MINISTRY OF WATER AND IRRIGATION
Water Resource Policy Support

STANDARDS, REGULATIONS & LEGISLATION FOR WATER REUSE IN JORDAN

May 2001

(Replaces in full the draft of February, 2001)

The Water Resource Policy Support activity is supported by
The United States Agency for International Development (USAID) through a
Contract with Associates in Rural Development Inc.(ARD):
USAID/ARD Contract No. LAG-I-00-99-00018-00, Delivery Order No. 800

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EXECUTIVE SUMMARY

An important reason for review and possible revision of current water reuse standards is the unequivocal statement in the Jordan Water Strategy—adopted by the Jordanian Council of Ministers—stating: *"Wastewater shall not be managed as 'waste'; It shall be collected and treated to standards that allow its use in unrestricted agriculture and other non-domestic purposes, including groundwater recharge".* Current standards for water reuse do not permit use of reclaimed water for unrestricted agriculture.

In addition, there are other good reasons for revising the existing standards, including:

- The need to update existing standards, periodically
- Desire to reflect the state of knowledge about use of reclaimed water
- Necessity of reflecting the importance of water reuse in Jordan, as part of its overall integrated water resources
- Bringing focus on safe implementation of water reuse, protecting the public health, leaving other important considerations (environmental protection, soil characteristics, agricultural productivity) to the discretion of customers and other governmental entities
- Need to simplify compliance with uniform standards by all involved
- Need to streamline enforcement of the standards

For Jordan, an important objective is protection of the export market against restrictions imposed by importers, based on the poor microbiological quality of the irrigation water. Existing standards for water reuse were reviewed and compared with similar standards in effect in neighboring countries, and in other regions of the world, with similar climatic conditions and water shortage situation. In the course of developing the proposed new standards, discussions were held with various stake-holders in the Ministry of Water and Irrigation, Water Authority of Jordan, Jordan Valley Authority, and Ministry of Health. Several stakeholder presentations were made, including one to the Water Authority of Jordan (WAJ) Committee on Sewerage and Treatment Plants, currently working on revisions to Jordanian water reuse standards.

In this report, a three-tiered set of criteria is recommended. The first tier would encompass only the legally enforceable water reclamation standards, primarily aimed at protecting the public health, and the workers' health. This would be accomplished through regulation of parameters that (1) ensure optimal performance of the wastewater treatment plant, (2) indicate microbiological safety of reclaimed water, and (3) can be controlled at the wastewater treatment plant.

A second tier of criteria is aimed at protection of the soil and crop yields, critically important concerns in water reclamation and reuse. Parameters dealing with these concerns are assigned limits in "guidelines"—not legally enforceable standards—for critical judgment of suitability of the reclaimed water for any given use. Agronomic and other users' concerns are critical, but most of the constituents of agronomic concern cannot be controlled or adjusted in a typical water reclamation plant. They are best handled technically and managerially by source control, and by the users of reclaimed water, in collaboration with the appropriate governmental agencies, including those producing reclaimed water from wastewater. It would be an unreasonable (if not impossible) burden on the treatment plant operations personnel to be responsible for every parameter that might affect soil and crop productivity or for industrial applications of water reuse, under all conditions. This concept is a major departure from existing standards, which attempt to regulate all parameters.

Finally, the third tier of criteria addresses a relatively new concern, called "emerging" contaminants, including synthetic organic compounds, various pharmaceutical products, such as veterinary and human antibiotics, sex and steroidal hormones, and other endocrine disruptors. These constituents are of greatest concern in the drinking water supply. Their relevance in water reuse arises from the fact that some reclaimed water (or wastewater effluent discharged to water bodies) may end up in the domestic water supply through the aquifers or surface water sources. The best way to manage these substances is through source control and with well-designed research programs conducted in appropriate academic institutions.

Based on the above, a regulatory framework is proposed primarily to ensure protection of the public and workers' health, while at the same time sending a clear message to the importers of Jordanian food crops about the safety of crops grown with reclaimed water. Qualitatively, tradeoffs between cost and strictness of standards were weighed. Also, risk levels were weighed against treatment standards, also in a qualitative[1] way. This report presents the rationale for the content of the framework, and offers the framework as a tool for discussion and stimulation of ideas. It is expected that these ideas and reactions to the proposed framework will form the basis for a forum at which the stakeholders can build the elements of a new set of standards for water reuse. The proposed regulatory framework consists of eight separate elements:

1. Definitions
2. Sources of Reclaimed Water
3. Uses of Reclaimed Water
4. Use Area Requirements
5. Monitoring Requirements
6. Reporting and Operational Requirements
7. Design Requirements
8. Reliability Requirements

Numerical standards for intensive monitoring, control, and legal enforcement of the tier 1 criteria are proposed to be limited to those in Table ES.1. These parameters would be monitored by the wastewater treatment plant personnel, as feedback to control strategies, and for maintaining a complete record of plant performance. Intensive monitoring of the primary control parameters (fecal coliform, helminth eggs, turbidity, BOD5, total nitrogen, and residual chlorine) is critical to reliability of production of safe reclaimed water. Monitoring for the primary process control

[1] It is not possible, at the current stage of knowledge, to draw quantitative relationships between these variables with any degree of accuracy.

parameters should be intense, to give quick feedback to treatment plant operators about any problems that may need immediate correction and adjustment. Criteria in the third column of Table ES.1, when and if implemented, would remove the restrictions imposed by current standards on irrigation of raw-eaten vegetables.

Table ES.1. Proposed Tier 1* Standards for Jordanian Water Reuse Regulation

Process Control Parameter	For Use in Restricted Irrigation of		For Use in Unrestricted Irrigation of
	Orchards, Forest, Fodder, Industrial Crops, Grains	Vegetables Eaten Cooked, Processed	Vegetables Eaten Raw, Public Parks, Other Urban Uses
Fecal Coliform	1,000	200	23
Nematode Eggs	1	1	1
B.O.D.	100	50	15
Turbidity	12	10	2
Total Nitrogen	45	45	30
Residual Chlorine	NR	NR	0.5

* Tier 1 includes parameters that can be controlled by wastewater treatment operators.
NR=Not Required

Other important parameters are placed in the second tier, or "guidelines", sampling and monitoring for which would be conducted by other governmental agencies, such as WAJ, JVA, Ministry of Health, Ministry of Agriculture, and the Royal Society for Scientific Research, as well as universities and other organizations. It is recommended that data generated by all these organizations be coordinated and shared. Further, it is recommended that all data on water quality be managed and displayed in user-friendly formats and made easily available to anyone interested in the safety of uses of reclaimed water. Secondary, guideline parameters should be monitored monthly by agencies other than the treatment plant operators.

It is recommended that the existing standards and the framework offered in this paper be used as a basis for eventual development of two sets of separate standards, one for treatment plant discharge requirements, and another for water reclamation and reuse. The standards for treatment plants emissions to the environment would be largely the same as the existing standards 893/1995 as specified for "Discharge to water bodies and catchment areas". The separate standards for treatment plants would be based on the framework presented in Section V of this report with three distinct tiers of criteria. Only the top tier of criteria should be the responsibility of treatment plant operators.

It is recommended to limit the scope of legally regulated water reuse standards to the primarily public health parameters, and provide for requirements and prohibitions that protect the health of field workers and the general public. These requirements should be legally enforceable, providing for measured and appropriate penalties for violations.

I. INTRODUCTION

The anticipated population increases for the Amman-Zarqa area demand that all water supplies--including reclaimed water--be considered in a systematic and integrated water resources plan. An integrated approach to water and sewerage planning can save wastewater disposal costs while increasing the water supply. The role of reclaimed water in the water supply picture is well established now in most of the arid and semi-arid regions of the world. The first step toward capturing this important resource is implementing and enforcement of appropriate standards.

Jordan's Water Strategy, formally adopted by the Council of Ministers[2] in May 1997, places a high priority on the resource value of reclaimed water. The strategy states unambiguously:

> ***"Wastewater shall not be managed as 'waste'; It shall be collected and treated to standards that allow its use in unrestricted agriculture and other non-domestic purposes, including groundwater recharge."***

This statement is a clear indication that the highest level of government in Jordan recognizes the full value of reclaimed water[3] to the overall water resources of the country. It is logical to expect that this recognition also provides the necessary financial resources, from Jordan's national coffers and external sources, to accomplish its purpose. The Water Strategy is explicitly cognizant of the importance of *sustainable* development of resources, public health and environmental protection, and economically sound planning and implementation of water projects. It calls for appropriate changes in institutional and regulatory frameworks to facilitate development of water resources in the best interests of the nation. Based on the adopted strategy, it is necessary to stress the objectives of the Water Strategy:

1. Meeting water supply needs,
2. providing sanitation services that protect the public health,
3. preserving the resource value of reclaimed water,
4. ensuring environmental protection, and
5. ensuring that the long-term export of Jordanian produce is not jeopardized.

The multi-objective strategy results in some instances of apparently conflicting and contradictory pressures on the planning process for a regulatory framework. Some examples of potential conflict are provided in the tabulation shown in Table I.1. Because of these potential conflicts, different governmental agencies should regulate the separate nationally important objectives. For example, environmental protection truly belongs in the purview of an independent environmental ministry or agency.

[2] Ministry of Water and Irrigation, Hashemite Kingdom of Jordan. "Jordan's Water Strategy", Amman, Jordan, April, 1997.
[3] The very word "waste" must be gradually removed from the vocabulary of water reuse, adopting instead "water reclamation" and "water recycling" as a positive step toward garnering public acceptance of safe practices in water reclamation and reuse for a wide variety of uses.

Table I.1. Pressures for Control of Constituents In Reclaimed Water

Constituent	For Public Health Protection	For Environmental Protection	For Resource Preservation
Nitrogen	Manage, to protect against infant methemoglobenemia	Minimize, to prevent open water eutrophication	Maximize in early season, minimize in late season
BOD	Minimize	Minimize, to avoid anoxic conditions in streams, and lakes	Maximize for soil enrichment
Organic Matter	Minimize	-	Maximize for soil conditioning
Trace Metals	Not relevant after settling and stabilization	Minimize, to prevent bioaccumulation	Manage for micronutrient benefit
Microorganism	Minimize indicator organisms to safe levels	-	-
Salts	Manage and minimize	Minimize against long-term accumulation	Minimize for sensitive crops

This tabulation points out that for certain constituents (such as nitrogen, BOD, organic matter content) there is a clear conflict, while for others (such as trace metals, microorganisms, and salts) there is across-the-board uniformity of objectives. Obviously, wherever it is not possible to meet both conflicting objectives, a sacrifice is necessary. For example, if it is not possible to preserve the nitrogen resource value in reclaimed water (due to its long-term threat to groundwater quality and infant mortality[4]), it becomes necessary to lower its concentration in reclaimed water, unless an ingenious way can be found to achieve both objectives simultaneously—for example, by adding dilution water or alternate irrigation with another source, at critical periods in the growing season.

Background

Standards and regulations for water reuse in Jordan need to be flexible and dynamic, to respond to the ever-changing environment, particularly water availability, meet the challenges of the markets, allow for the practical realities on the ground, and allow for the fiscal realities of the present.

Objectives of Activity

The objective of this activity is to determine the standards and regulations that are required for water reuse in the present and for the future. The recommendations have to be practical, with a high degree of success in being accepted and implemented in Jordan. This document lays the basis for a regulatory framework to be used for discussions leading to eventual adoption of revised standards.

Scope & Limitations

This paper is intended as a working document from which the standards and regulations, and possibly the laws, will be examined both in the present and future context. In this version of the paper all recommendations are preliminary and should be closely examined by stakeholders and discussed at great length.

[4] Nitrates in drinking water supply have been associated with methemoglobinosis, also known as the "blue baby" syndrome, resulting in death of the infant due to inability of the blood to carry oxygen.

II. REVIEW OF STANDARDS AND REGULATIONS

The need for standards for water reuse is self-evident; without standards one cannot objectively judge the adequacy (safety and long-term viability) of a source of reclaimed water for a given type of use. Water reclamation and reuse have expanded so rapidly in recent years that international and regional standards have evolved in different parts of the world. Jordan's special circumstances and requirements call for flexible standards tailored or adapted to its own local conditions. A review of prevailing standards in Jordan, and several other Countries would be fruitful before recommending changes to the criteria currently in effect.

Use of a new source of water--reclaimed or otherwise--for any purpose should begin with evaluation of its physical and chemical quality, aside from public health parameters. Standards for such uses in agriculture, industry and commerce have been established. These standards are not different for water that has been reclaimed from wastewater. The concentration of some parameters in reclaimed water being substituted for a pre-existing source may be different—making it inferior or possibly superior. The standards discussed here are those driven primarily by public health considerations. For a thorough discussion of *water quality for agriculture*--exclusive of public health considerations--refer to the FAO publication by that name[5].

Risk-Based Standards and Regulations for Water Reuse

Ideally, standards for the protection of public health would be established scientifically, based on the level of risk associated with a given level of exposure resulting from that standard. The art and science of risk assessment is highly specialized, relatively young, and generally undeveloped—especially in terms of microbial risk assessment. A thorough discussion of risk-based assessment of human health hazards from pollutants remaining in reclaimed water is presented in Chapter 13 of "*Wastewater Reclamation and Reuse*"[6], published in 1998.

The level of "acceptable" risk, which would be the basis for setting standards, is highly controversial, as a basis for setting limits on the acceptable maximum concentration of each pollutant in reclaimed water. There is generally a strong correlation between the level of economic development in a given country and the strictness of water reuse regulations in force. The more affluent a region's economy, the more stringent is the water reuse regulation adopted, in general. It can be shown empirically that the most stringent standards of water reuse do provide the greatest overall public health protection and economic benefits to the nations adopting them—accounting for the higher costs of treatment. The higher standards are clearly (though not necessarily quantitatively) associated with correspondingly lower levels of risk to the consuming public and to the farm workers. A compelling argument for stricter standards is that—if enforced—they would result in lower costs

[5] Food and Agriculture Organization of the United Nations, 1976, "Irrigation and Drainage Paper 29, Water Quality for Agriculture", Rome.

[6] Chang, Andrew, *et a*l., "*Evaluating Methods of Establishing Human Health-Related Chemical Guidelines for Cropland Application of Municipal Wastewater*", Chapter 13 in Asano, Takashi, Ed., "*Wastewater Reclamation and Reuse*", Technomic Publishing Co., Inc., Volume 10 of Water Quality Management Library, 1998.

for medical treatment, reduced number of lost days of work due to sickness from infectious disease agents, and most importantly, reduced infant mortality.

Standards, Treatment, Water Quality

The higher the standards, the higher is the level of treatment. The higher the treatment level, the better is the quality of reclaimed water intended for reuse. Table II.1 presents an overview of this relationship for a variety of conventional parameters, non-conventional parameters, and newly emerging constituents of concern in modern-day society.

Existing Water Reuse Standards and Regulations in Jordan

Jordan controls water reuse activities through country-wide standards. The legal basis governing use of reclaimed water is encoded in the *Jordanian Standards 893/1995*[7]. A translation of these standards is provided in Appendix A. Numerical criteria are provided for seven "uses" of reclaimed water in JS 893/1995:

1. Irrigation of vegetables eaten cooked
2. Irrigation of fruit trees, forests, industrial crops, and grains
3. Discharge to streams and catchment areas
4. Artificial recharge of groundwater
5. Use in aquaculture (fish hatcheries)
6. Irrigation of public parks
7. Irrigation of fodder

Discharge to streams and catchment areas (# 3, above) is not a water reuse activity as such. In fact, regulations for discharges of effluent to the environment must be promulgated and enforced separately from water reuse regulations and standards. A tabulation of 47 specific parameters, and their limits for each of the seven uses named above is provided in JS 893. Even though numerical criteria are provided for artificial recharge in the tabulation of criteria, JS 893 also specifically forbids it: "Groundwater aquifers being used for drinking purposes are prohibited from being artificially recharged with treated domestic wastewater."[8] On the other hand, the **Jordan Water Strategy** specifically includes groundwater recharge as one of the desirable uses of reclaimed water, as quoted in Section I, above.

[7] Department of Standards and Meteorology, Hashemite Kingdom of Jordan, JS 893, "Water Reclaimed from Treated Domestic Wastewater", adopted in 1995. Discussion of current Jordanian standards is based on unofficial translation into English, dated March 6, 2000, by Yasser K. Nazzal, Directorate of Environment, Ministry of Water and Irrigation.

[8] This apparent contradiction may be explained if the intent is to allow recharge of aquifers that have become too saline to be useful for drinking water supply. An aquifer recharged for the express purpose of irrigation water use must subsequently be controlled strictly to prohibit withdrawal of water for domestic use.

Table II.1 Typical range of effluent quality after various levels of treatment

Constituent Classification	Constituent	Range of effluent quality, mg/L: After secondary with BNR plus disinfection	After secondary with BNR plus depth filtration plus disinfection	After secondary with BNR plus microfiltration plus reverse osmosois plus disinfection
Conventional	Total suspended solids	5 - 20	1 - 4	1
	Colloidal solids	5 - 10	1 - 5	1
	Bichemical oxygen demand	5 - 20	1 - 5	1
	Total organic carbon	10 - 20	0 - 5	0 - 2
	Ammonia	0.1 - 1	0.1 - 1	0.1
	Nitrate	1 - 10	1 - 10	1
	Nitrite	0.001 - 0.1	0.001 - 0.1	0.001
	Total nitrogen	2 - 12	2 - 12	1
	Phosphorus	0.1 - 0.5	0.1 - 0.5	0.5
	Turbidity	2 - 6	2	0.1 - 1
	Bacteria	2.2 - 240	2.2	≈ 0
	Protozoan cysts and oocysts[a]	5 -10	1	≈ 0
	Viruses[b]	$10^1 - 10^4$	10^{-4}	≈ 0
Nonconventional	Refractory organics	1 - 5	1 - 5	1 - 5
	Volatile organic compounds	1 - 2	1 -2	1
	Metals			
	Surfactants	1 - 2	1 - 1.5	1
	Totals dissolved solids	500 - 700	500 - 700	10 - 50
Emerging	Prescription and non-prescription drugs[c]	Unknown	Unknown	Unknown
	Home care products	Unknown	Unknown	Unknown
	Veterinary and human Antibiotics	Unknown	Unknown	Unknown
	Industrial and household Products	Unknown	Unknown	Unknown
	Sex and steroidal hormones	Unknown	Unknown	Unknown
	Other endocrine disruptors	Unknown	Unknown	Unknown

Notes: It is assumed the secondary treatment includes biological nutrient removal
[a] Value per 100 mL
[b] Plaque forming units/100 mL
[c] Pharmaceutically active substances

Source: Tchobanoglous, G., F.L. Burton, and D. Stensel (2002), *Wastewater Engineering: Treatment, Disposal, Reuse*, 4th ed, McGraw-Hill Inc., New York (in press).

Prohibitions of use of reclaimed water in the existing regulations include the following:

- Irrigation during the last two-week period before harvest.
- Use of fruit fallen to the ground.
- Deterioration of soil properties.
- Damage to crops sensitivities to constituents of reclaimed water.
- Sprinkler irrigation.
- Irrigation of crops eaten raw (tomato, cucumber, carrot, lettuce, radish, mint, parsley, pepper, cabbage, cauliflower, and the like)
- Transport of reclaimed water in unlined channels across recharge areas.
- Dilution of reclaimed water with "fresh" water to meet the criteria is prohibited.
- Use of reclaimed water to recharge aquifers used for drinking water supplies

Other Countries' Water Reuse Standards and Regulations

Numerous organizations, countries and states have adopted standards specifically addressing water reuse. The basis for these standards is essentially the *protection of public health* against risk of exposure to microorganisms and chemicals that are typically found in raw wastewaters and lesser-treated effluents. None of the standards in effect in other countries are strictly based on the level of risk associated with the limits in those standards. However, the more intimate the contact—i. e., the greater the risk of exposure—the more treatment steps are generally required and the better is the expected quality of the finished water.

In this document, some of the most stringent water reuse regulations (such as those in use in California, Kuwait, and Japan) are compared with the more simple regulations and guidelines employed in other parts of the world. Many Mediterranean countries have adopted standards based on the guidelines of the World Health Organization (WHO). However, the more affluent Gulf countries and those in the resource-rich West have established much more stringent standards, especially for uses of reclaimed water, which involve intimate contact with humans—such as irrigation of raw-eaten food crops. Some countries, such as Jordan and Mexico have chosen to prohibit use of any reclaimed water for irrigation of food crops where the edible portion of the fruit and vegetables may come in contact with the irrigation water. While this provision—if adequately enforced—can be effective in protecting the public health, it reduces the farmers' choice of crops and reduces the value of reclaimed water as a source of irrigation water.

A thorough discussion of regulations and guidelines for water reuse from throughout the world is found in a publication of the United States Environmental Protection Agency, "Guidelines for Water Reuse"[9]. A summary of water reuse standards from other regions—some with similar climatic conditions to those of Jordan—is presented in Table II.2. In the following section, several of the current water reuse standards are reviewed.

World Health Organization Water Reuse Guidelines

The World Health Organization (WHO) has developed minimally appropriate

[9] USEPA, September 1992, EPA Manual: "Guidelines for Water Reuse", Washington, D. C.

standards for water reuse, intended primarily for use in developing countries[10]. These standards are based on removal of pathogens, such as intestinal nematode eggs and other disease-causing microorganisms. The potential for bacterial and virus survival, under these standards, is a common criticism of the WHO Guidelines and a reason for its less-than-universal adoption. However, if the uses of crops grown with reclaimed water can be controlled—usually a difficult part of enforcement of regulations—the WHO standards may be quite adequate. A summary tabulation of the WHO Guidelines for water reuse is shown in Appendix B.

United States Environmental Protection Agency Water Reuse Guidelines

The United States EPA does not have a regulatory role in setting or enforcing standards for water reuse. However, it provides suggested guidelines for selective adoption. These guidelines are general, providing elaborate criteria for treatment train, water quality, monitoring, buffer zone and other considerations for a large number of types of water reuse. They provide the most comprehensive coverage of use types, use conditions and applicable recommended limits for each use. There is a high degree of conservatism, incorporating redundant safety factors to compensate for some possible shortcomings in operation and maintenance.

State of California Water Recycling Criteria (Title 22)

The State of California has one of the most stringent regulations governing water reuse, requiring extensive treatment of the reclaimed water and intensive monitoring of the use sites. These requirements underwent recent revision and were finally adopted[11] on December 2, 2000; but they remain relatively strict and expensive for producers of the water to comply with. Table II.3 displays 43 specific uses of water for which recycled water is deemed suitable in California, with given treatment levels. Nearly all non-potable uses are permitted with disinfected tertiary reclaimed water.

AWWA Guidelines for Distribution of Nonpotable Water

The California-Nevada Section of AWWA has published guidelines[12] for distribution of reclaimed water in areas where potable water is also served. The purpose of these guidelines is primarily to provide unofficial standards for planning, designing, constructing, and operating nonpotable water systems delivering reclaimed water to urban customers. These guidelines are unique in that they do not provide water quality criteria, but do provide structural and operational criteria to protect the integrity of the potable water systems against the possibility of cross-connection with the reclaimed water distribution system. Use of these guidelines will be indispensable if/when indoor uses of reclaimed water—for toilet flushing, for example—become a possibility in the future, in Jordan.

[10] World Health Organization, 1989, "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture", Report of WHO Scientific Group, Technical Report Series 778, World Health Organization, Geneva.
[11] The complete text of the current official California Water Recycling Criteria can be found at http://www.dhs.ca.gov/ps/ddwem/publications/Regulations/recycleregs_index.htm
[12] California-Nevada Section, American Water Works Association, 1992, Guidelines for Distribution of Nonpotable Water,

Table II.2. Summary of Selected[13] Water Reuse Guidelines, Criteria and Standards from Around the World

Parameter or Requirement	W.H.O. Guidelines	JORDAN 893/1995	California	Texas	Tunisia	Kuwait	Japan	South Africa	Israel
Fecal Coliform (MPN/100mL)									
unrestricted urban irrigation	200		2.2	75			not detect[15]	--	12
restricted urban irrigation	1,000		23	800				< 1,000	250
food crops eaten raw		Prohibited[14]	2.2	75				0	12
non-food crops	1,000	<1,000	23	800				< 1,000	250
toilet flushing, dust control	--		2.2					0	
Total Coliform (MPN/100mL)									
unrestricted urban irrigation						100			
restricted urban irrigation						10,000			
limited public contact							< 50		
no public contact							< 1,000		
Intestinal Nematodes (eggs/L)	1	1			1				
Turbidity, NTU									
limited public contact			2	3			< 5		
no public contact							< 10		
ornamental lakes, streams							10		
Chlorine Contact (minute)									
food crops eaten raw			120						120
processed, peeled, cooked			120						60
Residual Chlorine (mg/L)			([16])						
raw-eaten vegetables		Prohibited				1			0.15
processed, peeled, cooked		0.5							0.5
landscape irrigation		0.5				1			

[13] Standards presented are mostly from countries and states where climatic conditions are somewhat similar to those of Jordan.
[14] Jordanian standards prohibit irrigation of food crops with reclaimed water, whether those food crops are consumed raw or cooked, and whether the food crop is skinned, peeled, or not. The current regulation does not make a distinction as to whether irrigation water contacts the edible portion of the crop.
[15] Not detectable: E. Coli (count/100 mL) is the applicable criterion in Japan.
[16] None required in the California Water Recycling Criteria. However, a chlorine residual is generally maintained (at least 0.5 mg/L) in the distribution system to minimize regrowth of coliform bacteria.

Parameter or Requirement	W.H.O. Guidelines	JORDAN 893/1995	California	Texas	Tunisia	Kuwait	Japan	South Africa	Israel
							0.4		
BOD, total (mg/L)[17]					30				
food crops eaten raw		Prohibited		30, 10[18]		10			15
processed, peeled crops		150		30, 10[18]					35
fodder, orchard		250		30, 20[19]		10			45
fiber, seed, trees		150		30, 20[19]					60
COD (mg/L)		200-700			90	40			
Suspended Solids (mg/L)		50-250			30	10			
Dissolved Oxygen (mg/L)		>2							0.5
Posting of Signs			required on all use sites						
Buffer Distance (meter)			18[20]						
restricted urban irrigation									--
fodder, orchard									250
fiber, seed, sugarbeets, trees									300
Treatment Prescribed									
unrestricted urban irrigation			disinf. tertiary			advanced		advanced	--
restricted urban irrigation			disinf. second.			advanced		prim., sec., tert.	--
food crops eaten raw		Prohibited	disinf. tertiary			advanced		advanced	filtr., disinf.
non-food crops			secondary	Ponds		advanced		prim., sec., tert.	--
toilet flushing, dust control			disinf. tertiary					Tertiary	

Source: Jordanian standards were obtained from the English translation of regulations (JS 893 / 1995) in effect in January 2001. Most of the other regional standards were adapted from the U. S. EPA Manual: "Guidelines for Water Reuse", 1992.

17 A dissolved BOD standard is also specified in the Israeli standard: 10 mg/L for unrestricted crop irrigation and 20 mg/L for processed crops, restricted access areas, football fields, and golf courses

18 30 mg/L with pond systems, 10 mg/L with other treatment methods. Spray irrigation not permitted on foods eaten raw.

19 30 mg/L with pond systems, 20 mg/L with other treatment methods.

20 Distance from nearest water supply well. Other buffer distances are required by local health authorities for less-than-tertiary-treated reclaimed waters.

Table II.3. California Water Reuse Standards Allowed Uses of Recycled Water

	Treatment Level			
Uses of Recycled Water	Disin-fected Tertiary	Disinf. Secondary 2.2[21] MPN	Disinf. Secondary 23 MPN	Undisin-fected Secondary
Irrigation of:				
Food crops where recycled water contacts the edible portion	**Allowed**	Not allowed	Not allowed	Not allowed
Parks and playgrounds	**Allowed**	Not allowed	Not allowed	Not allowed
School yards	**Allowed**	Not allowed	Not allowed	Not allowed
Residential landscaping	**Allowed**	Not allowed	Not allowed	Not allowed
Unrestricted-access golf courses	**Allowed**	Not allowed	Not allowed	Not allowed
Any other irrigation uses not prohibited by other provisions	**Allowed**	Not allowed	Not allowed	Not allowed
Food crops, surface-irrigated, above-ground edible portion	**Allowed**	**Allowed**	Not allowed	Not allowed
Cemeteries	**Allowed**	**Allowed**	**Allowed**	Not allowed
Highway landscaping	**Allowed**	**Allowed**	**Allowed**	Not allowed
Restricted-access golf courses	**Allowed**	**Allowed**	**Allowed**	Not allowed
Ornamental nursery stock and sod farms, w/public access	**Allowed**	**Allowed**	**Allowed**	Not allowed
Pasture for milk animals for human consumption	**Allowed**	**Allowed**	**Allowed**	Not allowed
Non-edible vegetation with access control	**Allowed**	**Allowed**	**Allowed**	Not allowed
Orchards with no edible portion contact with recycled water	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Vineyards with no edible portion contact with recycled water	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Non food-bearing trees, including Christmas trees	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Fodder and fiber crops and pasture for animals	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Seed crops not eaten by humans	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Food crops undergoing commercial processing	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Ornamental nursery stock, sod farms, no public access	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Recreational, landscape lakes:				
Non-restricted recreational impoundments	**Allowed**	Not allowed	Not allowed	Not allowed
Restricted recreational impoundments, fish hatcheries	**Allowed**	**Allowed**	Not allowed	Not allowed
Landscape impoundments without decorative fountains	**Allowed**	**Allowed**	**Allowed**	Not allowed
Cooling or air conditioning:				
Air conditioning involving cooling tower, that creates a mist	**Allowed**	Not allowed	Not allowed	Not allowed
Air conditioning that does not creates a mist	**Allowed**	**Allowed**	**Allowed**	Not allowed
Other uses (recharge, industrial, commercial, miscellaneous):				
Groundwater Recharge	(**Allowed,** under special case-by-case permits)			
Flushing toilets and urinals	**Allowed**	Not allowed	Not allowed	Not allowed
Priming drain traps	**Allowed**	Not allowed	Not allowed	Not allowed
Industrial process water that may contact workers	**Allowed**	Not allowed	Not allowed	Not allowed
Structural fire fighting	**Allowed**	Not allowed	Not allowed	Not allowed
Decorative fountains	**Allowed**	Not allowed	Not allowed	Not allowed
Commercial laundries	**Allowed**	Not allowed	Not allowed	Not allowed
Consolidation of backfill material around potable water pipes	**Allowed**	Not allowed	Not allowed	Not allowed
Artificial snow making for commercial outdoor uses	**Allowed**	Not allowed	Not allowed	Not allowed
Commercial car washes	**Allowed**	Not allowed	Not allowed	Not allowed
Industrial boiler feed	**Allowed**	**Allowed**	**Allowed**	Not allowed
Nonstructural fire fighting	**Allowed**	**Allowed**	**Allowed**	Not allowed
Backfill consolidation around nonpotable piping	**Allowed**	**Allowed**	**Allowed**	Not allowed
Soil compaction	**Allowed**	**Allowed**	**Allowed**	Not allowed
Mixing concrete	**Allowed**	**Allowed**	**Allowed**	Not allowed
Dust control on roads and streets	**Allowed**	**Allowed**	**Allowed**	Not allowed
Cleaning roads, sidewalks and outdoor work areas	**Allowed**	**Allowed**	**Allowed**	Not allowed
Flushing sanitary sewers	**Allowed**	**Allowed**	**Allowed**	**Allowed**

Source: Adapted (and simplified) from the California Code of Regulations (Title 22), the full text of which is available from the Internet, at: http://www.dhs.ca.gov/ps/ddwem/publications/Regulations/recycleregs_index.htm

[21] Total coliform as Mean Probable Number in 100 milliliters.

State of Florida Water Reclamation Standards

The State of Florida criteria for protection of public health in water reuse are similar to California's. Extensive requirements are placed on system reliability, storage requirement, loading rates, groundwater monitoring, buffer zone distances, etc. These considerations are important to good project design and to ensure reliable production of pathogen-free water. They do not directly affect the degree of public health protection afforded. A unique feature of Florida water reclamation is that residential landscape irrigation with reclaimed water is common in several cities.

Mexico's Water Reuse Standards

The Mexican standards for agricultural irrigation use of reclaimed water are probably one of the least stringent among the countries that regulate water reuse. These standards[22] classify reclaimed water into four types, based on indicator coliform and parasite eggs concentration:

Type of Water	Total Coliform (MPN / 100 mL)	Fecal Coliform (MPN / 100 mL)	Helminth Eggs (eggs / L)
1	<1,000	--	0
2	--	1 to 1,000	<1
3	--	1,001 to 100,000	--
4	--	>100,000	--

The four reclaimed water types, combined with three irrigation methods (flood, furrow, and spray) and a 15- to 20-day minimum interval between the final irrigation and harvest provide a list of allowed and disallowed food crops. The Mexican model for regulating irrigation use of reclaimed water may be of interest for partial adaptation to Jordanian conditions. Table II.4 presents a selective summary of the Mexican regulations for irrigation of food crops with reclaimed water.

Table II.4 Mexican Standards for Irrigation of Food Crops with Reclaimed Water

Irrigation Method	Water Type	No Irrigation Days	Food Crops Allowed for Irrigation with Reclaimed Water
Flood	1	> 20	garlic, bean, pickling cucumber, cucumber, melon, watermelon
	2	> 20	melon and watermelon
	3	> 20	none of the vegetables and fruits on the list, below*
	4	> 20	no food crops whatsoever
Furrow	1	> 15	garlic, kidney bean, pickling cucumber, cucumber, melon, watermelon, green tomato
	1	> 20	free to irrigate all vegetables and fruit—unrestricted
	2	> 20	garlic, cucumber, melon, watermelon, green tomato
	3	> 20	melon and watermelon
	4	> 20	no food crops whatsoever
Spray	1	> 20	garlic, pickling cucumber, cucumber, melon, watermelon
	2,3,4	> 20	no food crops whatsoever

* Generally disallowed vegetables: rhubarb, garlic, celery, watercress, beetroot, broccoli, onion, coriander, cabbage, cauliflower, parsley, radish, carrot, pickling cucumber, cucumber, pumpkin, tomato and green tomato. The last five vegetables are not included on the list if they are grown on trellises, aboveground. List of generally disallowed fruits: strawberry, melon, watermelon and brambleberry.

[22] Comision Nacional del Agua, 1993, "Aprovechamiento de Aguas Residuales en La Agricultura Situación actual en México", Instituto Mexicano de Tecnología del Agua

No restriction is placed on irrigation of non-food crops, or on those food crops not on the specifically disallowed lists, such as industrial crops, tree crops, peeled fruits, processed foods. Mexican standards also include a list of chemical parameters more relevant to soil and plant health than to human health.

The Mexican water reuse standards for public health are compatible with the WHO standards, and can be met with the use of stabilization ponds for wastewater treatment. The great advantage of such standards, for a community with limited local resources and inexpensive tracts of land, is their simplicity. The parameters associated with the criteria are easy to measure and monitor. Compliance can be readily determined, and violations are easy to document. The success of these standards in protecting the public health depends, to a large extent, on the level of government enforcement to prevent local farmers from growing disallowed crops.

The disadvantage of these standards is that they are limited to irrigation uses of reclaimed water only at the lowest treatment levels. If and when treatment levels increase, over the future years, and as urban and industrial water reuse becomes generally accepted, more protective criteria, specifying a wider range of uses, become necessary.

Saudi Arabia

The Kingdom of Saudi Arabia (KSA), largely an arid desert, similar and adjacent to Jordan's Western desert, has a goal of attaining total water reuse. The KSA is rapidly increasing the proportion of highly-treated effluent (disinfected tertiary) put to beneficial use. The nation has developed one uniform standard for unrestricted irrigation. This standard parallels the disinfected tertiary recycled water standard of the State of California. However, it specifies also heavy metals and certain trace constituents such as phenol, oil and grease, cyanide, and boron. This is a rigid and rather high standard, affordable where high capital, energy, and operating costs do not pose a limitation. But, it simplifies on-site enforcement and protects the public health without a significant compromise. Planning for the City of Riyadh's 25-year future development call for total use of reclaimed water in public and private landscaping as well as in future industries[23].

Republic of South Africa

The standards for water reuse in South Africa are extensive, varying by use type and the level of restriction of access to the use area. They require advanced treatment, often beyond tertiary—with zero fecal coliform and meeting general drinking water standards—for irrigation of food crops eaten raw, residential landscaping, children's playgrounds, and human washing. The standards for irrigation of non-food crops are more relaxed, allowing fecal coliform levels of up to 1,000 MPN / 100 mL. These standards are appropriate for South Africa, with a fairly developed technological base, and with relatively strong existing regulations for protection of the environmental health.

[23] Sheikh, B., *et al*., "Riyadh, Kingdom of Saudi Arabia: A Vision of 2021: Introducing Water Reuse to A World Capital", Presented to Water Reuse 2000, Joint AWWA-WEF Specialty Conference held in San Antonio, Texas, January 30-February 2, 2000.

Japan

Japan has elevated urban water reuse to a very high profile. All new buildings with floor area over 3,000 m^2 in Japan are required to be dual plumbed for use of reclaimed water in toilet flushing. In many buildings the reclaimed water is generated and treated within the building itself. Toilet flushing comprises almost 40 percent of water reuse in Japan, for a total of 110,000 m^3/day. Standards adopted for water reuse in Japan are quite strict, with E. Coli count less than or equal to 10 MPN / 100 mL for toilet flushing and non-detectable for landscape irrigation, use in ornamental lakes and discharge to streams. These are very high standards and are deemed appropriate for a country able to make great investment of its resources in wastewater management and advanced water reuse technology.

In Japan, in many commercial and residential buildings, untreated lavatory water (from hand washing) is directly led into the reservoir for toilet flushing. This is essentially a water conservation practice, but it achieves water reuse at the point of use, with minimal transmission and no treatment cost.

III. EVALUATION OF EXISTING STANDARDS

Other Regions of the World

In reviewing the standards adopted by other regions for water reuse, it is important to recognize (a) the economic conditions of the region for which those standards are adopted, (b) the level of protection "guaranteed" by those standards, and (c) the comprehensiveness of uses covered by the standards. Possibly at the two extremes are the standards in California and those in Mexico. The California standards are highly comprehensive, covering over 40 specific and general use types of recycled water. They are also very stringent, with high treatment levels. Consequently, it costs a great deal of resources to comply with these standards. Finally, they are designed for a region with relatively affluent water and wastewater agencies, able to afford a very high level of public health protection. Mexico, on the other hand has limited its standards to irrigation of agricultural crops, with a relatively simple restriction on irrigation of specific crops. These standards are much more affordable for a region with highly limited resources. In between these two extremes are the norms of several other regions in the world, where water reuse is currently being practiced under conditions both similar and dissimilar to those in Jordan.

Criteria for Protection of Soils and Crops

Few of the existing legally enforceable criteria and standards go beyond controlling parameters with a direct relevance to public health. It is generally preferable to separate public health concerns from the specific parameters of relevance to the particular use of reclaimed water. For example, TDS, boron, SAR, etc. are relevant in irrigation of crops and landscaping, without having any public health effects.

Trace Elements

Standards for water reuse generally do not include heavy metals because these elements tend to concentrate in the sludge (biosolids) and are rarely a proper concern of any of the uses of reclaimed water. Hardness, ammonia, heavy metals, iron, silica, etc. are important constituents of reclaimed water for some industries, without affecting the public health at all. By focusing only on the relevant public health issues, the standards can be made more relevant and are better amenable to enforcement.

Fecal Coliform, Nematodes, Turbidity

One public health indicator that is almost universal in the standards reviewed above is the use of fecal coliform as the criterion for meeting the test of treatment adequacy. The World Health Organization has attempted to strike a balance between protection of the public health and affordability of treatment schemes, emphasizing reduction of parasite eggs and cysts, through gravitational settling. Several regions use turbidity as an indirect measure of treatment integrity. Since turbidity can be easily and cheaply measured continuously on the effluent stream, it provides a convenient measure (and a permanent record) of success and a quick alarm for possible failure of the treatment processes, especially for mechanical treatment plants.

Nitrogen

Nitrogen is a very special constituent in reclaimed water, with both beneficial and harmful properties. As a macronutrient, it is highly desirable under most conditions, in correct amounts applied to the soil with irrigation water, for absorption by plant roots. In excessive amounts, and at the wrong times during the growing season, nitrogen can stimulate excessive vegetative growth, stunt reproductive functions, and reduce yield, fruit size, and sugar content. Also, excess nitrogen in irrigation water —beyond plant uptake quantities—can leach past the root zone and eventually reach the groundwater table and contaminate the domestic water supply.

Nitrogen, in excess of 45 mg/L (an N) in the drinking water supply is associated with the "blue baby" syndrome, resulting in death of young infants. Thus, excess amounts of nitrogen can be both a public health hazard, and a cause of yield reduction in agriculture. Nitrogen in reclaimed water occurs mostly in the form of nitrate and ammonia, with minor amounts as nitrite and as organic compounds. These forms are interchangeable in varying degrees in various environments. Therefore, the best measure for environmental protection and farming purposes is Total Nitrogen (T-N), which is usually estimated by summing the concentrations of the various dominant forms of nitrogen in the water.

Even though nitrogen is a valuable nutrient, and even though it is costly to remove from the wastewater, it is imperative that its concentration in reclaimed water be maintained below set standards—unless somehow threats to the public health and the farming community are positively eliminated in the field.

Emerging Contaminants

A relatively new and major concern is the "emerging" contaminants, including synthetic organic compounds, various pharmaceutical products, such as veterinary and human antibiotics, sex and steroidal hormones, and other endocrine disruptors. These constituents are of greatest concern in the drinking water supply. Their relevance in water reuse arises from the fact that some reclaimed water (or wastewater effluent discharged to water bodies) may end up in the domestic water supply through the aquifers or surface water sources. The best way to manage these substances is through source control and a well-designed monitoring program that would safeguard the nation's domestic water supply. At this point it is not recommended to monitor or regulate these constituents in reclaimed water.

Treatment Train

Most standards in current use include specification of treatment train, in addition to effluent quality. Specification of treatment process achieves an important objective—ascertaining that treatment plants intended for water reuse are designed, built, and operated with the necessary provisions for reliable production of a safe reclaimed water product, even when a part of the system fails as is likely to happen to all mechanical systems with continued long-term use.

Jordanian Standards

Current Jordanian water reuse standards are found in two legal documents. One deals with reuse of effluent reclaimed from domestic wastewater (JS 893/1995), and the other document applies to reuse of water reclaimed from industrial wastewater reused directly for irrigation, artificial recharge, discharge to sea, or discharge to rivers, wadis, and catchment areas (JS 202/1991). The latter relies for specific on JS 893/1995 for general provisions and protections of the environment and the public health.

Current Jordanian standards specifically and emphatically prohibit irrigation of vegetables, those whose edible parts may contact with reclaimed water used for irrigation. This strong prohibition effectively removes these food crops from the list of uses of reclaimed water in Jordan[24]. This may become a big barrier to water reuse, if irrigation of food crops is part of a preferred alternative in the Master Plan, as it is likely to be. It is possible to initiate a water reclamation project near one of Jordan's smaller wastewater treatment plants, with advanced treatment allowing unrestricted irrigation of crops, in the near future.

Current Jordanian standards for water reuse do not address the level of treatment (primary, secondary, tertiary, or advanced), or a process chain; they only address the effluent quality. This deficiency leaves the designers and operators of future wastewater treatment works with a wide range of opportunities to reduce treatment cost, possibly at the expense of safety and reliability of the water reuse program.

Neither do the current standards provide for posting, buffer zones, separation distances of dual pipes[25] carrying reclaimed and potable water, or any other site controls.

A possible source of complication is that the current Jordanian water reuse standards attempt to regulate not only water reuse, but also discharge to streams and watersheds (wadis and catchments). It would be most appropriate for environmental protection guidelines to be placed in specific regulations separate from water reuse standards.

The current standards include a long list of controlled trace elements whose relevance to water reuse is questionable or only marginal—where treatment processes have reduced the level of such constituents to safe levels. Many of these constituents can and should be dealt with on a case-by-case basis, in situations

[24] In spite of this prohibition, existing irrigation water supplies are generally so severly polluted that even legal use of water from rivers and canals results in contaminated food crops. This is probably the cause of restriction of import of food crops from Jordan into some of the neighboring and Gulf countries.

[25] Existing regulations do provide for separation of sewer lines from water lines.. Similar provisions need to be incorporated into the standards regulating reclaimed water distribution networks in communities with dual distribution systems. In the future.

where they actually are relevant to reuse or to environmental protection.

The standards also include maximum concentrations for use of reclaimed water in "fish culture", a use for which no examples can be found in Jordan at the present time. Specific use criteria for possible future aquaculture and industrial uses of reclaimed water should be developed in technical water reuse guidelines of good practice, and not legal regulations. The guidelines should then be widely distributed to the users of reclaimed water as part of a public information program.

Enforcement of Current Standards

Observations in the field indicate that site control of type of crop grown with reclaimed water has been sporadic in the past, in Jordan. Farmers normally grow whatever crops bring them the greatest economic return, irrespective of water quality and the standards of treatment in effect, sometimes to their own immediate peril, both in terms of health and economics. It is probably because of these violations that certain neighboring countries have refused to import Jordanian produce on the dubious rationale that all such produce is grown with raw wastewater. A focused educational effort, coupled with routine public health extension services could correct this situation.

IV. RATIONALE FOR REVISED WATER REUSE STANDARDS

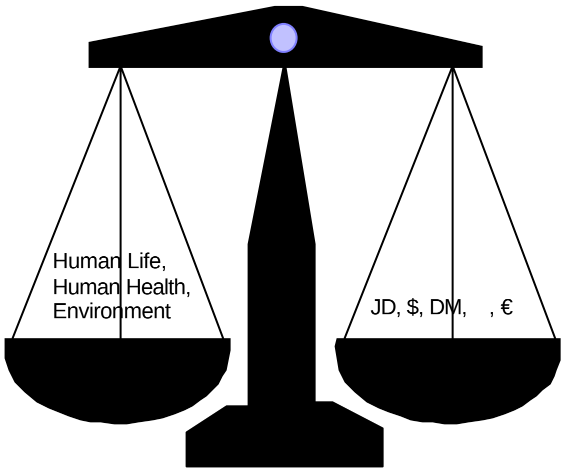
The purpose of recommending revised, focused, and expanded standards of water reuse is to ascertain that the next set of adopted standards are and remain pertinent and applicable to conditions in Jordan. At the same time, it is important to bear in mind the goals for regulating water reuse, i.e.:

1. to protect the health of the farm workers and others likely to come in direct contact with reclaimed water.

2. to protect the health of the public that consumes vegetables, fruits, other foodstuffs, and materials produced and services rendered with the use of reclaimed water.

3. to protect the environment[26] against degradation as a result of long-term accumulation of pollutants.

4. to protect export markets of produce against the unfair and inaccurate stigma that Jordanian food crops are grown with sewage.



Achieving these objectives without expenditure of inordinate sums of money is a delicate balancing act. On the one hand are the value of human life, public health, and the health of the environment. On the other is the level of resources needed to protect these values at the proper level. Unfortunately, national resources are excruciatingly limited and therefore difficult compromises must be made. The political judgment used to arrive at compromise must also take into account the relative importance and urgency of other societal needs demanding expenditure of limited national and donor resources. The recommendations offered here are based on an intuitive and informal combination of these considerations.

Tradeoff Between Protection Level and Cost

Certainly, more stringent standards are more protective and achieve the objectives of the standards with a greater degree of assurance. However, the cost of achieving the higher standards escalates rapidly and might make implementation less probable. it is possible to set standards and expectations too high to achieve,

[26] As has been indicated earlier in this paper, environmental protection should be the primary purview of the Directorate of the Environment, or (if established) the future Ministry of the Environment. However, other governmental agencies must coordinate their standards and regulations such that they do not contravene the principles of long-term protection against environmental deterioration.

leaving the public unprotected, thereby defeating the whole objective of setting standard. A delicate balance must be struck by the decision makers between the level of protection desired and the amount of monies committed to achieve those protections.

Tradeoff between Risk Reduction and Resource Allocation

Another important element of the balance between cost and the level of standards is recognition of risk, and the accepted or tolerated level of that risk. Risk is a fact of life, omni-present in all human endeavors. Risk cannot be completely eliminated, but it can be controlled and minimized through intelligent planning—including the adoption of appropriate standards. Risk can be brought into an acceptable range, but not without vigorous enforcement of the adopted standards.

It is impossible to achieve a “zero-risk” environment. Zero-risk is a theoretical concept toward which one strives to approach. However, it is possible to reduce risks (to the public health, to the environment, and to water supply availability) to low enough levels that are acceptable to most—if not all—the stakeholders. Technology exists for achieving as low a level of any given contaminant in reclaimed water as is deemed necessary. However, the cost to society for achieving extremely low levels is so high, and the marginal gains so incrementally small, that strategic compromises are necessary. It is within this spirit that the ranges of limits are proposed in this framework for discussion and debate among stakeholders: those who are affected by the results, and those who are asked to pay for achievement of the standards.

What level of risk is acceptable in Jordan?

This is a pivotal question, but unfortunately there is no simple answer for it. Practically all engineering works involve safety factors geared toward reducing risk of failure down to an elusive acceptable range. The lower the acceptable level of risk, the higher the cost. Theoretically, zero risk entails infinite cost, making it an untenable proposition even for the richest nations. Acceptability of risk, at any arbitrarily established level, is a political decision, sometimes reached through default, but commonly based on an informal analysis of measurable costs and subjective benefits associated with a specific project.

Important as the risks to the public health—due to microbes and chemicals—are, these are not the only risks of using poorly treated reclaimed water. Farmers also face a huge economic risk from foreign countries, including neighboring and Gulf countries, which may refuse to buy Jordanian food crops. These potential importers of Jordanian crops claim that the crops are grown with sewage; hence they are not admissible into their countries. Yet, those same countries have extensive irrigation schemes with highly treated reclaimed water for their own crops and landscapes. Continuation of import restrictions on Jordanian crops is a risk whose probability of occurrence is evidently 100 percent. Adoption of internationally common standards for irrigation of food crops with safe levels of reclaimed water and positive enforcement of such standards, along with an educational campaign, is the surest way to reduce this risk to near zero.

It is inevitable that the level of protection against all known risk factors afforded by an adopted standard suffers from some degree of arbitrariness, due to the infancy of the science of health risk assessment. The wealthier nations consciously err on the side of conservatism, setting standards that have a much higher factor of safety than necessary. The less well-endowed nations would be well advised not to err in the opposite direction.

Phased Approach to Regulation and Standard Setting

Based on the above discussion, we recommend a series of criteria for water reuse, which can be implemented in three phases over the next twenty-five years. We believe that the California-style water reclamation standards—adapted or copied by several other regions—are more than adequately protective of the public health, and bring the risks down to a very low level, quite acceptable by most (though not *all*) people in the highly industrialized countries. These standards are probably most appropriate as an *ultimate* goal—perhaps 25 or 50 years hence.

In the meantime, for practical usefulness and a high (though certainly not an absolute) degree of public health protection, the WHO or similar standards, coupled with strict use-site controls, may be adopted for the short-term. While our immediate-term recommendation is principally aimed at correcting existing public health risk problems, our mid-term recommendation is aimed toward augmentation of Jordan's water supply with a significant boost from safe and wholesome reclaimed water, for a large variety of urban, industrial and agricultural uses. For the long-term, we recommend an emphasis on groundwater recharge in appropriate aquifers, with the goal of supplying a major portion of the water demand with more highly treated water. It would be wise to stage regulatory reform for water reuse and link it to the progress in gradual upgrading of the nation's wastewater treatment plants and increased enforcement and compliance with interim regulations.

Rationale for Standards for Agricultural Irrigation

The World Health Organization has recommended reasonable guidelines[27] for use in developing countries, intended to address the most pressing public health problems without imposing inordinate expenditure of limited resources. Limits on the final effluent concentration of intestinal nematodes and indicator bacteria (fecal coliform) are the only criteria used in the WHO-recommended guidelines for water reuse in agriculture. It is possible to achieve adequately safe levels of water quality for irrigation of crops eaten after being cooked, with stabilization ponds or aerated lagoons[28], as long as a ten-day detention time is afforded for settlement and removal of eggs and cysts of parasites found in domestic wastewaters. Other crops require even lesser treatment levels, as long as workers and the public are not exposed to the irrigation water. The most critical requirements for the continued effectiveness and success of implementing the WHO standard are:

27 World Health Organization, "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture", Technical Report Series 778, Geneva, Switzerland, 1989.

28 The other effective method of removing parasite eggs and cysts is through appropriate filtration of a secondary effluent, producing tertiary reclaimed water. This method requires very high capital expenditures and intricate operation and maintenance with highly trained and motivated operators. On the positive side, disinfected tertiary reclaimed water can be used for nearly all non-potable purposes without limitation.

1. Availability of large tracts of land near the current discharge points or where the effluent is needed for reuse;
2. Provision of adequate capacity (hence land area) into the design of the ponds to accommodate anticipated future flows; and
3. Periodic maintenance to prevent channeling of flow and excessive accumulation of sludge, both of which can result in short-circuiting and reduced effective detention time.
4. Monitoring of effluent water quality and prevention of its use when not meeting performance specifications.
5. Enforcement of the prohibition against growing raw-eaten vegetables and fruits, the edible parts of which can come in contact with reclaimed water.

The other effective method of removing parasite eggs and cysts is through filtration of a secondary effluent, producing tertiary reclaimed water. This method requires relatively high capital expenditures and intricate operation and maintenance with trained and motivated operators. Disinfected tertiary reclaimed water can be pathogen-free[29] and if so, it can be used for nearly all non-potable purposes, without limitation. This treatment level can be added to the effluent from waste stabilization ponds to produce a superior quality of reclaimed water for unrestricted irrigation uses.

Rationale for Standards for Urban (Landscape) Irrigation

Urban irrigation (for parks, school grounds, athletic fields, golf courses, street plantings, etc.) potentially exposes the general public to the microorganisms that might survive in reclaimed water. This is due to adherence of particles of suspended matter (harboring bacteria, viruses, parasitic worms, eggs and cysts) to grass, plant leaves and park tables and benches. The WHO criteria provide some protection to the public health where city parks are irrigated with reclaimed water by recommending a more stringent guideline (<200 MPN fecal coliform/100mL) as appropriate for irrigation of public lawns, with which the public may come into direct contact.

Rationale for Standards for Industrial Uses

Generally, industrial water users require consistent quality water for any one of a large variety of uses. As a minimum, secondary reclaimed water is recommended as a basic substitute to potable water offered to a target industry. Beyond that level, each specific industrial use may impose its own particular set of water quality requirements. The quality requirement for each use depends on the industry's specific water demand characteristics, type of process in use, cycles of in-plant reuse, and type of product manufactured. Additional water quality requirements—beyond those regulated for public health and environmental protection—for industries should be examined and established on a case-by-case basis, within a set of "guidelines". Examples of requirements of several industrial uses are briefly described below to illustrate the variability of user-specific water quality demands.

[29] Proper disinfection, with adequate exposure to oxidizing agents is critical in reliable production of pathogen-free reclaimed water.

Cooling Towers and Cooling Ponds

Most cooling systems can convert to using reclaimed water relatively readily as long as biological and chemical fouling of the cooling surfaces can be controlled. Silica and calcium can precipitate at high temperature and form mineral scales which reduce the heat transfer capability of the heat exchanger components.

Biological fouling can occur if coliform bacteria levels are not kept low by maintaining an adequate chlorine residual concentration in the water. Some cooling systems are equipped with condenser tubing made of special alloys, such as brass. These alloys can be corroded in time if the water, which they contact, contains even a small concentration of ammonia.

Additional treatment may be necessary to remove fouling and corroding agents. Also, as water evaporates and its salt concentration increases with each cycle, the cooling properties of the water decline. This too limits the number of cycles of cooling with high-TDS water compared with a water having a lower initial TDS. The economic implication of the reduced number of use cycles is significant for the industries involved.

Boiler Feed Water

Water is generally pre-treated before use in boilers, regardless of its source—potable or reclaimed. Several constituents must be controlled, using chemical treatment, prior to such use. Boilers operating at higher pressures (greater than 700 psig[30]) require the highest quality water, usually de-ionized water. Such additional treatment is common and should not be considered peculiar to reclaimed water use.

Concrete Mixing

Use of reclaimed water for mixing concrete for construction purposes is appropriate, resulting in a comparable strength with concrete made with potable water. Concrete trucks transporting "ready-mix" also typically carry wash water to clean the truck's dispensing facilities after each delivery. Nutrients in reclaimed water can stimulate growth of algae in open water. Thus, the sight tube employed for gauging the level of wash water in the reservoir carried on concrete trucks can be fouled with algae, if it is not brushed off and rinsed frequently. Some concrete companies choose to use potable water for the relatively small volume of water needed in the wash tank, to avoid this problem.

Fabric Dyeing

Fabric dyers do not object at all to the elevated salt content of reclaimed water, because it reduces their need for salt addition--a normal practice to improve dye adhesion to fabrics. However, they are critical about the level of iron and any other color-altering constituents in the water. Consistency of water quality is their most critical requirement, because fabric dyeing involves an intricate balance of water chemistry and dye characteristics.

Process Water

Industries that use water in delicate operations or integrate water into the process of manufacturing their product are generally even more critical of the water quality they

[30] Equal to about 5 million pascal

use than others. Most of them (electronics firms, food processors, beverage makers, chemical and pharmaceutical companies...) pre-treat any water they receive to a very high level before putting it to use. Some treatment processes (such as reverse osmosis, employed by electronics firms) require feed water that is free from biological contaminants that could give rise to fouling of the RO membranes. In general, use of reclaimed water in any food processing industry should not be considered.

Rationale for Standards for Groundwater Recharge

The Jordan Water Strategy specifically advocates use of reclaimed water for groundwater recharge. However, existing Jordanian Standard 893/95 prohibits use of reclaimed water for groundwater recharge, where the aquifer is used for drinking water supply. Paradoxically, the same standards include a list of criteria (minimum concentrations) that must be met for "artificial recharge". Based on the discussion below, it is strongly recommended that both references to groundwater recharge be eliminated from the future water reuse standards and replaced with a provision to review each proposed project separately, on its own merits. For example, where existing groundwater quality is already degraded with excess salts or other contaminants—making it unsuitable as a source of drinking water—it may be possible to recharge the aquifer with a lesser quality reclaimed water and dedicate it for irrigation water supply only. On the other extreme, a pristine aquifer used for potable water supply should be strictly guarded, possibly to the extent of prohibiting even irrigation with waters containing high nitrogen levels on grounds overlying the aquifer. In various parts of Jordan, a variety of conditions spanning these extremes are encountered. Therefore, a high degree of flexibility and site-specific knowledge is necessary in regulating groundwater recharge with recycled water.

Artificial recharge of groundwater aquifers is accomplished in two distinct ways. In the most common way, called "surface spreading", water is ponded at sandy recharge sites with appropriate soil permeability—not too high, and not too low. Alternatively, injection wells are used to introduce recharge water directly into the aquifer under pressure. The quality of the recharge water in combination with site characteristics at the recharge location determine the level of protection afforded to the groundwater aquifer. Use of reclaimed water for recharge is not new; however, the experience of other locations cannot be directly translated to all the various conditions prevailing in Jordan. Therefore, one of the basic initial requirements for groundwater recharge would be a detailed hydrogeological study of the aquifers to determine, as a minimum, the following parameters:

- Depth of the unsaturated zone above the water table
- Aquifer boundaries and depth to confining strata
- Inflow and outflow from/to adjacent basins
- Porosity, particle-size distribution and storage capacity of aquifer media
- Aquifer transmissivity
- Flow regimes, usually defined by mathematical modeling
- Location of abstraction wells and the historical pumping regime
- Existing quality of water in the aquifer
- Treatment train, reliability features, expected water quality, assurance of compliance with drinking water standards.

Designation of Groundwater Basins

The first step in protection of the quality of water in the nation's aquifers is a country-wide program to designate groundwater basin characteristics in a systematic way. This process would involve collection and review of data relevant to each basin's historic and current water quality, capacity, geology and water use patterns. Based on this information, a formal designation can be adopted. Such designation would only be subject to change after another intensive study and complete characterization. From this effort, some basins will emerge as having very high quality water capable of supplying drinking water needs on a sustainable basis. These specially valuable aquifers should be protected to the maximum extent possible through regulations and standards. Other aquifers will be found to be of degraded water quality or incapable of sustainable yields for municipal use. Such a formal designation should free these latter type of aquifers for dedication to recharge with reclaimed water strictly for irrigation—and other non-potable—uses.

For the aquifers designated as having the highest quality water and being potential source of drinking water supply, a special protective principle may be adopted. This principle is embodied in the "*non-degradation*" policy, which would prohibit introduction of any constituent at a higher concentration than initially present in the aquifer. In addition to the non-degradation policy, other established drinking water quality standards must be met before it is allowed to recharge into such a pristine aquifer.

Groundwater Recharge Guidance Criteria

Where reclaimed water is proposed for recharge, total organic carbon (TOC) is often used as a criterion to further evaluate its quality. Some of the organic carbon comes from treated wastewater. Since there are no simple tests to distinguish wastewater-origin organic matter fom natural humic matter, TOC indirectly indicates how well the contribution from wastewater is eliminated—by treatment and by filtration through the aquifer's porous media.

Where groundwater recharge augments an existing drinking water supply aquifer, it is probably appropriate to set a limit of 10 mg/L for TOC of recharge water, using surface spreading. It is strongly recommended that recharge, using direct injection wells not be contemplated, especially in aquifers supplying drinking water. If direct injection is considered, a TOC concentration of 2 mg/L or lower may be suitable as an upper limit for protection of the drinking water supply. An additional provision may be included so that at withdrawal wells, TOC shall not be higher than 3 mg/L. Recharge into a brackish water aquifer—not used for domestic water supply—may be permitted with reclaimed waters of lesser quality (higher TDS, TOC, etc.), if such aquifer is subsequently dedicated for irrigation water supply, prohibiting and preventing its use as a drinking water resource.

Other criteria to consider for groundwater recharge with reclaimed water might include:

- Vertical distance from the bottom of spreading basins to the top of aquifer (Three meters or greater);
- Horizontal distance from recharge sites to withdrawal wells (One kilometer or farther);

- Ratio of reclaimed water volume used for recharge to the volume of water recharged from other sources--naturally and otherwise--over a period of any five consecutive years (20 to 75 percent depending on field conditions.)

Almost certainly, partial desalinization (using reverse osmosis) will be necessary, to meet the non-degradation principle for groundwater replenishment. This will increase the treatment costs even further, putting off the option for serious consideration at a more distant future.

At this point, we are not recommending specific limits for groundwater recharge criteria, because of inadequate hydrogeological database[31]. It would be too easy to propose criteria that might be unnecessarily difficult to meet and hence the local agencies would be unable to comply with them. It is premature to propose criteria for groundwater recharge until some experience is gained, through pilot projects, an extensive groundwater database is established, and Jordan's aquifers are formally designated.

[31] Unofficial guidelines for these parameters in California are in use, but have not been formally adopted, in part because they have not received unqualified support from the various segments of the California water industry. Some believe that the proposed guidelines are unnecessarily stringent. Others argue that an aquifer's water quality must be protected with greatest care even if it means adopting extremely conservative criteria.

V. A REGULATORY FRAMEWORK

Regulatory Authority

A competent authority must be designated to take responsibility for updating, interpretation, and enforcement of the regulations promulgated for safe use of reclaimed water. In other regions, the responsible authority is usually that in charge of protection of the public health and/or the environment. Without appropriate, measured, and consistent enforcement, standards and guidelines are of little use. It is generally preferred that the agency charged with enforcing the regulations be separate and independent from the agency trying to expand use of reclaimed water. This separation provides for a healthy environment of checks and balances, minimizing the potential for conflict of interest.

Guiding Principles

Drafting of regulations must be guided by certain basic rules to maximize their effectiveness in achieving their objectives. These principles are:

- Simplicity and Clarity
- Comprehensiveness
- Uniformity
- Flexibility
- Fairness and Equity
- Reasonableness
- Enforceability
- Affordability

It is not possible to achieve all of these principles all of the time. In fact, some of these criteria are in direct conflict with others. Nonetheless, being cognizant of the need for adhering to these principles can prevent formulation of Byzantine rules and regulations, which might either be ignored or used to thwart widespread water reuse.

Components of A Regulatory Framework

The proposed framework may contain the following eight components:

1. Definitions
2. Sources of Reclaimed Water
3. Uses of Reclaimed Water
4. Use Area Requirements
5. Monitoring Requirements
6. Reporting and Operational Requirements
7. Design Requirements
8. Reliability Requirements

In the following sections, each of these components is described and a skeletal content provided as a starting point for formulation of regulations and standards.

Definitions

As used in this framework, specific words and phrases listed below are used to mean exactly as they are defined. It is recognized that documents prepared by others may use some of the same phrases to mean something different from that used here. The main objective of these definitions is to make a clear distinction between planned water reuse and unplanned utilization of effluents found in wadis and channels by the riparian owners and lessees of adjacent land.

Direct Water Reuse: The beneficial use of reclaimed water that has been transported from the treatment plant to the point of use directly through pipes or in lined channels, without an intervening discharge to a natural water body, such as a stream of pond.

Domestic Wastewater: Wastewater generated in residential and commercial activities, possibly also including minor amounts of industrial wastewater subjected to pre-treatment meeting the requirements of connection to the sewer network issued by the Department of Meteorology and Standards.

Effluent: flow discharged at the end of a treatment process or a treatment train, which may be suitable for some uses, depending on the level of remaining pollutants.

Food Crops: Any crops intended for human consumption.

Guidelines: Semi-official rules and limits for long-term sustainability of water activities in agricultural, industrial or urban sectors.

Indirect Water Reuse: The use of effluent from a wastewater treatment plant after it has been discharged to a natural water body, such as a stream, pond, or reservoir.

Reclaimed Water: is synonymous with "recycled water," and usually used interchangeably. Strictly speaking, "reclaimed" water originates at a central water reclamation facility, whereas "recycled" water originates onsite. This is especially true at an industrial site recycling its own water over and over again, for example in a cooling tower.

Recycled Water: water created as a result of treatment and disinfection of wastewater, and deemed safe for specific, intended uses (defined above). Recycled water is a water resource, with beneficial usefulness, the only limitations being dependent upon level of teatment, salt content and other characteristics that might restrict it to certain uses, as specified in the following sections.

Regulations: Legally adopted, enforceable rules and limits for water reclamation activities, with measured penalties provided for violations.

Standards: Limits on specific parameters, set for the purpose of protecting the public health, or the environment. Standards are usually incorporated in regulations. Sometimes "standards" are used synonymously with "regulations".

Undisinfected Reclaimed Water with Fecal Coliform <1,000 MPN/100mL: Reclaimed water produced as a result of treatment in waste stabilization ponds or mechanical treatment plants, meeting the Helminth limit of <1 egg/L and fecal coliform maximum limit of 1,000 MPN/100mL.

Undisinfected Reclaimed Water with Fecal Coliform <200 MPN/100mL: Reclaimed water produced as a result of treatment in waste stabilization ponds or mechanical treatment plants, meeting the Helminth limit of <1 egg/L and fecal coliform maximum limit of 200 MPN/100mL.

Unplanned Use of Wastewater Effluent: Withdrawal by gravity or pumping from wadis where a major portion of the flow is effluent from an upstream wastewater treatment plant. This is an unauthorized use of wastewater, even if at the point of discharge, effluent quality meets the standards in effect.

Unrestricted Use: Use of pathogen-free reclaimed water for all non-potable uses, including irrigation of any food crops consumed without further processing. (The restriction on potable use still applies—unless treatment includes membrane filtration and robust multi-barrier provisions against survival of microorganisms and presence of harmful concentrations of trace organic compounds. This framework does not address potable reuse[32].)

Use Area: Any area where reclaimed water is used, with defined boundaries.

Wastewater Reuse: Unregulated (illicit) use of wastewater or inadequately treated wastewater effluent for irrigation of crops or for any other uses.

Water Reclamation: The process of safe salvaging of usable water from wastewater by a combination of treatment processes (physical, chemical, biological), disinfection, and/or salt removal.

Water Recycling: Water recycling is synonymous with "water reuse." This term is used in some regions exclusively in reference to all water reclamation and reuse activities, because of the positive public image of "recycling" as an environmentally good deed.

Water Reuse: is the intentional, planned reclamation of water from wastewater and its conveyance and distribution to agricultural, industrial, and other sites, where it can be put to beneficial use.

Sources of Reclaimed Water

The requirements of this regulatory framework apply to reclaimed water derived from sources that contain domestic wastewater in whole or in part, including the 17 existing public-sector wastewater treatment plants in Jordan.

[32] Potable reuse is technically achievable. However, there are cultural and psychological barriers to its implementation, which appear unsurmountable in Jpordan, at the present time. It is conceivable that in the distant future, some indirect potable reuse options may be considered under a separate, or expanded regulatory framework.

Uses of Reclaimed Water

Only uses specifically defined in this section are authorized. All other uses are illegal and subject to penalties as provided in law (needs more specifics, references to other regulations, etc.)

Use of Reclaimed Water for Irrigation

Reclaimed water used for irrigation shall be used with use-area controls that protect the health and safety of workers and the general public who may be exposed to the water. Control of constituents of reclaimed water that may be harmful to the soil or to the crop or affect the yield of crops shall be the responsibility of the user. Undisinfected reclaimed water with fecal coliform level consistently below 1,000 MPN/100 mL may be used for irrigation of specific use areas given in Table V.1, as further limited by the irrigation methods in use.

Table V.1 Proposed Allowed* Uses of Undisinfected Reclaimed Water **with <1000 MPN/100 mL** Fecal Coliform for Irrigation

	Irrigation Method		
Type of Crop or Landscaping	Mulch/ Drip	Surface	Sprinkler
Raw-eaten & above-ground & contacts water (lettuce, cabbage, celery)	No	No	No
Raw-eaten & above-ground, does not contact water (orchard, vineyard)	Yes	Yes	No
Raw-eaten, edible parts below-ground (carrot, onion, radish, turnip)	No	No	No
Peeled, or cooked, or Processed (potato, cereals, processed tomatoes)	Yes	Yes	Yes
Non-food crops, seed crops, oil crops, fiber crops	Yes	Yes	Yes
Pastures, fodder	-	Yes	No
Parks, playgrounds, Athletic Fields	-	No	No
Highway landscaping, restricted public access	-	Yes	No
Forest, woods, ornamental tree nurseries, with use area control	-	Yes	Yes

* A "Yes" indicates that use of reclaimed water for the given irrigation application with that Particular method of irrigation is allowed. A "No" means that that combination of use and irrigation method is prohibited under all circumstance.

Undisinfected reclaimed water with fecal coliform level consistently below 200 MPN/100 mL can be used for irrigation of specific use areas given in Table V.2, as determined by the irrigation methods in use.

Table V.2 Proposed Allowed* Uses of Undisinfected Reclaimed Water with **<200 MPN/100 mL** Fecal Coliform for Irrigation

	Irrigation Method		
Type of Crop or Landscaping	Mulch/ Drip	Surface	Sprinkler
Raw-eaten & above-ground & contacts water (lettuce, cabbage, celery)	Yes	No	No
Raw-eaten & above-ground, does not contact water (orchard, vineyard)	Yes	Yes	No
Raw-eaten, edible parts below-ground (carrot, onion, radish, turnip)	Yes	Yes	Yes
Peeled, or cooked, or Processed (potato, cereals, processed tomatoes)	Yes	Yes	Yes
Non-food crops, seed crops, oil crops, fiber crops	Yes	Yes	Yes
Pastures, fodder	-	Yes	Yes
Parks, playgrounds, athletic Fields with use area control	-	Yes	Yes
Highway landscaping, restricted public access	-	Yes	Yes
Forest, woods, ornamental tree nurseries, with use area control	-	Yes	Yes

* A "Yes" indicates that use of reclaimed water for the given irrigation application with that Particular method of irrigation is allowed. A "No" means that that combination of use and irrigation method is prohibited under all circumstance.

Disinfected tertiary treated reclaimed water[33] can be used without restriction for irrigation of any crops, orchards, parks, or landscape, without restriction.

Use of Reclaimed Water for Industries

Reclaimed water used for industrial purposes, such as cooling, processing, boiler feed, concrete mixing, fabric dyeing, aquaculture, etc. shall be accompanied with use-area controls and protective clothing that shield workers and the public against exposure to microbial agents. Removal or reduction of constituents (such as TDS, silica, calcium, iron, nutrients, and other parameters), potentially harmful to the particular industrial application, shall be the responsibility of the specific industry. Disinfected tertiary reclaimed water can be used in industries without use-area restriction.

Use of Reclaimed Water for Groundwater Recharge

Reclaimed water may be used for groundwater recharge upon approval by the Ministry of Water and Irrigation. Such approval shall be contingent upon submittal, peer review, revisions (as necessary), and final publication of an exhaustive geohydrological study of the artificial recharge site, method of recharge, mixing with other sources of recharge water, points of abstraction for potable use, and mathematical modeling of the fate and transport of the recharged water and its constituents (including, but not limited to TDS, TOC, nitrates, and viruses. The ministry may require additional studies, additional parameters, outside reviews, and consultation with other ministries, as appropriate[34].

Use of Reclaimed Water for Other Purposes

The following uses of reclaimed water are permitted, only if pathogen-free water can be supplied in the use area: flushing toilets and urinals, priming drain traps, structural and non-structural fire fighting, decorative fountains, commercial laundries, backfilling of pipelines, commercial vehicle washing, soil compaction, dust control, road and street cleaning. Removal or reduction of constituents potentially harmful to the particular miscellaneous application shall be the responsibility of the specific user.

Use Area Requirements

No irrigation or ponding with reclaimed water shall take place within 50 meters of any domestic water supply well.

Protective clothing and breathing apparatus shall be supplied to and shall be worn by workers likely to contact undisinfected reclaimed water.

[33] Disinfected tertiary reclaimed water is intended to indicate a reliably pathogen-free reclaimed water produced at a water reclamation plant where fully oxidized wastewater is coagulated, settled, filtered and effectively disinfected with chlorine (90-minute minimum modal contact time) or with an equivalent ultraviolet or ozonation disinfection method. This clause is inserted to preserve the option for long-term future, when this use may be deemed “economical”.

[34] Rejection of any groundwater recharge proposal may be deemed in the best long-term interests of the country for preserving the integrity of a given aquifer, if assurances of long-term safety cannot be supplied..

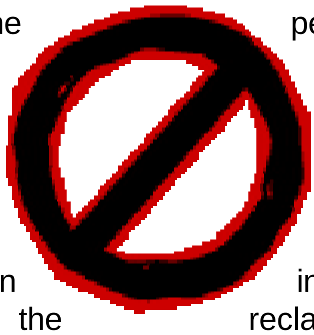
Spray, mist or runoff from reclaimed water use shall be prevented from entering neighboring properties, dwellings, outdoor eating areas, or food handling facilities.

Drinking water fountains shall be protected against contact wit reclaimed water spray, mist or runoff.

A buffer zone of 30 meters shall be provided between a reclaimed water irrigation use area and residences, parks, playgrounds, and school yards to prevent public exposure to reclaimed water, except where disinfected tertiary reclaimed water is used.

Irrigation method used shall conform to the treatment level that recycled water has received. A guide to the method of irrigation and its relation to water quality and crop types is given in Tables V.1 and V.2. The goal is to minimize the opportunity for any microorganisms in the reclaimed water attaching to the edible portion of food crops.

Signs shall be posted along the periphery of the reclaimed water use areas informing the public that undisinfected reclaimed water is being used and that direct skin contact with the water should be avoided. Such signs shall be in clear, and adequately large lettering in Arabic (and possibly in English as well), at entrances and other locations where members of the public can readily see and read them. The signs shall display an international symbol that indicates no drinking of the reclaimed water is permitted.



No connection shall be allowed between reclaimed water and a separate potable water conveyance systems.

In public access areas of reclaimed water use areas, no hose bibbs shall be provided (to prevent accidental drinking from reclaimed water distribution system.) Only quick couplers shall be used in such areas.

Monitoring Requirements

Reclaimed water shall be sampled at least once daily[35] for analysis for turbidity and fecal coliform bacteria. Samples shall be taken at a point before reclaimed water leaves the premises of the treatment plant, and analyzed by an approved laboratory. The results of the daily average turbidity and total coliform counts should be reported monthly to the regulatory agency with oversight powers on all water reclamation and reuse activities.

Reporting and Operational Requirements

Prior to initiation of a reclaimed water delivery system, a technical report shall be filed by the reuse agency with the responsible authority. The report shall be prepared by a qualified engineer experienced in wastewater treatment and shall contain the following elements:

[35] Frequency of sampling and specific parameters to be sampled, responsibility for such monitoring, and recording and reporting procedures should be subjected to further study and may be tied to level of treatment, and whether the treatment plant is operated by a public authority or a private entity.

- Description of design of treatment and features of the reclamation system
- Means of compliance with water reuse regulations
- Plan of operation and maintenance
- Contingency plan ensuring that no untreated or inadequately treated wastewater will be delivered to the use area(s).

Each water reclamation plant shall be staffed with a sufficient number of qualified personnel to operate the facility effectively and to achieve the required level of treatment at all times.

A preventive maintenance program shall be provided at each water reclamation plant to ensure that all equipment is kept in a reliable operating condition.

- Operating records shall be kept at the water reclamation plant by the water reclamation agency. These records shall include:
- Analyses specified in the criteria
- Records of operational problems
- Plant and equipment breakdowns
- Diversions to emergency storage or disposal
- Corrective actions taken.

Process or equipment failures causing an alarm shall be recorded and the record maintained in a separately maintained file. The recorded information shall include the time and cause of failure and the corrective action taken.

A monthly summary of operating records as specified above shall be filed with the regulatory agency.

Any discharge of untreated or partially treated wastewater to the use area, and the cessation of such discharge, shall be reported immediately by telephone to the regulatory agency.

Bypassing of untreated and partially treated wastewater from the water reclamation plant to the point of use is prohibited under all conditions.

Design Requirements

The design of process piping, equipment arrangements, and unit structures in the water reclamation plant must allow for efficiency and convenience in operation and maintenance and provide flexibility of operation to permit the highest possible degree of treatment to be obtained under varying circumstances.

Alarms

Alarm devices required for various unit processes shall be installed to provide warning of (1) loss of electrical power, (2) failure of biological processes, (3) failure of disinfection process, (4) any other failure resulting in inadequate treatment.

All alarm devices shall be independent of the normal power supply of the water reclamation plant.

The person to be warned shall be the plant operator, superintendent, or any other responsible person designated by the management of the water reclamation plant and capable of taking prompt corrective action.

Individual alarm devices may be connected to a master alarm to sound at a location where they can be conveniently heard or seen by the attendant.

Power Supply

Power supply for the water reclamation plant shall be provided with either (1) alarm and stand-by power source, or (2) alarm, and automatic short-term or long-term retention, treatment, and disposal provisions.

Reliability Requirements

Emergency Storage or Disposal

Where short-term retention or disposal provisions are used as a reliability feature, these shall consist of facilities reserved for the purpose of storing or disposing of untreated or partially treated wastewater for at least a 24-hour period. The facilities shall include all the necessary diversion devices, provisions for odor control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

Where long-term storage or disposal provisions are used as a reliability feature, these shall consist of ponds, reservoirs, percolation areas, downstream sewers leading to other treatment or disposal facilities or any other facilities reserved for the purpose of emergency storage or disposal of untreated or partially treated wastewater. These facilities shall be of sufficient capacity to provide disposal or storage of wastewater for at least 20 days, and shall include all the necessary diversion works, provisions for odor and nuisance control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

Diversion to a less demanding reuse is an acceptable alternative to emergency disposal of partially treated wastewater provided that the quality of the partially treated wastewater is suitable for the less demanding reuse.

Biological Treatment

All biological treatment unit processes, including waste stabilization ponds, shall be provided with one of the following reliability features:

- Alarm and multiple biological treatment units capable of producing oxidized wastewater with one unit not in operation.
- Alarm, short-term retention or disposal provisions, and standby replacement equipment.
- Alarm and long-term storage or disposal provisions.
- Automatically actuated long-term storage or disposal provisions.

Secondary Sedimentation

All secondary sedimentation unit processes shall be provided with one of the following reliability features:

- Multiple sedimentation units capable of treating the entire flow with one unit not in operation.
- Standby sedimentation unit process.
- Long-term storage or disposal provisions.

Filtration

All filtration unit processes shall be provided with one of the following reliability features:

(1) Alarm and multiple filter units capable of treating the entire flow with one unit not in operation.
(2) Alarm, short-term retention or disposal provisions and standby replacement equipment.
(3) Alarm and long-term storage or disposal provisions.
(4) Automatically actuated long-term storage or disposal provisions.
(5) Alarm and standby filtration unit process.

Disinfection

All disinfection unit processes where chlorine is used as the disinfectant shall be provided with the following features for uninterrupted chlorine feed:

(1) Standby chlorine supply,
(2) Manifold systems to connect chlorine cylinders,
(3) Chlorine scales, and
(4) Automatic devices for switching to full chlorine cylinders.

Automatic residual control of chlorine dosage, automatic measuring and recording of chlorine residual, and hydraulic performance studies may also be required.

All disinfection unit processes where chlorine is used as the disinfectant shall be provided with one of the following reliability features:

(1) Alarm and standby chlorinator;
(2) Alarm, short-term retention or disposal provisions, and standby replacement equipment;
(3) Alarm and long-term storage or disposal provisions;
(4) Automatically actuated long-term storage or disposal provisions; or
(5) Alarm and multiple point chlorination, each with independent power source, separate chlorinator, and separate chlorine supply.

Numerical Standards

The proposed numerical standards are arranged in three tiers. The first and most important tier is reserved for the most critical parameters for assurance of treatment plant operational integrity for protection of the public health. The criteria in this tier would then become legally binding requirements for water reclamation plants, whether operated by the public sector, or by private contract, producing water for reuse in agricultural irrigation and other approved uses. It would be simplest and most effective to hold the treatment plant managers responsible and accountable for those parameter over which they can reasonably exert control within the design limitations of the plant—and within budgetary limitations.

In the first tier of legally enforceable standards, three distinct qualities of reclaimed water are recognized for appropriate uses. The top-tier criteria, which would protect the public at large, are summarized in Table V.3.

Table V.3. Proposed Legal Standards for Jordanian Water Reuse Regulation

Process Control Parameter	For Use in Restricted Irrigation of: Orchards, Forest, Fodder, Industrial Crops, Grains	For Use in Restricted Irrigation of: Vegetables Eaten Cooked, Processed	For Use in Unrestricted Irrigation of: Vegetables Eaten Raw, Public Parks, Other Urban Uses
Fecal Coliform	1,000	200	23
Nematode Eggs	1	1	1
BOD_5	100	50	15
Turbidity	12	10	2
Total Nitrogen	45	45	30
Residual Chlorine	NR	NR	0.5

NR=Not Required

It would be important to monitor these few important parameters as frequently as possible, continuously in the case of turbidity (with automatic analyzers and recorders), and daily in the case of fecal coliform, residual chlorine, BOD_5, and total nitrogen.

A second tier of criteria is listed in Table V.4 for the protection of soils and crops irrigated with reclaimed water. These criteria generally are not affected in the treatment process, and their control should not be the responsibility of the treatment plant operator. Most of the criteria in Table V.4 can only be manipulated with source control, on-farm management, or with much more sophisticated treatment processes, such as membrane treatment. Criteria in the second tier should be regarded as guidelines for evaluation of suitability of a given reclaimed water, or a wastewater effluent, by the users. These guidelines may also help set governmental policy for source control or (in rare instances) more advanced treatment processes. Note that in the second tier of criteria a distinction is **not** made between different uses of reclaimed water, because for these parameters the degree of intimacy of contact with the reclaimed water is irrelevant, public health is not an issue, and the treatment plant operations generally do not affect the outcome.

Table V.4. Proposed Guideline Criteria for Jordanian Water Reuse and for Evaluation of Wastewater Effluents As Sources of Irrigation Water

Parameter	Concentration, mg/L unless indicated	
COD	500	
TDS or EC as dS/m	1,000	1.6 dS/m
TSS	100	
‘pH, as pH units	6.0 to 9.0	
F, O, &G	0.5	
NO3, as N	45	
NH3, as N	15	
Cl	350	
HCO_3	400	
Na	230	
SAR	6	
Al	5.0	
As	0.10	
Be	0.10	
Cu	0.2	
F	1.5	
Fe	5.0	
Li	2.5	0.075 for citrus crops
Mn	0.2	
Mo	0.01	
Ni	0.2	
Pb	5.0	
Se	0.05	
Cd	0.01	
Zn	5.0	
CN	0.1	
Cr	0.1	
Hg	0.002	
V	0.1	
Co	0.05	
B	1.0	
Mo	0.01	

The parameters listed in Table V.4, above, should be monitored and controlled at source and/or managed on the farm. Monitoring at the treatment plant should be conducted—but it should not be the responsibility of the treatment plant operator. Instead, JVA, WAJ, RSS, or the Ministry of Agriculture should perform this function. Monitoring for the secondary tier of criteria should be conducted at a frequency of monthly or quarterly, depending on the availability of resources. Data generated from the monitoring program should be shared widely with all stakeholders, including the farming community and those responsible for the introduction of the various constituents into the sewers.

A third tier of parameters of concern is classified as “emerging constituents”. These constituents do not have an impact on irrigated crops or landscapes. However, the concern lies in the movement of runoff from irrigated fields and leaching below the root zone toward ground water used as a drinking water resource. Monitoring and tracking of the movement of such constituents is a proper function of academic research institutions and ultimately a responsibility of the public health officials. If they determine that such constituents may pose a credible threat to the public health, only then additional restrictions on the use of reclaimed water may need to be imposed. Determination of a credible risk from any one constituent must be based on the results of sound scientific research, subjected to peer review and replication. Constituents in this category include elements such as strontium, and compounds such as pharmaceutically active substances (prescription and non-prescription drugs), home care products, veterinary and human antibiotics, industrial and household products, sex and steroidal hormones, and other endocrine disruptors.

VI. CONCLUSIONS

Review of existing Jordanian standards, and field observations of water use in various parts of the Amman-Zarqa Basin and Jordan Valley results in the following conclusions:

1. Planned water reuse, is relatively uncommon in Jordan, limited to smaller wastewater treatment plants at isolated communities.

2. Unplanned reuse of wastewater effluent from the Wadis dominated with treatment plant discharges is relatively widespread.

3. Unplanned and unrecognized wastewater reuse occurs along Jordan Valley, downstream of King Talal Reservoir (KTR). The KTR water contains a relatively high proportion of wastewater effluent originating from the As Samra treatment plant and a small percentage of surface runoff. Microbiological contamination of the water from both sources is very high, raising grave public health concerns.

4. Discharge of wastewater effluent to streams and catchment areas is not a water reuse activity as such. In fact, regulations for discharges of effluent to the environment must be promulgated and enforced separately from water reuse regulations and standards.

5. The export market for food crops grown in Jordan suffers from restrictions imposed by some of the importing countries. They have claimed that Jordanian crops are irrigated with untreated or inadequately treated wastewater. The contaminated nature of much of the irrigation water supply must be acknowledged and dealt with. A great deal of the contamination is secondary, in part from non-point sources. However, some of it does originate from inadequate treatment of wastewater effluents discharged into the water ways of the nation.

6. Current water reuse standards attempt to regulate not only water reuse, but also environmental discharges. It is necessary to establish discharge requirements for treatment plants irrespective of, and in addition to the standards for specific uses of the effluent as reclaimed water.

7. The current standards include a long list of constituents, over many of which plant operations generally have little or no control. Many of these constituents can and should be dealt with on a case-by-case basis, in situations where they actually are relevant to water reuse or to environmental protection. These parameters have little or no direct public health significance from water reuse.

8. There is a need for active and collaborative involvement of other Ministries and agencies in aspects of water reuse that relate to environmental

protection and to the public health, especially record keeping, publication of compliance data and relevant information, and enforcement.

9. There is a need for continued scientific research in actual risk assessment in relation to levels of contamination (microbiological and chemical, including a long list of emerging contaminants) found in existing sources of water used for irrigation of various crops in Jordan, among the exposed farm worker population, as well as among the consumers of raw-eaten vegetables.

VII. RECOMMENDATIONS

The following recommendations are preliminary, offered for stimulation of discussion, and ultimately, for formulation of more definitive recommendations.

1. Use the existing standards and the framework offered in this paper as a basis for eventual development of two sets of separate standards, one for treatment plant discharge requirements, and another for water reclamation and reuse. The standards for treatment plants would be largely the same as the existing standards 893/1995 as specified for "Discharge to water bodies and catchment areas". The separate standards for treatment plants would be based on the framework presented in Section V, above, with three distinct tiers of criteria. Only the top tier of criteria should be the responsibility of treatment plant operators. Limit the scope of water reuse regulations (and standards) to the primarily public health parameters, and provide for requirements and prohibitions that protect the health of field workers and the general public. These requirements should be legally enforceable, providing for measured and appropriate penalties for violations. Intensive monitoring of the primary control parameters (fecal coliform, helminth eggs, turbidity, BOD5, total nitrogen, and residual chlorine) is critical to reliability of production of safe reclaimed water. Secondary, guideline parameters should be monitored monthly by agencies other than the treatment plant operators.

2. Make the water reuse (for irrigation) portion of JS 202/1991 consistent with the revised water reuse standards to be set for water reclaimed from domestic wastewater.

3. Widely share the recommended revisions to the water reuse standards among stake-holders including the agricultural community, public health officials, and those responsible for production and distribution of reclaimed water.

4. Nominate an independent governmental entity to maintain responsibility for implementation of treatment plant emissions (to wadis, lakes, on-site disposal, etc.) regulations and their monitoring and rigorous enforcement[36].

5. During the interim period, enforce existing standards and prohibitions against use of inadequately-treated effluent for irrigation of raw-eaten crops.

6. In the revised standards, provide for a treatment level[37] that can produce a reclaimed water quality that is safe for irrigation of raw-eaten vegetable crops and for a variety of other non-potable urban (unrestricted) uses in the future. It is

[36] Discharge to streams and catchment areas is not a water reuse activity as such. Therefore, regulations for discharges of effluent to the environment must be promulgated and enforced separately from water reuse regulations and standards.

[37] Disinfected tertiary reclaimed water is recommended. It provides a reliably pathogen-free reclaimed water. This level of safety is produced at a water reclamation plant where fully oxidized wastewater is coagulated, settled, filtered and effectively disinfected with chlorine (90-minute minimum modal contact time) or with an equivalent ultraviolet or ozonation disinfection method.

recognized that this level of treatment may not be feasible in the immediate future at any of the existing treatment plants in Jordan. However, adoption of the higher standard places an expectation on the needed level of treatment for the customers who might otherwise be tempted to use the lesser quality waters for irrigation of raw-eaten crops.

7. Remove the prohibition against use of reclaimed water to irrigate of raw-eaten vegetables and fruits, relying on # 6, above to achieve the same objective.

8. Conduct a thorough basin designation effort to define and designate the specific nature and use of each basin and its groundwater for appropriate levels of protection and utilization.

9. Regulate groundwater recharge on a case-by-case basis, relying on designations recommended in # 8, above, and further intensive, site-specific, geohydrological studies, mathematical modeling, and public input, as detailed in Section V, above. Remove the current prohibition against such uses of reclaimed water.

10. Work cooperatively with other governmental agencies to ensure source controls, enforcement, and penalties against introduction of excessive[38] quantities of salts into the wastewater collection system.

11. Provide official technical guidelines (not regulations), based on available publications, for parameters of importance to specific users[39], including:

    a. Agricultural irrigation—to protect soil resources against long-term deterioration, and to maximize crop yields
    b. Landscape irrigation
    c. Cooling towers
    d. Process-specific industrial uses
    e. Fisheries, aquaculture, constructed wetlands

12. Develop, budget, and implement a public education campaign to spread knowledge of the new regulations and guidelines, and to promote safe uses of reclaimed water to farmers, industries, and other potential customers. The Irrigation Advisory Service may implement this function.

13. Conduct research aimed at future adjustment of standards based on actual field experience with risks associated with different uses of reclaimed water at existing and future treatment levels. These studies may include immunological testing of affected populations, exposure assessment, intensive water quality assessments, and controls on other environmental variables that might confound cause-and-effect relations. The Department of Laboratories and Water Quality of the

[38] Normal domestic use of water tends to add a certain amount of salt to the wastewater. Certain appliances (water softeners used at some homes, restaurants, hotels) add inordinate amounts of salt, as do some industries with cooling tower blowdown, reverse osmosis brines, and fabric dyeing wastes.
[39] This recommendation is because control and management of constituents of reclaimed water that may be harmful to the soil or to the crop or affect the yield of crops is generally considered the responsibility of the user of reclaimed water, not the producer.

Ministry of Water and Irrigation has the qualified scientists and the necessary laboratory equipment to conduct these research activities, in association with local Universities and other scientific associations.

14. Publicize water quality data compiled in compliance with recommended standards and regulations and make related information readily available to the public, through publication of periodic reports and upon request by anyone with an interest in public health and safety of reclaimed water. The responsibility for this effort lies with all governmental agencies that collect data relevant to safety of reclaimed water.

APPENDICES

Appendix A, Jordanian Standard 893/ 1995

Water – Treated Domestic Wastewater

Department for Standards and Meterology

Contents

1. Scope

This Metrological standard is concerned with the requirements, which must be **available (met**) in the treated domestic wastewater effluent discharged from wastewater treatment plants or reused that are shown in Table 1.

2. Definitions

Domestic Wastewater is water resulted from residential use and activity that might be also be mixed with industrial or commercial wastewater from establishments that have met the requirements to be connected to the sewer network issued by the approving authority.

Treated Domestic Wastewater is water discharged from the wastewater treatment plants, which meets the requirements of this standard, unless it is mixed with water from other sources.

3. General Requirements

3-1 Treated domestic wastewater must meet the criteria shown in Table 1, according to the intended end use.

3-2 Irrigation must be stopped two weeks before harvesting (fruit collection) as treated domestic wastewater used for irrigation of fruit trees, vegetables eaten uncooked, field crops**,** fodder (forages) before grazing, and fallen fruits that are touches the ground surface must be disposed of.

3-3 In crop selection, the sensitivity of some crops to some elements or some characteristics in treated domestic wastewater must be taken into consideration as well as the negative effect on the soil properties.

3-4 Sprinkler irrigation methods using wastewater are prohibited .

3-5 Irrigation of crops eaten raw by treated domestic wastewater is prohibited. These crops include but are not limited to: tomato, cucumber, carrot, lettuce, radish, mint, parsley, pepper, cabbage, and cauliflower.

3-6 Closed pipes or lined canals must be used when conveying treated domestic wastewater through areas of high permeability (infiltration), which might effect the ground water aquifer or surface water used for drinking purposes.

3-7 It is prohibited to dilute the treated domestic wastewater on-site with fresh water for the sake of meeting the criteria of this standard.

3-8 Ground water aquifers being used for drinking purposes may not be artificially recharged by treated domestic wastewater.

4. Metrological Requirements

The treated domestic wastewater must meet the metrological requirements shown in Table 1 according to the end use, and in accordance with the following criteria:

4-1 The samples of the treated domestic wastewater must be representative, collected all over the day except those parameters that only require single samples. In addition, the number of samples and the interval between taking samples must follow the requirements shown in Table 2.

4-2 For the sake of assessing the treated domestic wastewater quality for different purposes shown in Table 1, the time period shown in Table 2 must be considered.

4-3 The percentage of samples that do not meet the requirements shown in Table 1, must not exceed 20% of the total number of samples collected during the time period shown in Table 2. No individual sample may exceed five times the allowable limit shown in Table 1.

4-4 Samples must be taken, stored and analyzed according to the Standard Methods for Water and Wastewater Examination issued by the American Society for Public Health and the American Federal Society for Water Research and Pollution Monitoring and its amendments, in addition to any other recognized method of analysis that is not available in the aforementioned references.

Table 1: Requirements for Reuse of Treated Domestic Wastewater

(Maximum allowable concentrations unless otherwise indicated.)

Quality parameters mg/L except otherwise indicated	Vegetables eaten cooked	Fruit trees, forestation, industrial crops and grains	Discharge to wadis and catchment areas	Artificial Recharge	Fisheries (2)	Public Parks	Fodder (1)
BOD_5 (3)	150	150	50	50	-	50	250
COD	500	500	200	200	-	200	700
DO	> 2	> 2	> 2	> 2	> 5	> 2	> 2
TDS	2000	2000	2000	1500	2000	2000	2000
TSS	200	200	50	50	25	50	250
PH	6 – 9	6 – 9	6 – 9	6 - 9	6.5 - 9	6 - 9	6 – 9
Color (PCU) (4)	-	-	75	75	-	75	-
FOG	8	8	8	Nil	8	8	12
Phenol	0.002	0.002	0.002	0.002	0.001	0.002	0.002
MBAS	50	50	25	15	0.2	15	50
NO_3-N	50	50	25	25	-	25	50
NH_4-N	-	-	15	15	0.5	50	-
T-N	100	100	50	50	-	100	-
PO_4-P	-	-	15	15	-	15	-
Cl	350	350	350	350	-	350	350
SO_4	1000	1000	1000	1000	-	1000	1000
CO_3	6	6	6	6	-	6	6
HCO_3	520	520	520	520	-	520	520
Na	230	230	230	230	-	230	230
Mg	60	60	60	60	-	60	60
Ca	400	400	400	400	-	400	400
SAR	9	9	9	9	-	12	9
Residual Cl_2 (5)	0.5	-	-	-	-	0.5	-
Al	5	5	5	1	-	5	5
As	0.1	0.1	0.05	0.05	0.05	0.1	0.1
Be	0.1	0.1	0.1	0.1	1.1	0.1	0.1
Cu	0.2	0.2	0.2	0.2	0.04	0.2	0.2
F	1.0	1.0	1.0	1.0	1.5	1.0	1.0
Fe	5.0	5.0	2.0	1.0	0.5	5.0	5.0
Li	2.5	5.0	1.0	1.0	-	3.0	5.0
Mn	0.2	0.2	0.2	0.2	1.0	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.4	0.2	0.2
Pb	5.0	5.0	0.1	0.1	0.15	0.1	5.0
Se	0.02	0.02	0.02	0.02	0.05	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.015	0.01	0.01
Zn	2.0	2.0	15	15	0.6	2.0	2.0
CN	0.1	0.1	0.1	0.1	0.005	0.1	0.1

Cr	0.1	0.1	0.05	0.05	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.00005	0.001	0.001
V	0.1	0.1	0.1	0.1	-	0.1	0.1
Co	0.05	0.05	0.05	0.05	-	0.05	0.05
B	1.0	1.0	2.0	1.0	-	3.0	3.0
Mo	0.01	0.01	0.01	0.01	-	0.01	0.01
TFCC (MPN/100 ml) (6)	1000	-	1000	1000	1000	200	-
Pathogens	-	-	-	-	100000(9)	nil	-
Ameba & Gardia (Cyst/L) (7)	< 1	-	-	-	-	nil	-
Nematodes (Eggs/L) (8)	< 1	-	< 1	-	-	< 1	< 1

(-): N/A

(1): Trace elements and heavy metals values are calculated based on the quantity of wastewater used for irrigation (1000 m^3/dunum/yr.), in case the quantity of water increases above the aforementioned figure the concentrations of trace elements and heavy metals decreases accordingly.

(2): these figures depend upon the type of fish, pH, TDS, and T^o.

(3): BOD_5 in WSP is filtered BOD_5, but in mechanical treatment plant is nonfiltered.

(4): Unit weight measured by unit of Platen Cobalt.

(5): Touching time not < 30 min.

(6): Most Probable Number/ 100 ml.

(7): One Cyst/ L

(8): Mean Ascaris, Enclostoma, and Trycus.

(9): Salmonella / 100 ml.

Table 2: Quality monitoring

No.	Criteria	Sampling frequency	Evaluation Interval (1)
1	Microbiological Tests *Testing TFCC * Testing Pathogens	One sample/ 2 wks One sample/ 2 wks in summer time (2) One sample/month in winter time (3)	3 months When the test result of any sample shows positive sign then 2 samples should be taken with 2 days interval between them. If the results of the last 2 samples are positive, then it should not be used any more for irrigation until the pollution is end.
2	Biological Tests *Nematodes and Parasites	One sample / 2 months	One year
3	Chemical Tests *Usual Tests *Trace elements & Heavy metals	One sample/ month One sample/ 2 months	One year One year

(1): Evaluation interval: the previous interval for the evaluation phase is considered as a base for judging the water quality.
(2): Summer time: the period from 1st of May until the end of October.
(3): Winter time: the period from the 1st of November until the end of April.

5- Technical Terms

1- Biochemical Oxygen Demand, Five Day (BOD_5)
2- Chemical Oxygen Demand (COD)
3- Composite Sample
4- Conventional Wastewater Treatment Plant
5- Dissolved Oxygen (DO)
6- Faecal Coliforms
7- Filter
8- Nutrients
9- Grab Samples
10- Intestinal Nematodes
11- Suspended Solids (SS)
12- Total Dissolved Solids (TDS)
13- Waste Stabilization Ponds (WSP)

6- Technical References

1- Jordanian Metrological Standard No. 202/ 1991.
2- Health Aspects of Using Liquid Waste in Agriculture and Fisheries, Technical Report Series No. 778, WHO, 1990.
3- Canadian Council of Resources and Environmental Ministers, " Canadian Water Quality Guidelines," March,1987.
4- FAO Guidelines for Agriculture, 1991.
5- Reuse of Effluents, Methods of Wastewater Treatment and Health Safeguards. WHO, 1989.
6- Standard Methods for the Examination of Water and Wastewater, 1989

APPENDIX B, Summary of World Health Organization "Microbiological Guideline for Wastewater Use in Agriculture"

Category	Reuse Conditions	Exposed Groups	Intestinal nematodes[b] (arithmetic mean number of eggs per liter)[c]	Fecal Coliforms (geometric mean number per 100 mL)[c]	Wastewater Treatment Expected to Achieve the Required Microbiological Quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]	Workers, consumers, public	<=1	1,000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	<=1	No standards recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in Category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

[b] *Ascaris* and *Trichuris* species and hookworm
[c] During the irrigation period
[d] A more stringent guideline (200 fecal coliforms per 100 mL) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact
[e] In the case of fruit trees, irrigation should cease 2 weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.