PILOT PROJECT
REUSE OF TREATED WASTEWATER IN AGRICULTURE IN MEKNES, MOROCCO

REPORT 4: GUIDELINES FOR TREATED WASTEWATER REUSE IN AGRICULTURE

JANUARY/MAY 2009

This publication was produced for review by the United States Agency for International Development. It was prepared by DAI.

ABRI-ADVANCING THE BLUE REVOLUTION INITIATIVE

COLLABORATING ENTITIES

DAI (Prime Contractor)

Subcontractors:

Academy for Educational Development
Aiken Global Environmental Services, LLG
AIS Development, LLC
CDM International, Inc.
CDR Associates
Duke University
ECO Consult (Jordan)
Emerging Markets Group
Environmental Quality International (Egypt)
Hatch Mott Macdonald
Hydro-Yemen (Yemen)
Institute for Public-Private Partnerships
International Development Enterprises
International Executive Service Corps
The Media Network Inc.
Kredo (Lebanon)
Metropolitan Consulting Corporation
Riverside Technology, Inc.
SETS (Lebanon)
Social Impact
TCG International, LLC
Texas Universities Partnership
Training Resources Group, Inc.
ValuAdd Management Services

Resource Organizations:

Center for Conflict Resolution (Uganda)
Dolsar Engineering Limited (Turkey)
International Society for Development in the Euphrates and Tigris Region (Iraq)
MASCA (Morocco)
Oregon State University (USA)
Overseas for Sustainable Development (Jordan)
Resource Mobilization Advisors
Water Environment Federation (WEF)
Yilma Global Consult (Ethiopia)

USAID – DAI Contract No. EPP-I-00-04-00023-00

ADVANCING THE BLUE REVOLUTION INITIATIVE

"Transforming the culture and governance of water in the Middle East and Africa"

PILOT PROJECT
REUSE OF TREATED WASTEWATER IN AGRICULTURE IN MEKNES, MOROCCO

REPORT 4: GUIDELINES FOR TREATED WASTEWATER REUSE IN AGRICULTURE

Prepared by DAI team:
Said Ouaattar, Water Management, Team Leader, Morocco
Mustapha Naimi, Soil and GIS Expert, Morocco
Ahmad Abu Awwad, Wastewater Management Expert, Jordan
Jean Karam, Institution Expert, Lebanon
Mohamed Bourrass, Ag. Engineering Expert, Morocco
Peter Reiss, COP/ABRI Project, USA

ABRI-ADVANCING THE BLUE REVOLUTION INITIATIVE

CONTENTS

TABLES AND FIGURES

TABLE

EXECUTIVE SUMMARY

REGULATIONS AND MANAGEMENT GUIDELINES FOR USING RECLAIMED WATER

Despite the influence of the Atlantic Ocean, which contributes to the area's relatively abundant precipitation, Morocco is an arid to semi-arid country. Most Moroccan towns are equipped with sewage networks that also collect industrial effluent. In the last three decades, the annual volume of wastewater has almost tripled, and it is expected to reach about 900 MCM/year in 2020. Of the 60 largest Moroccan towns, however, only 7 have treatment plants, and their design and operation are considered insufficient.

The Moroccan application Decree (No 2-97-875, 1998) related to the use of wastewater stipulates that no wastewater can be used if it has not been recognized as treated wastewater; however, most of the wastewater produced by inland towns is reused, mainly as raw or insufficiently treated wastewater, to irrigate about 8,000 hectares.

The widespread reuse of untreated sewage for agricultural production (with significant accompanying health risks) is a special case to be regulated in separate (more field-based) "standard guidelines."

In the last 50 years, many countries have taken action to create a legislative framework for the safe use of municipal wastewater in the form of regulations and guidelines. Whereas regulations are legally adopted, enforceable, and mandatory, guidelines are advisory, voluntary, and nonenforceable, but can be incorporated into water reuse permits and thus become enforceable requirements. Some national and international organizations, including the World Health Organization (WHO), prefer to use guidelines, which offer regulatory flexibility with different requirements for similar uses, depending on site-specific conditions.

By comparing the guidelines and regulations enforced by different countries, the following conclusions can be drawn:

- Only few states in the US have criteria and standards for all water reuse applications.
- The majority of the Mediterranean countries, along with WHO, consider reclaimed wastewater suitable for agricultural purposes.
- During the review, it was noted that only a limited number of countries have developed comprehensive water reclamation and reuse standards, or encourage and provide direction for water reuse. Some countries have adopted less comprehensive and less rigorous standards.

Generally, standards and guidelines are structured to provide information on several aspects: water reuse applications (for agriculture-aquaculture), methods of reuse application, level of treatment, microbiological constituents, chemical constituents, physical Properties, and monitoring and evaluation.

This report presents regulations and guidelines for the safe on-farm use of reclaimed water. It is intended for use by irrigators who already use or intend to use reclaimed water so that they can avoid health risks to themselves, their families, and the members of general public who may use their products. It provides detailed information and best practices for the Meknes Wastewater Treatment Plant (WWTP) effluent reuse in five areas: crop selection, irrigation activities, agricultural activities, harvesting, and post-harvest.

The fundamental aspect of treated wastewater use is personal hygiene. If irrigators take appropriate precautions when using treated wastewater then health and environmental risks are kept at a minimum. If, on the other hand, irrigators handle treated wastewater casually, then they expose themselves, their families, and consumers to the risk of infection.

Crops best suited for irrigation with treated wastewater outflow from Meknes wastewater treatment plant include olive trees, cereals, legumes, and fodder crops. While it is legal to grow vegetables that will be cooked after harvesting, this is only recommended when the quality of effluent is very high and where farmers are already proficient in controlled irrigation. Farmers should select crop patterns that maximize water use in both summer and winter seasons. This will require a combination of perennial and seasonal crops.

Irrigation designs must follow all standards, including the use of sand filters and screen or disk filters. If irrigators follow proper design guidelines, then there is minimal risk of breaks and leaks that may contaminate produce and the environment. The design must include the provision of fresh water for toilets and handwashing. Irrigation application must allow for leaching because of the higher salinity levels of treated wastewater. Irrigators must install drippers and emitters properly to avoid wetting of leaves and fruits.

Agricultural activities that require special attention include soil testing to identify fertilization practices that avoid over-application of nitrogen, proper pruning, and preventing animals from entering areas irrigated with treated wastewater.

Harvesting techniques focus on the need to minimize contact with the crop and to ensure that edible parts do not come into direct contact with water or soil. Irrigation should be stopped two weeks before harvesting winter fodder and fruit trees. Fodder crops are best suited for mechanical harvesting, while all fruit is picked by hand.

Produce grown using treated wastewater should be labeled and stored separately, and not brought into living quarters.

TREATED WASTEWATER REUSE

BACKGROUND

Despite the influence of the Atlantic Ocean, which contributes to the area's relatively abundant precipitation, Morocco is an arid to semi-arid country. Out of 150 billion m^3 of annual rainfall, only 30 billion m^3 are estimated to be usable (70 percent as surface water and 30 percent from aquifers). Through a sustained water mobilization effort, approximately 13.2 billion m^3 are regulated annually, and about 2.7 billion m^3 are drawn from groundwater. Thus, about 16 billion m^3 are available for industrial and domestic uses, especially for irrigation: Some 88-93 percent of this amount is used to irrigate 1.2 million hectares.

Most Moroccan towns are equipped with sewage networks that also collect industrial effluent. In the last three decades, the annual volume of wastewater has almost tripled. It has increased from 48 million cubic meters (MCM) in 1960 to 500 MCM/year in 1999 and is expected to reach about 900 MCM/year in 2020 (CSEC, 1994). Out of the 60 largest towns, however, only 7 have treatment plants, and their design and operation are considered insufficient. Most of the wastewater produced by inland towns is reused, mainly as raw or insufficiently treated wastewater, to irrigate about 8000 hectares. Sometimes the wastewater is mixed with water from the wadis into which it spills. A large proportion of the remaining water is discharged to the sea. The irrigated crops are mainly fodder crops, fruit, cereals, and produce. The growing and selling of vegetables to be eaten raw is prohibited if they have been irrigated with wastewater.

The largest water reuse project in Morocco was implemented in 1997 in Ben Slimane (near Rabat), where 5600m3/day of wastewater is treated by stabilization ponds (anaerobic, facultative, and maturation ponds), and the disinfected effluent (absent helminth eggs, less than 20 CF/100 ml) is used for golf course irrigation during the summer (for an average volume of reused water of 1000 m3/day). The country does not yet have any specific wastewater reuse regulations and usually defers to the WHO recommendations.

The lack of wastewater treatment before reuse in inland cities has resulted in adverse health impacts, and Morocco experiences a high incidence of waterborne diseases. Improvement in wastewater reuse methods and in the quality of reuse water for irrigation is recognized as essential.

Major improvements are urgently needed because of the heavy migration of the rural population toward the towns and the rapid demographic expansion. The application Decree (No 2-97-875, dated February 4, 1998), acting as Water Law 10-95 related to the use of wastewaters, stipulates that no wastewater can be used if it has not been recognized as treated wastewater. The use of raw wastewaters is thus prohibited and banished. The Norms and Standards Committee (NSC) that comes under the National Environment Council is setting objectives for the quality of receptor milieus (quality norms). The NSC is made up of representatives from all relevant ministerial departments. Among the suggested norms is a project relating to quality standards of wastewaters designed for irrigation, which specifies the bacteriologic, parasitic, and physical-chemical parameters (Table 1).

TABLE 1: QUALITY STANDARDS OF WATERS DESIGNED FOR IRRIGATION IN MOROCCO

Parameters		Limit Values
	Bacteriological	
1	Fecal Coliform	1000/100ml *
2	Salmonella	Absence in 5 L
3	Cholera Vibrio	Absence in 450 ml
	Parasitological	
4	Pathogen	Absence
5	Eggs, Parasite cysts	Absence
6	Ancylostoma larva	Absence
7	Flurococercaires of Schistomosa hoematobium	Absence
	Physical-Chemical	
8	Mercury Hg mg/l	0.001
9	Cadmium Cd mg/l	0.01
10	Arsenic As mg/l	0.1
11	Chrome Cr mg/l	0.1
12	Lead Pb mg/l	5
13	Copper Cu mg/l	0.2
14	Zinc Zn mg/l	2
15	Selenium Se mg/l	0.02
16	Fluorine F mg/l	1
17	Cyanide Cn mg/l	1
18	Phenol	3
19	Aluminum Al mg/l	5
20	Beryllium Be mg/l	0.1
21	Cobalt Co mg/l	0.05
22	Iron Fe mg/l	5
23	Lithium Li mg/l	2.5
24	Manganese Mn mg/l	0.2
25	Molybdenum Mo mg/l	0.01
26	Nickel Ni mg/l	0.2
27	Vanadium V mg/l	0.1

* 1000 CF/100 ml for crops consumed raw.

These standards for the reuse of wastewater apply to all types of irrigation water, including treated wastewaters. The aim of the standards is to protect environment and health.

INTRODUCTION

Because of certain factors, including water shortages and the need to treat sewage or somehow discharge the sewage produced, water use and sometimes reclamation have been practiced since ancient times. In many countries, actions have been taken over the last 50 years to create a legislative framework for the safe use of municipal wastewater. The modern legislative framework includes two types: regulations and guidelines.

Whereas regulations are legally adopted, enforceable, and mandatory, guidelines are advisory, voluntary, and nonenforceable, but can be incorporated into water reuse permits and thus become enforceable requirements. Some international and national organizations prefer the use of guidelines, which provide flexibility in regulatory requirements for site-specific conditions, which can result in different requirements for similar uses. This is the case with some international organizations, such as the World Health Organization (WHO), federal government entities, such as the US Environmental Protection Agency, and states, which have limited or no regulations and can use the guidelines as a resource.

The existence of guidelines for wastewater reuse is considered crucial to overcoming barriers that discourage the development of further reuse activities. These barriers include the risks of wastewater reuse to public health and the environment if appropriate guidelines are not available and accepted, and a lack of understanding of both the risks and benefits of wastewater reuse.

Generally, the guidelines are structured to provide information on several aspects of wastewater, as follows:

- Wastewater reuse applications: agricultural irrigation, landscape irrigation, dual distribution systems and in-building uses, impoundments, industrial uses, aquifer recharge for non-potable purposes, aquifer recharge for potable purposes, aquaculture, other non-potable uses
- Methods of wastewater reuse: agricultural irrigation, surface irrigation, sprinkler irrigation, localized (drip) irrigation, spray drift control (spray irrigation), spray buffer zone (spray irrigation), subsurface irrigation
- Treatment: secondary (activated sludge process, trickling filters, rotating biological contactors, stabilization ponds), filtration (passing wastewater through natural undisturbed soils, sand, anthracite, filter cloth, or through microfilters or other membrane processes), advanced wastewater treatment (chemical clarification, carbon adsorption, reverse osmosis and other membrane processes, air stripping, ultrafiltration, ion exchange)
- Microbiological constituents: bacteria, protozoa, helminths, viruses
- Chemical constituents: biodegradable organics, total organic carbon, nitrates, heavy metals, pH, trace constituents, disinfection by-products, total dissolved solids
- Physical properties: total suspended solids, turbidity, temperature
- Monitoring: pH, BOD, COD, TSS, coliforms, chlorine, turbidity, baseline
- Validation, operational, verification

GLOSSARY

TABLE 2: TERMS AND DEFINITIONS

Term	Definition
Aquifer or groundwater recharge	Groundwater recharge is the infiltration or injection of natural or reclaimed waters into an aquifer, providing replenishment of the groundwater resource or preventing seawater intrusion. Aquifer storage and recovery is the storage of water in a suitable aquifer though a well during times when the water is available and recovery of the water from the same well during times when it is needed.
Direct reuse	The conversion of wastewater directly into recycled water, irrigation water, process water, or cooling water without any interim storage.
Disinfection	The process designed to kill most micro-organisms in water, including essentially all pathogenic (disease-causing) bacteria. Chlorine is the disinfection method most frequently used in water treatment. The inactivation of pathogenic organisms using chemicals, radiation, heat, or physical separation processes (e.g. membranes).
Effluent	Liquid (e.g., treated or untreated wastewater) that flows out of a process or confined space.
Guideline value	The concentration or measure of a water quality characteristic that, based on present knowledge, either does not result in any significant risk to health of the consumer (or users) (health-related guideline value), or is associated with good quality water (aesthetic guideline value).
Indirect reuse	The use of reclaimed water for irrigation or other non-potable applications after a period of storage in surface or a groundwater body.
Primary treatment	The initial wastewater treatment process used to remove organic and inorganic solids by sedimentation and floating substances (scum) by skimming. Examples of primary treatment include primary sedimentation, chemical-enhanced primary sedimentation, and up-flow anaerobic sludge blanket reactors. The first stage of wastewater treatment, which may consist of screening, grit removal, and settlement.
Raw water	Water in its natural state before any treatment, or the water entering the first treatment process of a water treatment plant.
Reclaimed water	Wastewater reclamation – the treatment or processing of wastewater to make it reusable. Municipal wastewater that has been treated to a specific water quality criteria so it can be beneficially reused.
Restricted irrigation	Use of wastewater to grow crops that are not eaten raw by humans. Use of low-quality effluents in limited areas and for specific crops only; restrictions are imposed based on the type of soil, the proximity of the irrigated area to potable aquifer, irrigation method, crop harvesting technique, and fertilizer application rate. Simple and low cost, in general only applicable to small amount of wastewater; used in specific locations where areas and crops are well defined and unlikely to change. Impose crop limitation; must be enforced and controlled; farmers must be trained to handle the low-quality effluent.
Secondary treatment	Wastewater treatment step that follows primary treatment. Involves the removal of biodegradable dissolved and colloidal organic matter using high-rate, engineered aerobic biological treatment processes. Examples of secondary treatment include activated sludge, trickling filters, aerated lagoons, and oxidation ditches.
Tertiary treatment	Advanced wastewater treatment beyond secondary level to produce water that is safe for subsequent uses. In most cases, this will consist in an intense disinfection. Some pre-treatments may be needed to remove SS and turbidity in order to make disinfection efficient.
Treated wastewater	Primary treated wastewater, secondary treated wastewater, tertiary treated waste-water, or a higher standard.
Unrestricted irrigation	The use of treated wastewater to grow crops that are normally eaten raw.

Term	Definition
Wastewater	Liquid waste that is discharged from homes, commercial premises, and similar sources to individual disposal systems or to municipal sewer pipes and that contains mainly human excreta and used water. When produced mainly by household and commercial activities, it is called domestic or municipal wastewater or domestic sewage. In this context, domestic sewage does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health, or the environment.
Wastewater reuse	Wastewater (or water) reuse: the beneficial use of treated water.

MEKNES, MOROCCO

Meknes is a city in northern Morocco, located 130 kilometers from the capital Rabat and 60 kilometers from Fes. The total population of Meknes was estimated to be 950,322 in 2006.

The USAID/Morocco has requested the technical services of the Advancing the Blue Revolution Initiative (ABRI) to assist the Government of Morocco in identifying and assessing options for wastewater reuse for agriculture in the region of Meknes. ABRI, in close partnership with the responsible government entities in Meknes, will develop a pilot project design for wastewater reuse in agriculture.

The objectives of this activity include the following:

- Assisting the Wilaya of Meknes in using treated wastewater in financially profitable, socially acceptable, and environmentally safe ways.
- Developing institutional and technical recommendations for a pilot project for regulating and managing wastewater reuse for agriculture.
- Developing and reinforcing collaborative relationships among participating local agencies to support wastewater reuse for agriculture.
- Ensuring that the operational, financial, and health interests and concerns of farmers about using treated wastewater are understood by the government and integrated into its implementation plan.

IMPLEMENTATION APPROACH

The ABRI study team will carry out the study through the Coordination Committee for Wastewater Treatment and Reuse formed by the Walli of Meknes in May 2008. Member agencies include: the National Office of Potable Water (ONEP), which chairs the committee; the Autonomous Authority for the Distribution of Water and Electricity (RADEM); the Directorate for Agricultural Production (DPA); the Regional Department of Commerce and Industry (MCI); the Regional CGEM representative; the Sebou River Basin Agency (ABH-Sebou); the Office of the Walli; the regional counsel/municipality representative; the regional Department of Health; and the Department of Environment.

This report provides regulations and guidelines for the safe, on-farm use of reclaimed water. It is intended for use by irrigators who already use or intend to use reclaimed water so that they can avoid health risks to themselves, their families, and members of the public who may use their products. The report does not provide information on normal irrigation practices used when water is of normal quality. It focuses on the specific activities required to deal with use of reclaimed water, and assumes that people who follow these guidelines are already familiar with normal irrigation practices.

REFERENCE FRAMEWORK OF GUIDELINES FOR SAFE USE OF TREATED WASTEWATER

The full value of reclaimed wastewater has been recognized in relatively few countries worldwide (among them, Israel, Jordan, Tunisia, and South Africa) and in some US states (including California, Florida, Texas, and Arizona). At the country level, full-fledged regulations set the basic conditions for a safe use of wastewater. In other places (such as Texas), regulations require that a study be conducted to investigate the possibility of using reclaimed water for applications that currently use potable water or freshwater. As of March 1992, 18 US states had adopted some form of regulations for the reuse of reclaimed water and another 18 had full-fledged guidelines or design standards. In the 18 states with no specific regulations or guidelines, wastewater use projects are permitted on a case-by-case basis.

Because environmental conditions differ from region to region, and because different end uses of the reclaimed water require different levels of treatment, a universal quality standard for reclaimed water does not exist.

Knowledge of the chemical constituents in the effluent, the level of treatment, and the treatment processes provided is important in evaluating the WWTP's suitability as a water reclamation facility and in determining possible reuse applications. An existing plant that provides at least secondary treatment, though not originally designed for water reclamation and reuse, can be upgraded by modifying existing processes or adding new unit processes to the treatment train to supply reclaimed water for most uses. For example, with the addition of chemicals, filters, and other facilities to ensure reliable disinfection, most secondary effluents can be enhanced to provide a source of reclaimed water suitable for unrestricted urban reuse.

The following Mediterranean countries regulate the use of reclaimed water with the restrictions shown in the table:

TABLE 3: RESTRICTIONS IN MEDITERRANEAN COUNTRIES THAT REGULATE THE USE OF RECLAIMED WATER

Country	Regulation	Reclaimed Water Uses	Criteria and Standards
Cyprus	Provisional standards (1997)	Agricultural irrigation	Quality criteria for irrigation stricter than WHO/1989 standards but not as strict as Californian Title 22 (TC<50/100 mL in 80% of the cases of a monthly basis and <100/100 mL always).
France	Art. 24 Decree 94/469 3 June 1994 Circular DGS/SDI.D/91/nº 51	Agricultural irrigation	Both refer to water reuse for agricultural purposes and follow the WHO/1989 standards, with the addition of restrictions for irrigation techniques, and setback distances between irrigation sites and residential areas and roadways.

Country	Regulation	Reclaimed Water Uses	Criteria and Standards
Israel	Regulation set by MoH	Unrestricted irrigation	There are criteria and standards for four different groups of crops; methods of treatment and setback distances are included.
Italy	Decree of Environmental Ministry 185/2003	• agriculture • non-potable urban uses • industrial uses	There is a possibility for the Regional Authorities to add some parameters or implement stricter regional norms.
Regional authorities: Sicily, Emilia Romagna and Puglia	Guidelines		The proposed microbiological standards are similar to those of the Title 23 California regulation for Puglia and Emilia Romagna and the WHO/1989 guidelines for Sicily.
Country	Regulation	Reclaimed Water Uses	Criteria and Standards
Spain	Law 29/1985, BOE n. 189, 08/08/85 Royal Decree 2473/1985	Draft proposal with 14 end-use classes	Water reuse may be practiced, but no specific regulation is followed. Draft legislation was issued in 1999, with a set of standards for 14 possible applications for treated water. The proposed microbiological standards range is similar to that of the Title 23 California regulations in defined use categories but not in the standards set for each category.
Regional health authorities: Andalucia, Balearic Isl. and Catalonia	Guidelines from the Regional Authorities	Up to 14 reuse classes	Regional guidelines, in particular, in the field of the irrigation, based on the WHO approach.
Tunisia	1975 Water Code and Decree of 1989 1989 Tunisian standards	Agriculture	The parameters include standards for chemical constituents and physical properties, as well as for intestinal nematodes. There are lists of crops that can be irrigated.
Turkey		Agriculture	The regulation refers to several agriculture types and the technical limitations for recycling, the treatment methods for wastewater, and the suitability of industrial wastewaters to be used for irrigation.
Jordan	Jordanian technical base No 893/2006	Irrigation purposes; Artificial recharge of aquifers for non-potable uses	The parameters include a variety of chemical constituents, physical properties, and microbial constituents (E. coli and Helminth eggs).

By comparing the guidelines and regulations in force, a number of conclusions can be made:

- Only a few US states have criteria and standards for all water reuse applications.
- The majority of the Mediterranean countries, along with WHO, consider reclaimed wastewater to be suitable for agricultural purposes. This is quite evident, as 70% of water consumption is for irrigation, although site-specific needs may sometimes require a different water use.

- During the review, it was noted that only a limited number of countries have developed comprehensive water reclamation and reuse standards, provide direction, and encourage water reuse. Some countries have adopted standards that are less comprehensive and rigorous than others.

REGULATION/STANDARDS FOR TREATED WASTEWATER REUSE

For the purpose of reuse planning, it is best to consider reclaimed water quality from the standpoint of water supply (i.e., what quality is required for the intended use?). Where a single large customer dominates the demand for reclaimed water, the treatment selected may suit that particular, major customer.

One of the most critical objectives in any reuse program is to ensure, by limiting public exposure (contact, inhalation, ingestion) to reclaimed water, that public health protection is not compromised through its use. Other objectives, such as preventing environmental degradation, avoiding public nuisance, and meeting user requirements, must also be satisfied; but the starting point remains the safe delivery and use of properly treated reclaimed water.

Reclaimed water projects may vary significantly in the level of human exposure incurred, with a corresponding variation in the potential for health risks. Where human exposure is likely in a reuse application, reclaimed water should be treated to a high degree prior to its use. Conversely, where public access to a reuse site can be restricted so that exposure is unlikely, a lower level of treatment may be satisfactory, provided that worker safety is not compromised.

Consideration should be given to the expected degree of human contact with the reclaimed water. It is reasonable to assume that reclaimed water used for the irrigation of non-food crops on a restricted agricultural site may be of lesser quality than water used for landscape irrigation at a public park or school, and that this water, in turn, may be of lesser quality than reclaimed water intended to augment potable supplies.

WHICH TREATMENT PROCESSES ARE NEEDED TO ACHIEVE THE REQUIRED RECLAIMED WATER QUALITY?

While it must be acknowledged that raw wastewater may pose a significant risk to public health, it is equally important to point out that current treatment technologies allow water to be treated to achieve almost any quality desired. For many uses of reclaimed water, appropriate water quality can be achieved through conventional, widely practiced treatment processes.

Advanced treatment beyond secondary treatment may be required as the level of human contact increases. Levels of wastewater treatment are generally classified as preliminary, primary, secondary, and advanced. Advanced wastewater treatment, sometimes referred to as tertiary treatment, is generally defined as anything beyond secondary treatment.

Proposed standards for reuse in irrigation:

Scope: The proposed Morocco standard is purposely set to specify the conditions that the reclaimed domestic wastewater discharged from wastewater treatment plants should meet in order to be used in the fields mentioned in this standard.

TABLE 4: PROPOSED ALLOWABLE LIMIT FOR PROPERTIES AND CRITERIA FOR REUSE IN IRRIGATION

Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within City Limits	Fruit Trees, Sides of Roads Outside City Limits, and Landscape	Field Crops, Industrial Crops and Forest Trees
		Group A		
		A	B	C
Biological Oxygen Demand	mg/l	30	200	300
Chemical Oxygen Demand	mg/l	100	500	500
Dissolved Oxygen	mg/l	>2	-	-
Total suspended solids	mg/l	50	150	150
pH	Unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70
Escherishia Coli	Most probable number or colony forming unit/100 ml	100	1000	-
Intestinal Helminthes Eggs	Egg/l	≤ 1	≤ 1	≤ 1
Grease, oils and fats	mg/l	8	8	8

TABLE 5: PROPOSED GUIDELINES FOR REUSE IN IRRIGATION

Group B	Unit		Restricted Irrigation
			A+B+C (in Table 4)
Phenol	mg/l	Phenol	<0.002
Detergent	mg/l	MBAS	15-100
Total Dissolved Solides	mg/l	TDS	2000
Total Phosphate	mg/l	$T\text{-}PO_4$	30
Chloride	mg/l	Cl	400
Sulfate	mg/l	SO_4	500
Bicarbonate	mg/l	HCO_3	400
Sodium	mg/l	Na	230
Magnesium	mg/l	Mg	100
Calcium	mg/l	Ca	230
Sodium Adsorption Ration	-	SAR	9
Aluminium	mg/l	Al	5
Arsenic	mg/l	As	0.1
Beryllium	mg/l	Be	0.1
Copper	mg/l	Cu	0.2
Floride	mg/l	F	1.0-2.0
Iron	mg/l	Fe	5.0
Lithium	mg/l	Li	2.5(0.075 for citrus crops)
Manganese	mg/l	Mn	0.2
Molibdinum	mg/l	Mo	0.01
Nikel	mg/l	Ni	0.2
Lead	mg/l	Pb	0.2
Selenium	mg/l	Se	0.02-0.05
Cadmium	mg/l	Cd	0.01
Zinc	mg/l	Zn	2.0-5.0
Chrome	mg/l	Cr	0.1
Mercury	mg/l	Hg	0.002
Vanadium	mg/l	V	0.1
Cobalt	mg/l	Co	0.05
Boron	mg/l	B	0.75-1.0
Cyanide	mg/l	CN	0.1

For unrestricted irrigation, water quality must comply with Morocco quality standards of waters designed for irrigation (in Table 1).

MONITORING AND EVALUATIONS PROCEDURE

QUALITY MONITORING

Effluent water quality sampling and analysis are required as a condition of WWTP effluent discharge permits. The specific parameters tested are those required for preserving the water quality of the receiving water body (e.g., biochemical oxygen demand, suspended solids, coliforms or other indicators, nutrients, and sometimes toxic organics and metals).

Quality monitoring must be conducted as follows:

- The owner of the reclaimed water treatment plant station must make sure that the quality of the reclaimed water complies with the adopted standards, by conducting the necessary lab tests and keeping records of the results to submit to the government investigator's party.
- The operation's party is responsible for taking mixed specimens every 4 hours, according to the sequence shown in Table 6, while the investigator's party collects specimens as needed.
- The sequence according to which the investigator's and operation's parties need to collect specimens is shown in Table 6.
- Specimens are to be taken, stored, and analyzed according to the standards book for test water and wastewater issued by the US health institution and the US federal institution for water research and water pollution.
- For mechanical treatment stations that contain pools and for the natural treatment stations, the consumed O_2 is to be calculated after the fertilization process.
- A scientific average is used to calculated results of thermo tolerant coliforms or Escherichia coli for reclaimed wastewater evaluation.
- The average of at least 5 samples should be used to evaluate the total nitrogen content of the treated wastewater.
- If an Escherichia coli test is not technically possible, a thermo tolerant coliforms test is considered as a substitute.
- In infectious cases, operating and monitoring parties must investigate for infectious germs that may be present in the water.

EVALUATION PROCEDURES

For the purpose of this standard, the following procedure must be followed:

- To evaluate the quality of the reclaimed water, the time period shown in Table 6 must be applied.

- In cases of noncompliance with (violation of) any reuse regulations, an insurance specimen is to be taken. If the lab results show violation, the concerned party is to be informed of the results immediately to correct the mistake. If such situations persist for a period of more than 3 months, the reclaimed water usage is to be stopped until the water quality problems are resolved.

TABLE 6: NUMBER OF TREATED WASTEWATER SAMPLES THAT MUST BE COLLECTED AND ANALYZED FOR THEIR CHEMICAL, PHYSICAL, AND BIOLOGICAL CHARACTERISTICS FOR MONITORING AND EVALUATION

Wastewater Treatment Plants	**Sampling Frequency**		**Evaluation Frequency**
Type	**Operating Parties**	**Monitoring Parties**	
Mechanical	• Routine tests: 8 representative samples, monthly. • Physical and chemical characteristics: 3 samples, monthly • Intestinal helminthes eggs: 4 representative samples, monthly • Escherichia coli: 8 samples, Monthly	• Routine tests: 2 samples, monthly. • Physical and chemical characteristics: 2 samples, monthly • Intestinal helminthes eggs: 2 samples, monthly • Escherichia coli: 2 samples, Monthly	3 Months
Physical	• Routine tests: 4 representative samples, monthly. • Physical and chemical characteristics: 3 samples, monthly • Intestinal helminthes eggs: 2 representative samples, monthly • Escherichia coli: 4 samples, monthly	• Routine tests: 1 sample, monthly. • Physical and chemical characteristics: 1 sample, monthly • Intestinal helminthes eggs: 1 sample, monthly • Escherichia coli: 1 sample, monthly	6 Months
Small Communities	• Routine tests: 4 representative samples, monthly. • Physical and chemical characteristics: 3 samples, monthly • Intestinal helminthes eggs: 2 representative samples, monthly • Escherichia coli: 4 samples, monthly	• Routine tests: 1 sample, monthly. • Physical and chemical characteristics: 1 sample, monthly • Intestinal helminthes eggs: 1 sample, monthly • Escherichia coli: 1 sample, monthly	6 Months

According to the season: December–February, March– May, June–August, September–November.
Summer and Winter: Summer (May–October; Winter (November–April).

Note: Routine analysis includes: NO_3, BOD_5, COD, TSS, NH_4, T-N, and for chemical and physical characteristics: pH, DO, RCL_2, Turbidity, Temperature.

GUIDELINES FOR ON-FARM USE OF RECLAIMED WATER

SELECTING THE PROPER CROPS

Several factors need to be taken into account in selecting the proper crops for irrigation using reclaimed water: water quality, water supply and demand, economics, and site specific factors.

WATER QUALITY

Morocco should have clearly defined standards for the use of reclaimed water that is suitable to the end uses. At present, the application Decree (No 2-97-875, dated February 4, 1998), acting as Water Law 10-95 related to the use of wastewaters, stipulates that no wastewater can be used if it has not been recognized as treated wastewater. Current standards apply not only to irrigation with treated wastewaters but to all types of irrigated water. The aim of these wastewater reuse standards is to protect environment and health.

Current standards specifically prohibit cultivation of any crops using reclaimed water unless its characteristics comply with irrigation water standards. Such regulations might be required for unrestricted irrigated agriculture, including crops eaten raw or uncooked.

Treating wastewater may be more feasible, however, if done in accordance with the intended end use. (Is it going to be used for restricted or unrestricted irrigation?) If all concern parties agree on the intended end use for the treated wastewater, then the WWTP should be designed to match effluent quality to that use. Integrated planning also allows user fees for treated wastewater to cover the operation and maintenance costs of the WWTP itself. Current standards specifically prohibit cultivation of any crops unless wastewater is treated to irrigation water standards.

In Meknes, farmers along and downstream from the raw wastewater course are using raw wastewater as is, without any treatment, a practice that endangers the health of farmers, workers, and consumers. The quality of raw (untreated) wastewater inflow to the WWTP in April 2006 is illustrated in Table 7. No data available, however, for effluent (outflow) from the wastewater plant (currently under construction). Analysis of outflow effluent is necessary to evaluate its quality.

The physical and chemical constituents of inflow wastewater to the Meknes WWTP (Table 7) comply with proposed standards, WHO guidelines, and the Morocco Decree (No 2-97-875, dated February 4, 1998), acting as Water Law 10-95 related to the use of wastewaters, stipulates that no wastewater can be used if it has not been recognized as treated wastewater.

The total suspended solid (TSS) is high, however, and is not suitable for localized drip irrigation without a good filtration system that includes sand filters and screen and/or disc filters. Usually, such a filtration unit is an essential component of a drip irrigation system. Construction of a main sand filter unit at the WWTP effluent outlet might be a good idea to guarantee better water quality through careful operation and maintenance.

Also, the values of BOD5, COD, and fecal coliforms are high, and wastewater should be treated to reduce these values as much as possible in order to comply, at a minimum, with the proposed standards for restricted irrigation.

Wastewater management policy focuses on the direct reuse of treated wastewater for irrigation purposes, where the treatment technologies adopted are based on classical biological treatment systems, mainly trickling filters, waste stabilization ponds, and combinations.

Bacterial levels in wastewater can be significantly lowered through either a “removal” or an “inactivation” process. The removal process involves the physical separation of the bacteria from the wastewater through sedimentation and/or filtration. Due to density considerations, bacteria do not settle as individual cells or even colonies. Typically, bacteria can absorb to particulate matter or floc particles. These particles settle during sedimentation, secondary clarification, or an advanced treatment process, such as coagulation/flocculation/sedimentation using a coagulant. Bacteria can also be removed through a filtration process that includes sand filters, disk (cloth) filters, or membrane processes. Filtration efficiency for a sand or cloth filter is dependent on the effective pore size of the filtering medium and the presence of a “pre-coat” layer, usually other particulate matter.

Secondary treatment processes include activated sludge processes, trickling filters, and rotating biological contractors, and may include stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do not exceed 30 mg/l. Some stabilization pond systems may be able to meet a coliform limit of less than 200 fecal coli/100ml without disinfection.

The proposed standards allow the use of treated wastewater based on the level of treatment and effluent quality. Excluding crops eaten raw—such as tomato, cucumber, Egyptian cucumber, pepper, cabbage, onion, carrot, radish, lettuce, parsley, mint, rocket (watercress), coriander, purslane, strawberry, watermelon, and cantaloupe)— secondary treated wastewater will allow for restricted irrigated agriculture. All other crops are permitted, including vegetables that are usually eaten cooked, including eggplant, squash, beans, cornflower, potato, okra, peas, broad beans, turnip, spinach, jew’s mallow, and artichoke. As shown in Table 4, however, the standards for vegetables that are normally cooked are much more stringent for many parameters, including BOD, COD, DO, total suspended solids, turbidity, nitrates, total nitrogen, and E. coli.

Standards for fruit trees are also slightly more stringent than for other crops, with lower permitted values for BOD and E. coli.

Standards are the least strict for field crops (such as forages, grains, legumes, fibers, oils, and sugar), industrial crops (such as wood trees and olives), and forest trees.

Therefore, from a strictly legal point of view, it is possible for farmers to cultivate all crops other than vegetables likely to be eaten raw; however, if there is any doubt at all that the quality of reclaimed water may not reach the standards required for the cultivation of vegetables normally cooked before eating, it is better not to encourage farmers to grow these crops.

Our experience is that water quality from different wastewater treatment plants varies significantly from one time of year to another, and it is difficult to guarantee that wastewater treatment plant operators will always be able to meet the stringent standards for water quality established for permitted vegetable crops.

As a result, these guidelines strongly recommend that reclaimed water not be used for vegetables, whether they are to be consumed raw or cooked. If farmers are already experienced in controlled irrigation, however, and if the effluent from the WWTP is very good quality, then it is possible to grow vegetables that will be cooked.

Experience shows that it is simpler and more manageable to concentrate on crops that can use lower-quality water. This approach will eliminate the potential risk of irrigating any vegetables with sub-standard water.

WATER SUPPLY AND DEMAND

Morocco has a high seasonal variation in evapotranspiration. This means that crop water demand will be high in the hot, dry summer months and significantly lower in the cooler and more humid winter months. Crop water demand may be as high as 10 mm/day in the summer, but fall to below 1.0 mm/day in the winter. At the same time, discharges from wastewater treatment plants are comparatively steady, with some variation throughout the year, so that there is no simple match between supply and demand.

To eliminate the need to construct a storage reservoir, and to protect the environment, it is recommended that the planned end use of reclaimed water use all water available.

It is also recommended that a cropping pattern be selected that seeks to optimize the use of all available water, so that a good balance is achieved between the supply of reclaimed water and crop water demand. Choosing a single crop that uses all available water in the summer will not allow farmers to use all available water in the winter because demand will be too low.

To determine a suitable cropping pattern, it is first necessary to identify the preferred crops in order of priority. Water allocations for each crop should be calculated in the same order of priority, maximizing the area for the highest-priority crop.

By introducing winter crops, a significant proportion of the surplus water can be used where crop water demand is minimal.

It is possible to increase the winter crop area if the winter crop is under-irrigated. This is desirable because it will allow the crop to make use of any rainfall that occurs in the winter months and will maximize the use of treated wastewater. Also, because production of the crop is more or less in proportion to the water applied, there is no significant reduction in total yield if under-irrigation occurs.

In the case of surplus water in the winter months, farmers can use this water for leaching and/or replenishment of water in the soil; otherwise, the surplus must be stored or disposed of properly into the wadi to conform to environmental requirements. The appropriate balance between the summer and winter crops needs to be calculated for each agro-ecological zone in Morocco, but in each location it is also possible to determine the proper area cultivated under each crop in order to use all available water.

If there is sufficient land available, deliberate under-irrigation of winter crops is recommended. This will maximize the use of any winter rainfall, help increase leaching, and ensure that all available water is used.

TABLE 7: MEKNES RAW (UNTREATED) WASTEWATER INFLOW QUALITY, APRIL 2006

Parameters	Unit	Station				Average	Morocco Standards	Proposed Standards	WHO
		A	AX	F	G				Long Term
BOD_5	mg/l	269.0	441	218	177	*276*		30-300	
COD	mg/l	919.0	1029	441	414	*701*		100-500	
Total coliform	per 100ml	4.0E+07	2.0E+07	2.4E+07	2.0E+07	*2.6E+07*	1000	100-1000	1000
Fecal coliform	per 100ml	7.9E+06	2.4E+06	6.2E+06	2.6E+06	*4.8E+06*	1000	100-1000	1000
TSS	mg/l	969.0	361	250	158	*435*		50-150	
Grease, fat, oil	mg/l	24.1	26.700	12.600	14.433	*19.5*		8	
SO_4	mg/l	0.3	0.2	0.6	1.7	0.7		500	
pH	Unit	7.6	7.7	7.3	7.5	7.5		6-9	
TDS	µS/cm	1237	1883	1612	1479	1552.4		2000	
NTK	mgN/l	33.8	95.525	63	36.55	57.2		70	
PO_4	mgp/l	1.3	10.020	4.449	4.935	5.2		30	
Detergent	mg/l	1.034	1.775	1.560	1.932	1.6		15-100	
As	mg/l	0.003	0.002	<0.0013	<0.0013	<0.0013	0.1	0.1	0.1
Cd	mg/l	0.002	0.002	0.001	0.001	0.001	0.01	0.01	0.01
Cr	mg/l	0.023	0.010	0.011	0.067	0.028	0.1	0.1	0.1
Cu	mg/l	0.086	0.033	0.058	0.046	0.056	0.2	0.2	0.2
Ni	mg/l	0.010	0.013	0.007	0.007	0.009		0.2	0.2
Pb	mg/l	0.024	0.016	0.025	0.068	0.033	5	0.2	5
Se	mg/l	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	0.02	0.05	0.02
Al	mg/l	4.69	1.571	1.279	1.611	2.29	5	5	5
Fe	mg/l	2.88	2.782	2.083	2.042	2.45	5	5	5
Mn	mg/l	0.19	0.158	0.091	0.269	0.18	0.2	0.2	0.2
Zn	mg/l	0.47	0.351	0.278	0.716	0.45	2	5	2
ML	mg/l	8.37	4.9	3.8	4.8	5.49			
Flow	l/s	30.45	12.05	27.025	1.595	17.8			

ON-FARM ECONOMICS AND MARKETING

A third factor in helping farmers make optimal crop selections is the profitability of different crops, and the ease of marketing the product. A detailed economic analysis for each of the agro-ecological zones should be provided for sustainability.

SITE-SPECIFIC CONSIDERATIONS

The proposed Morocco standards anticipate that there will be a planned end use for water, and that that use must meet both health and environmental dimensions.

Two separate factors must be taken into consideration when designing the cropping pattern: disposal of unused reclaimed water when demand is less than supply, and environmental limitations.

In the middle of winter, it is likely that crop water demand will be less than the available supply. Although excess water can be diverted into wadis and can help recharge groundwater, there is no guarantee that environmental conditions will be met. It may be advisable for farmers to use excess water for leaching and replenishing soil moisture, rather than just dumping it into the wadi.

BEST IRRIGATION PRACTICES

PERSONAL HYGIENE

The overriding principle in irrigation systems that use reclaimed water is the minimization of all contact between exposed flesh and the reclaimed water. As long as irrigators follow basic hygiene techniques, the risk of infections to them and their families can be kept to an absolute minimum.

Irrigators should always wear rubber gloves and boots when applying water. The use of rubber gloves and proper footwear is also recommended when touching crops irrigated with reclaimed water.

Agricultural instruments used on fields where reclaimed water has been used should be washed after use, and should not be brought into irrigators' homes.

All people who have been on farms where reclaimed water is used for irrigation should wash their hands thoroughly with soap and clean water as soon as they leave the fields. This is necessary to avoid accidental contamination of equipment, vehicles, and family members.

Food and drink should not be taken onto fields where reclaimed water has been used for irrigation, nor should personal possessions be laid on the ground in such areas.

Irrigators who experience skin irritation or intestinal problems should visit a doctor as soon as possible. They should also get regular check-ups at least once a year to ensure that they have not been infected.

DESIGN OF IRRIGATION SYSTEMS

The design of irrigation systems that use reclaimed water generally conforms to the design standards for any regular irrigation, but with additional safeguards to minimize the risk of infection of irrigators or contamination of produce.

Types of Irrigation Systems Suitable for Using Reclaimed Water

Regulations should prohibit the use of sprinkler irrigation when using reclaimed water to prevent the risk of airborne pathogens and chemicals. All irrigation must therefore be conducted using either surface irrigation or pressurized drip systems.

Drip systems are preferred because they help to minimize the risk of infection and have much higher application efficiencies than surface irrigation systems. Mini-spray heads are not suitable for irrigation using reclaimed water as they also may spread infections through airborne pathogens.

For high-value crops, hydroponic irrigation is another option because, in that case, the water does not touch any part of the plants other than the roots. Hydroponic irrigation requires a large investment, however, and is not suitable for widespread adoption.

Irrigation equipment

All pipes that will use reclaimed water must conform to local standards, which require the use of a certain color (i.e., purple color code VT 6512 or any other color) to indicate that the water has been reclaimed.

Signs warning people that reclaimed water is being used must be erected at all entry points into the irrigation system. These signs should include warnings against drinking the water and letting livestock or other animals enter the area.

To prevent farmers from piping reclaimed water to areas outside the designated limits of the system, no hose bibs may be included in the distribution system.

All pressurized systems using reclaimed water should have high-volume sand filters at the system head and disk or screen filters at the head of each individual farm.

Field Layout for Drip Irrigation Systems

For drip irrigation systems, application should be through pressure-regulating drippers or in-line emitters placed at or below the ground surface. The use of variable flow emitters is not recommended as it is difficult to maintain constant emitter discharge with this application method and over-irrigation can easily result.

For **alfalfa and rye-grass**, appropriate burying of pipes with in-line emitters is recommended. If mechanized harvesting is planned, burying the lines is essential to avoid damage by the wheels of the cutter.

Typical spacing should be one meter between lines for sand to medium soils and 1.5 meter between lines for clay soils, with emitters placed every 40-50 cm along the line for alfalfa, rye-grass, and winter fodder crops. These guidelines should be modified, however, if soils are particularly porous, with dry areas between laterals and emitters. In clay soils, spacing could be wider to minimize contact between plants and water. If the soil is very sandy, the pressurized pipe can be inserted into a larger-diameter, colored pipe that has been partially perforated. Such a system also makes it easier to pull out lines and inspect the in-line emitters for clogging. This should be done at least once a year.

For **winter fodder and other row crops**, the simplest layout is a line with in-line emitters laid on the soil surface. This line can be pulled up before harvesting and re-laid after land preparation for the next crop. Typical spacing should be 1.5 meters between lines, with emitters placed every 50 cm along the line.

For **fruit trees**, a separate loop is recommended with 2 emitters, 0.5–1.0 meters apart, provided for each tree, according to soil type, with close spacing for sandy soil and large spacing for clay soil. Using more than 2 emitters is recommended for some trees, such as large mature trees (i.e., palm, olive, and citrus). For such trees, a loop of 3.0 meters in-line emitters, with emitters 4.0-8.0 Lph placed every 50 cm along the lateral, should be used. The loop should surround the tree so that all parts of the root ball receive equal amounts of water. Lines can be pulled aside when annual weeding between trees takes place.

Additional Design Requirements

Clean water supplies must be provided at convenient locations surrounding the areas irrigated with reclaimed water to allow irrigators to wash their hands as soon as they leave the farm area. Toilets using clean water should also be provided at convenient locations.

WATER APPLICATION TECHNIQUES

In most cases, irrigation application techniques are the same as for regular irrigation; however, a few additional precautions should be taken.

Regular inspections of the distribution network must be made during irrigation to ensure that there are no leaks or ruptures. When leaks and ruptures are observed, that part of the system should be shut down immediately and repairs made as soon as possible. There should be no run-off from fields as a result of leaks and ruptures.

Irrigation scheduling must allow for potential salt accumulation due to higher TDS levels in reclaimed water compared to normal irrigation water. If salt accumulation is seen, then additional irrigation is required to flush it out. Routine over-irrigation is not recommended, however, or excess flow of reclaimed water into shallow groundwater can result.

The irrigation system for alfalfa and winter fodder should be shut off in times of rainfall to maximize the leaching effect of rainfall and avoid over-irrigation, which can lead to runoff and groundwater contamination. For fruit trees, some continued irrigation is desirable to stop accumulated salts from going into the root zone of the trees.

Regular checks must be made along the down slope edge of fields during irrigation to ensure that runoff does not occur. If runoff does occur, then the system should be shut down and the irrigation application rate reduced, if possible; otherwise, irrigation should be applied more frequently to reduce the amount of water used during each irrigation event.

When irrigating **fruit trees** and **vegetables** that will be eaten cooked, water should not be applied to leaves or fruits. Proper alignment of drippers and in-line emitters will prevent contamination of leaves and fruits.

In some locations, reclaimed water may occasionally contain sludge that can lead to emitter clogging. Farmers should routinely inspect emitters, replace broken ones, and carry out uniformity tests to ensure equal irrigation between emitters. Also, monthly injection of phosphoric acid in a rate of a 1.0 liter of 85% or 2.0 liters of 50% phosphoric acid concentration per dunum is recommended.

System operators must check the inflow and outflow pressure valves and backflush the sand filter whenever the difference between the two readings is outside the acceptable limits of 0.5-0.7 bars. Each system must have specific values for inflow and outflow pressures that are included in the O&M manual for that system.

Screen or disk filters at the head of each farm must be cleaned daily or at each irrigation event to minimize any sludge intake into the drippers and in-line emitters.

The main conveyance line must be flushed once or twice a year to ensure that there is no build-up of sludge or sediment. Effluent during flushing must be directed into a wadi or other approved drainage channel.

BEST AGRICULTURAL PRACTICES

In most respects, agricultural activities are the same whether reclaimed or fresh water is used. Land preparation and tillage is the same regardless of whether water is normal or reclaimed. For regular activities, such as weedicide and pesticide application, there are no recommendations specific to the use of reclaimed water, and farmers should follow normal practice.

A few additional precautions that should be taken when using reclaimed water.

Personal Hygiene

Whenever possible, agricultural activities on fields irrigated with reclaimed water should be conducted immediately before irrigation when the fields are driest. Irrigators must try to minimize entry onto newly irrigated fields to reduce contact with water.

Proper footwear must be worn whenever entering fields where reclaimed water has been used. If it is necessary to handle fruits, then protective gloves also should be worn to prevent accidental contamination. Everyone must wash their hands after completing work on fields irrigated with reclaimed water.

FERTILIZATION

Reclaimed water normally has high levels of nitrogen, so to prevent nitrogen build-up in plant materials and soil, fertilizers with high nitrogen levels should not be used. The use of too much nitrogen can also contaminate groundwater.

Once a soil test has been done to determine the deficiency levels of key nutrients, the appropriate fertilizer must be chosen. Normally, a mixture of P and K will be sufficient due to high N content in the reclaimed water.

It is recommended that regular soil tests be conducted in the spring months to determine whether alfalfa and/or rye-grass fields require fertilization, and in early winter to test soils where winter fodder crops will be grown.

Soil Salinity

Reclaimed water normally has a higher total dissolved solids (TDS) level than normal irrigation water. Therefore, there is a risk of salt build-up in the soils unless adequate water is applied for leaching. The extent of the risk of soil salinity depends on both the salt content of the available reclaimed water and the amount of winter rainfall that will help leach salts out of the root zone.

A simple soil test once a year is recommended to determine if there is any salt build-up. If salt build-up is observed, then the amount of water reserved for leaching should be increased.

Pruning Fruit Trees

Fruit trees must be pruned so that branches are well clear of the ground surface, and so that no fruits come within 1 meter of the soil. Where possible, pruned branches should not be allowed to fall to the ground where they can become contaminated.

Prevention Of Grazing and Browsing

Livestock and other animals must not be allowed to walk on fields irrigated with reclaimed water. Ideally, fields will be fenced to prevent animal access, but if this is not feasible, animals must be kept well away from irrigated areas.

BEST HARVESTING PRACTICES

All harvesting activities should be undertaken with minimum risk of contamination of the people doing the harvesting and the produce they are collecting.

PERSONAL HYGIENE

Appropriate footwear should be worn at all times during harvesting so that there is minimal risk of infection. If **alfalfa and rye-grass** are being cut by hand, then harvesters should wear gloves, as well, and should try to avoid kneeling on wet soil.

All harvesters must wash their hands thoroughly after leaving fields irrigated with reclaimed water.

HARVEST IN DRY CONDITIONS

Harvesting should never be undertaken immediately after irrigation. The soil should be allowed to dry out as much as possible between irrigation and harvesting. For winter fodder and fruit trees, there should be a minimum of 14 days between the last irrigation and harvesting.

For alfalfa and rye-grass, fields should not be irrigated for at least 5 days before harvesting. Wherever possible, alfalfa should be harvested mechanically. This significantly reduces the exposure by harvesters to damp soil and produce.

Baling of **alfalfa and rye-grass** and **winter fodder** is highly recommended. This makes storage and transport easier and reduces contact with cut material.

Fodder crops, rye-grass, and alfalfa should never be grazed directly in fields irrigated with reclaimed water. The fodder should be brought to animals after cutting.

HARVESTING FRUIT

All **fruit** should be plucked by hand and should not come into direct contact with the soil. Fruits that fall to the ground should be discarded, unless they will be processed prior to consumption.

Olives can be harvested by shaking branches, but cloth or plastic sheets under the trees should be free of holes and large enough to catch all of the olives. The sheets should always be used with the same side up, so that only one side comes into contact with the soil.

BEST POST-HARVEST PRACTICES

PERSONAL HYGIENE

Farmers and their families must wash their hands after handling stored products. Stored products should not be kept in the living areas of the farmstead. Instead, a separate storage area with a door is recommended so that children and animals cannot enter.

All fruits consumed without processing should be thoroughly washed in clean water before consumption.

SALE OF PRODUCE

When selling products intended for human consumption that are grown using reclaimed water, the seller must inform the buyer that reclaimed water was used. The buyer should be made aware of the need to wash hands properly after handling produce.

FEEDING ANIMALS

Alfalfa, rye-grass, and winter fodder should be dried at least one week before animals are allowed to eat them. Alfalfa and rye-grass, in particular, should not be served fresh to animals under any circumstances.

ANNEX: PERSONS MET

1. **Mr. Jaouad Bahaji,**
   Chef de Projet
   Departement de la Croissance Economique
   US Agency for International Development
   10, avenue Mehdi Ben Barka
   BP 120. Souissi, Rabat, Maroc
   Tel. (212) (0) 37.63.20.20
   E-mail: jbahaji@usaid.gov
   Website: www.usaid.gov/ma/

2. **Mr. James N. May,**
   Directeur du Departement de la Croissance Economique
   US Agency for International Development
   10, avenue Mehdi Ben Barka
   BP 120. Souissi, Rabat, Maroc
   Tel. (212) (0) 37.63.20.13
   E-mail: jmay@usaid.gov
   Website: www.usaid.gov/ma/

3. **Mr. Moustafa El Hamzaoui,**
   Directeur du Departement de la Croissance Economique
   US Agency for International Development
   10, avenue Mehdi Ben Barka
   BP 120. Souissi, Rabat, Maroc
   Tel. (212) (0) 37.63.20.13
   E-mail: melhamzaoui@usaid.gov
   Website: www.usaid.gov/ma/

4. **Mohamed Berkia, Directeur**
   Directeur de la Région du Centre Sud, ONEP
   20, rue Antsirabé, Meknes
   Tél: 0535520508, O535522898, 0661052950
   mberkia@hotmail.com

5. **Najib Lahlou Mimi, Directeur**
   Regie de Distribution d' Eau et d' Electricité , Meknès, RADEEM
   78, Avenue de l'Armée Royale
   50000 Meknès
   Téléphone: 0 5 35 52 18 01- 05 35 52 18 04
   Fax: 05 35 52 28 22
   Email: radeemdr@menara.ma

6. **Boujir Mohamed, Directeur**
Direction Provinciale d’Agriculture de MEKNES
9, Rue Othmane Ibn Affane.
B.P S/14. MEKNES
Standard: 05 35 52 12 92 – 05 35 52 08 71
Direct: 05 35 52 03 17 – 05 35 52 21 34
Email: dpameknes22@yahoo.fr

7. **Ahmed Belkheiri, Directeur**
Agence de Bassin hydraulique du Sebou (Fès)
Adresse:B.P. 2101, Fès
Direct: (05) 55 64 29 79 / 55 64 29 98
Téléphone: (212)(0)55.64.29.97/ 55.64.29.98
Fax : 055.64.04.44
Email : adbsebou@iam.net.ma
Site web: www.abhsebou.ma

8. **Abdelmajid Behayoune,**
Chef de Division Planification
Regie de Distribution d' Eau et d' Electricité , Meknès, RADEEM
78, Avenue de l'Armée Royale
50000 Meknès
Téléphone: 0 5 35 52 18 01- 05 35 52 18 04
Fax: 05 35 52 28 22
Email: radeemdr@menara.ma

9. **Mimoun El Mers**
Direction Provinciale d’Agriculture de MEKNES
9, Rue Othmane Ibn Affane.
B.P S/14. MEKNES
Standard: 05 35 52 12 92 – 05 35 52 08 71
Direct: 05 35 52 03 17 – 05 35 52 21 34
Email: dpameknes22@yahoo.fr

10. **Abdellah Erraya**
Direction Provinciale d’Agriculture de MEKNES
9, Rue Othmane Ibn Affane.
B.P S/14. MEKNES
Standard: 05 35 52 12 92 – 05 35 52 08 71
Direct: 05 35 52 03 17 – 05 35 52 21 34
Email: dpameknes22@yahoo.fr

11. **Rirke Abdellatif**
Chef Division, ONEP, Région du Centre Sud, ONEP
20, rue Antsirabé, Meknes
Tél: 0535520508, 0535522898, 0661052950

12. **Mme Malika Houate**
Chef de Service de protection de la qualité de l’eau
Agence de Bassin hydraulique du Sebou
Adresse:B.P. 2101, Fès
Direct: (05) 55 64 29 79 / 55 64 29 98
Téléphone: (212)(0)55.64.29.97/ 55.64.29.98
Fax : 055.64.04.44
Email : adbsebou@iam.net.ma
Site web: www.abhsebou.ma

13. **Sahar Lahmouz,**
Chargée du service contrôle qualité et dépollution
Regie de Distribution d' Eau et d' Electricité , Meknès, RADEEM
78, Avenue de l'Armée Royale
50000 Meknès
Téléphone: 0 5 35 52 18 01- 05 35 52 18 04
Fax: 05 35 52 28 22
GSM: 06 61 85 97 03)
Email: radeemdr@menara.ma

14. **Moh Hicham,**
Regie de Distribution d' Eau et d' Electricité , Meknès, RADEEM
78, Avenue de l'Armée Royale
50000 Meknès
Telephone: 0 5 35 52 18 01- 05 35 52 18 04
Fax: 05 35 52 28 22
GSM: 06 61 28 60 85
Email: radeemdr@menara.ma

15. **Bousselham Rahal**
Délégué du Ministère du Commerce et de l’Industrie
Place rue de l’Unité Africaine
BP S/44 Meknes
Tél : 212 535522870, Fax : 212535524894
Email : Rahal@mcinet.gov.ma

16. **El Mostafa Elhairouri**
Chef de Service de l’industrie, DPCI, Meknès
Délégué du Ministère du Commerce et de l’Industrie
Place rue de l’Unité Africaine
BP S/44 Meknès
Tél : 212 535522870, Fax : 212535524894
elhadourim@yahoo.fr

17. **Secrétariat d'Etat Chargé de l'Eau et de l'Environnement**

18. **Direction de la Coopération de l’ONEP, Rabat**