to irrigate vegetables eaten uncooked (raw).

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- 4.3 Sprayers must not be used for the purposes of irrigation except in golf yards. Such sprayers have to be used at night (00:00 a.m. to 05:00 a.m.) only.
- 4.4 Irrigation should be stopped two weeks before reaping the harvest if reclaimed water was used to irrigate fruit trees. Falling fruits and those touching the ground should be eliminated.
- 4.5 Containers, tanks, cisterns, trucks and pipes storing or transferring treated wastewater for agriculture have to be marked with a shining orange color and label stating that they are intended for treated domestic wastewater reuse for irrigation.
- 4.6 Humans should not come in direct contact with treated wastewater to be reused for irrigation through skin contact or inhalation.

Table 1: Characteristics and Standards which should be maintained for Treated Domestic Wastewater Reuse for Irrigation

Parameter/unit	Permitted limits according to aspects of uses		
Aspect of Use	Cooked vegetables, parks, public gardens, lawns, golf courses, playgrounds and planted road sides in populated areas and other areas with direct public exposure	Fruit trees, lawns, wooded areas, and other areas with limited public access, road sides outside urban areas, ponds, water bodies and ornamental streams, where public contact with water is not allowed	Field crops, industrial crops and forest trees, areas without public access
Category	1	2	3
BOD ₅ (mg/L)	30	200	300
COD (mg/L)	100	500	500
DO (mg/L)	>2	-	-
TSS (mg/L)	50	200	300
pH (unit)	6-9	6-9	6-9
Turbidity (NTU)	10	-	-
NO ₃ (mg/L)	30	45	70
T-N (mg/L)	45	70	100
E. Coli MPN or CFU/100ml	100	1000	-
Intestinal Helminth Eggs (egg/L)	≤ 1	≤ 1	≤ 1
FOG (mg/L)	8	8	8

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Table 2: Maximum Allowable Limits for Reuse of Treated Domestic Wastewater for Irrigation – Threshold Values for Crop Production

Characteristic and standards	Maximum Allowable Limit
Phenol (mg/L)	< 0.002
MBAS (mg/L)	100
TDS (mg/L)	1500
Total PO ₄ (mg/L)	30
Cl (mg/L)	400
SO ₄ (mg/L)	500
HCO ₃ (mg/L)	400
Na (mg/L)	230
Mg (mg/L)	100
Ca (mg/L)	230
SAR	9
Al (mg/L)	5
As (mg/L)	0.1
Be (mg/L)	0.1
Cu (mg/L)	0.2
F (mg/L)	1
Fe (mg/L)	5
Li (mg/L)	2.5 (0.075 for citrus fruits)
Mn (mg/L)	0.2
Mo (mg/L)	0.01
Ni (mg/L)	0.2
Pb (mg/L)	0.2
Se (mg/L)	0.02
Cd (mg/L)	0.01
Zn (mg/L)	2
Cr (mg/L)	0.1
Hg (mg/L)	0.002
V (mg/L)	0.1
Co (mg/L)	0.05
CN (mg/L)	0.1

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5 Quality Control

- 5.1 Wastewater treatment plant owners and operators should make sure that treated domestic wastewater quality complies with required specifications according to its final use. They have to perform essential laboratory tests and the results should be documented and presented to governmental monitoring authorities whenever requested.
- 5.2 Wastewater treatment plant owners and operators are responsible for taking composite samples every 2 hours for 24 hours according to the succession illustrated in Table 3. A duplicate sample, for potential control by government monitoring authorities, has to be kept for 1 week and may be used by the governmental monitoring authority for control purposes. The governmental monitoring authority has the duty and right to take and analyze samples of treated domestic wastewater for reuse in irrigation whenever necessary. Access to their staff must be granted at all times by the wastewater treatment plant owners and operators.
- 5.3 Succession of collecting and analyzing samples for monitoring and operating agencies shall be according to Table 3.
- 5.4 Samples are to be taken, kept, transmitted and analyzed according to the Standard Methods for the Examination of Water and Wastewater issued by the American Public Health Authority and American Society for Water Research and Pollution Control and its appendixes or any other accredited analysis methods if not available in the above reference.
- 5.5 As for mechanical treatment plants that include polishing ponds and waste stabilization ponds, BOD₅ is calculated after filtration.
- 5.6 Geometric mean is used to calculate heat resistance faecal coliforms results or E.Coli at evaluating reclaimed wastewater quality.
- 5.7 As for evaluating total nitrogen content in the reclaimed wastewater, geometric mean is used but for not less than 5 samples.
- 5.8 Heat resistance faecal coliforms test results are considered to be an alternate for E.Coli test results when technical instrument are not available.
- 5.9 In case of specifying new criteria unstated in these specifications, the national institution responsible for standards and norms is to be referred to.
- 5.10 In epidemic cases, monitoring and operating authorities should investigate in detail the intestinal pathogens presence in wastewater resources.

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Table 3: Number of Samples and Tests Required for Quality Control of Treated Wastewater

Parameter	Sampling frequency* Operating Agency	Sampling frequency Monitoring Agency
Inflow/outflow (m ³ /sec)	continuously	
pH, temperature, colour, TDS, electric conductivity, residual chlorine, turbidity, DO	continuously	2/month
BOD ₅ , COD, TSS, total N, total P, NO ₃ , E. Coli, FC,	twice per week or every 5,000 m ³	2/month
AOX, phenols, FOG	weekly or every 10,000 m ³	2/month
helminth eggs, thermotolerant coli, cryptosporidia, gardia	weekly or every 10,000 m ³	2/month
Na, Ca, Mg, K, SO ₄ , Cl, B, Li	12/year or every 50,000 m ³	12/year
Cd, Cr, Cu, Hg, Ni, Pb, Zn	12/year or every 50,000 m ³	12/year
Al, As, Be, B, Co, Fe, Li, Mn, Mo, Se, V	6/year or every 0.1 Mio m ³	6/year

* whichever occurs earlier, i.e. for larger WWTPs (about >10 000 people) the sampling frequency would be based on outflow; for smaller WWTPs sampling frequency would be based on time

6 Evaluation Procedures

- 6.1 Samples of treated domestic wastewater will be taken independently by
a) the wastewater treatment plant owners and operators
b) the governmental supervising authority
- 6.2 For the purpose of evaluating reclaimed water quality according to in this standard, internationally accepted methods will be used. The laboratory has to be accredited by the government supervising the operation of the wastewater treatment plant and the methods used for analysis have to be accepted by this supervising authority.
- 6.3 If results of the operator and the governmental supervising authority do not sufficiently match (difference must be <10 % for any parameter) for more than five samplings, the neutral entity needs to review the sampling and analysis procedure of the operator and suggest changes thereof. This review should be handed over to the Government (Ministry of Energy and Water) and to the operator. If 3 months after this handover there are still differences >10 % in the results of any parameter, the Government would put a certified laboratory of their choice in charge of conducting the sampling and monitoring of reclaimed wastewater quality at the expense of the operator.
- 6.4 If any of the parameters concerning the quality of reclaimed water is exceeded, an extra set of two samples is to be taken from reclaimed water. If laboratory results of the two samples do not comply with the standards, the concerned governmental supervising authority should be notified immediately to correct the situation as soon as possible. If the governmental supervising authority confirms the exceedance of the limit values of any of the parameter

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listed in Tables 1 and 2, the use of treated wastewater should be stopped. The wastewater treatment plant owners and operators must inform the farmers (irrigation committees) using reclaimed water and stop delivery thereof immediately. Delivery can only be resumed if quality is again below the allowed maximum limits and the governmental supervising authority has agreed in writing to resume delivery of reclaimed wastewater for reuse in irrigation.