Kuwait Institute for Scientific Research

WATER REUSE STANDARDS FOR KUWAIT

Prepared by

Bahman Sheikh, PhD, PE
Water Reuse Consultant
San Francisco, California USA

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Kuwait City

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- Australian Water Recycling Guidelines Part 1, 2007
- Australian Water Recycling Guidelines Part 2, 2007
- California Water Recycling Criteria, 2000
- California Groundwater Recharge, Draft August 5, 2008
- Florida Water Reuse Standards, 2007
- Islamic Scholars' *Fatwa,* Recycled Water, 1999
- Israel and Palestine Water Reuse Standards, 2001
- Jordan Water Reuse Standards, 2006
- Tasmania Recycled Water Guidelines, 2002
- USEPA Guidelines for Water Reuse, 2004
- Virginia Proposed Reuse Regulations, 2002

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WATER REUSE STANDARDS FOR KUWAIT

EXECUTIVE SUMMARY

A Review of current water reuse standards and practices in Kuwait indicates that (a) current standards and guidelines are inadequate to address the future water supply needs of this country; (b) implementation, enforcement, and quality assurance for dependable and reliably safe water reuse are lacking; (c) current treatment systems are apparently producing high-quality recycled water, judging by the monitoring data supplied by the treatment plant operators; (d) the uses to which recycled water is put are relatively low-priority compared to the high quality of water that is produced at the wastewater treatment plants; and (e) there is a dire need for establishing public confidence in the quality of recycled water and its potential for use in urban areas and for groundwater recharge.

Based on these findings, it is recommended that mandatory, enforced standards be adopted for production of recycled water that meets the following limits for the indicated uses:

Parameter	Orchard, Fodder, Industrial Crops, Grains	Commercially Cooked, Processed Food Crops	Vegetables Eaten Raw, Public Parks, Other Urban Uses, GWR*
Total Coliform	200	23	2.2
Nematode Eggs	1	1	1
BOD	100	50	15
TSS	50	30	5
Turbidity	12	10	2
Total Nitrogen	45	45	30
Residual Chlorine	NR	NR	0.5

*GWR = groundwater recharge

Further, it is recommended that the current proposed water reuse standards of the Ministry of Public Works and the water reuse guidelines of the Kuwait Environmental Public Authority be reconciled into a single set of advisory guidelines (excluding the parameters listed above, which would be compulsory).

It is recommended that the following implementation steps be undertaken, primarily to ensure a robust system for the protection of public health and the environment. Secondarily, these steps would help garner public confidence in the safety of water recycling in Kuwait and enlist their support for increased uses of recycled water.

- Intensive monitoring of the effluent from wastewater treatment plants on a pre-set schedule of sampling, chain-of-custody routine, and analysis using published standard methods for every analyte at a certifies laboratory.
- An approved quality assurance and quality control (QA/QC) program to ensure the veracity, credibility, and reliability of monitored data.
- Ready and easy availability of monitoring data for public inspection. The current practice of confidentiality of wastewater treatment monitoring data is counter to gaining public confidence in using the water for irrigating their gardens and crops.
- Oversight by an independent agency (such as KEPA or the Ministry of Health) to ensure accountability and responsibility in the water reuse system.
- Fines and other punishment for repeat violation of standards, imposed upon persons responsible for plant operation and treatment efficacy
- An administrative and/or judicial process for resolution of instances of violation of standards and their final settlement.

WATER REUSE STANDARDS FOR KUWAIT

INTRODUCTION

Kuwait is one of the driest countries in the world, reliant almost entirely on desalinized seawater for nearly all uses. A diminishing brackish groundwater resource is utilized in a dual-distribution system for domestic irrigation of residential gardens in many parts of Kuwait. Because of the energy costs of producing the desalinated seawater, it is imperative that its use be as efficient as possible and wastewater generated from its use be treated and put to a second cycle of use before it is evaporated or discharged back to the sea. Desalinized seawater has a very high quality with a very low mineral content. After an initial cycle of use, the resulting wastewater can be treated to produce a high-quality reclaimed (or recycled) water for reuse applications—if the domestic wastewater is not further degraded with highly polluted industrial and other discharges.

There are three primary objectives in adopting and enforcing water reuse standards:

1. Protect field workers exposed to reclaimed water;
2. Protect the general public who might become exposed inadvertently to the water; and
3. Protect consumers any eating food crops irrigated with the water

The proper balance for the level of protection afforded these three groups must be struck in standards. Water reuse standards or regulations are in effect in most of the countries in the world's semi-arid and arid zones. Setting standards is a balancing act between the desire for maximum protectiveness and the need to conserve economic resources. Where this balance is ultimately struck depends upon the willingness and ability of the community to spend money to achieve a healthful water resource on the one hand and their aversion to taking risk on the other. Risk is a double edged sword, however: Not using recycled water runs the risk of limiting available water resources even further, while using recycled water runs the risk of treatment failure, power failure resulting in untreated wastewater being sent into the distribution system, and the possibility of cross-connection between recycled and potable water lines. These risks are controllable and amenable to being minimized to an acceptable level with the standards and guidelines recommended in this paper. These recommended standards and guidelines are based on global professional experience, the record of performance at countries and regions utilizing similar or lower standards, and on awareness of local economic and social conditions in Kuwait.

Separate standards exist in Kuwait for treated sewage effluent (TSE) discharge to the sea and for reuse for irrigation of greenery and grass grown for animal feed. Separation of the two sets of standards is important, because the objectives for the two sets of standards are very different. In the case of discharge to sea, the primary objectives are environmental protection, maintaining clean beaches and seashores, and protection of the public health. In the case of water reuse, the main objective is prevention of disease transmission in areas irrigated with reclaimed water, safety of the public consuming food crops grown with recycled water, and minimization of field workers' exposure to pathogens. These various (and sometimes conflicting) motives for quality control of effluents are shown in Table 1.

Table 1. Motives for Control of Constituents in Effluent and Reclaimed Water

Constituent	For Public Health Protection	For Environmental Protection	For Water Reuse
Nitrogen	Manage against infant methemoglobenemia	Minimize, to prevent open water eutrophication	Maximize in early season, minimize in late season
BOD, Suspended Solids	Minimize	Minimize, to avoid anoxic conditions in streams, and lakes	Maximize for soil enrichment
Organic Matter	Minimize	-	Maximize for soil conditioning
Trace Metals	Usually not relevant after sedimentation, settling and removal in sludge	Minimize, to prevent bioaccumulation	Manage for micronutrient benefit
Microorganisms	Eliminate pathogens: minimize indicator organisms to safe levels	-	-
Soluble 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, and 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. Wherever it is not possible to meet conflicting objectives, there should be enough flexibility in standards and regulations to determine which objective has the higher priority. 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[1]), it becomes necessary to lower its concentration in reclaimed water, unless a technical solution can be implemented reliably, to achieve both objectives simultaneously—for example, by balancing agronomic water and fertilizer application rates with the demand of crops for nitrogen fertilizer.

REGULATORY FRAMEWORK

A regulatory framework is proposed primarily to ensure protection of the public and workers' health. Qualitatively, tradeoffs between cost and strictness of standards are weighed. Also, risk levels re weighed against treatment standards, in a qualitative way. The water reuse regulatory framework would contain numerical standards and should also have a narrative section including some or all of these 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

Typically, numerical standards are established for parameters with the greatest potential for public health impact. These parameters primarily include coliform bacteria as indicators of pathogen destruction. In addition, they generally include limits on turbidity and the concentrations of BOD and TSS. Some standards place a high level of importance on controlling the concentration of nitrogen in recycled water. Other constituents, such as

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

cations, anions, heavy metals and microconstituents are generally not regulated, but provided as advisory guidelines for customers (actual users) of recycled water.

REVIEW OF AVAILABLE TREATED, UNTREATED WASTEWATER EFFLUENT DATA IN KUWAIT

Data on a wide range of parameters, monitored in recent years from raw sewage, secondary effluent, and final product recycled water from the four treatment plants in Kuwait were reviewed. Table 2 presents average values of total suspended solids (TSS) over the past several years from these four wastewater treatment plants.

Table 2. Average TSS Values at Kuwait Wastewater Treatment Plants, 1999 to 2008

Wastewater Treatment Plant	Raw Sewage	Secondary Effluent	Final Effluent
Sulaibiya[2]	224	25	0
Um Al-Haiman	249	7	4
Jahra	202	27	5
Riqqa	205	14	5

Source: Calculated from raw monitoring data provided by the respective WWTPs

Total suspended solids (TSS) is an important parameter and can readily represent (along with BOD and biological indicators) the capability of a treatment plant to remove pollutants consistently. The data on which the averages above are based have been reported by the operators and contractors of the respective treatment plants. It is not evident that any of the data have been subjected to quality assurance procedures or to independent verification.

Assuming that the data are indeed representative of treatment efficacy, these four plants are producing excellent quality reclaimed water for urban landscape irrigation and other uses that might involve human exposure. For most agricultural and landscape uses, the recycled water, especially from the Sulaibiya WWT&RP, is better than the minimum quality necessary for irrigation. In fact the quality of the Sulaibiya effluent is so pure that its salt content over the last three years averaged only 23 mg/L! This is an excessive level of treatment for production of reclaimed water intended merely for irrigation. Water of such high quality can be used for replenishment of Kuwait's groundwater resources that have been declining

[2] The Sulaibiya WWT&RP provides reverse osmosis as the final treatment process and its final effluent is superior to "tertiary" treatment level achieved by the other three treatment plants.

rapidly in recent years—of course, the water ultimately withdrawn from the aquifer should meet drinking water standards and be monitored for unregulated chemicals also, in order for it to be used for drinking water purposes.

On the basis of the above analysis of available data, and the evaluations presented in the following sections, it is concluded that the ongoing project for evaluation of existing treatment systems in Kuwait and recommendation of future improvements has a high likelihood of success.

EVALUATION OF WASTEWATER EFFLUENT AND BY-PRODUCT QUALITY FOR REUSE

Indicator Organisms

Indicator organisms (total or fecal coliform bacteria) are surrogate indicators of absence of pathogenic microorganisms. In some countries, *E. Coli* are used as indicator organisms with similar limits to fecal coliform (i.e., absence). Use of such indicators for monitoring and control of treatment plant performance is standard practice throughout the world and is widely accepted by the sanitary engineering, public health, and sanitation professions.

It is not necessary to monitor for specific microorganisms on a routine basis or as part of a regulatory program. However, for research and investigation of specific workings of the treatment process, it is often desirable to maintain a capability for identification and detection of specific bacteria, parasites, and viruses, particularly at academic institutions, such as KISR. The limited data reviewed on the microbial character of the final effluent at the SulaibiyaWWT&RP in Kuwait indicate a total absence of total coliform and viruses.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is an indicator of stabilization and removal of organic matter in the reclaimed water (TSE). The lower the level of BOD, the less will the effluent be able to extract oxygen from the receiving waters of the Gulf, the lower is the possibility of odors, nuisance conditions, and regrowth of microorganisms. For reuse of the effluent, BOD is not, by itself, a critical parameter. In fact, the organic matter may be considered beneficial for the dry, mineral soils of Kuwait. However, BOD acts as an indicator of the level of treatment. Therefore, the lower the BOD level, the more highly treated is the finished water, the more readily amenable is the water to effective disinfection, and it can be employed for the more intimate uses (e. g., irrigation of edible crops).

Turbidity and Total Suspended Solids

Turbidity is a highly useful (and inexpensive to monitor) parameter to help keep continuous track of treatment plant performance. Automatically recording turbidimeters are available and can be coupled with visual, remote, and auditory warning signals. A properly treated tertiary effluent should have a consistently low turbidity. Any significant departure from the standard should immediately send warning bells ringing and red lights flashing, so that the operators can quickly diagnose and correct the problem.

Suspended solids in water are the cause of turbidity and there is an association between the two parameters. The three graphic depictions in Figure 1 indicate a fairly consistent and good quality of effluent produced at Kuwait's wastewater treatment plants, meeting stringent standards. However, these data cannot be completely relied upon, because of the absence of quality control, quality assurance procedures and independent oversight inspections.

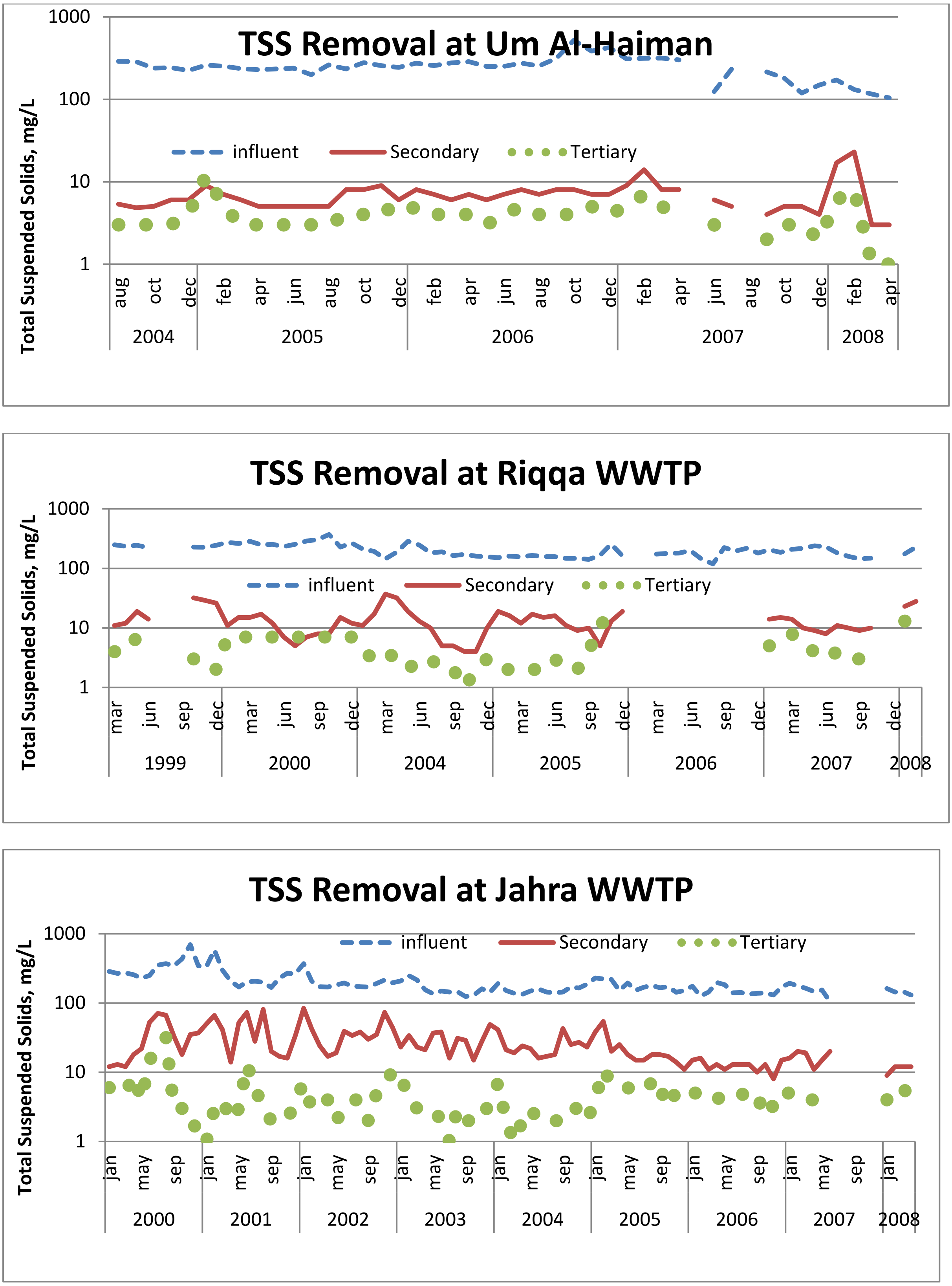
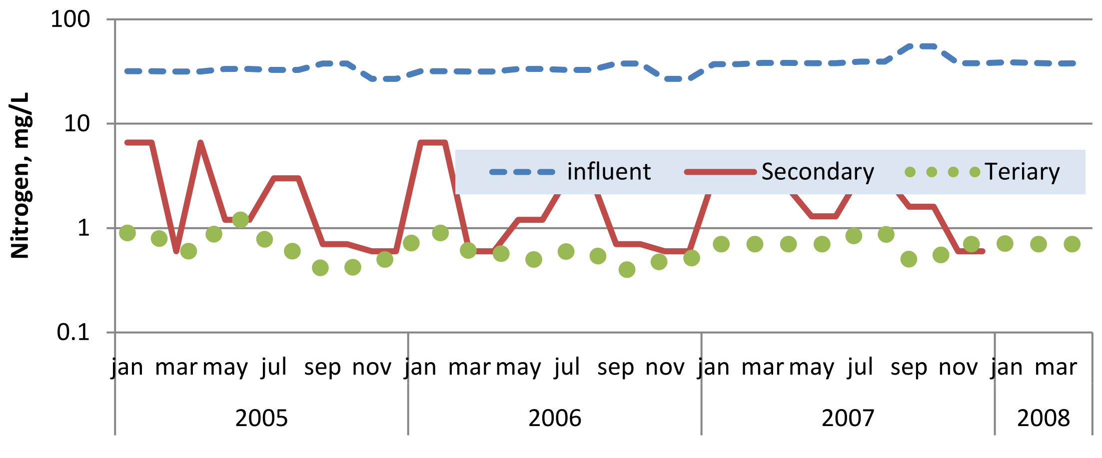


Figure 1. Historical Pattern of Suspended Solids Removal at Three of Kuwait's WWTPs

Nitrogen

Nitrogen is regulated, in part to prevent excess nutrients from leaching to the groundwater aquifers. The form of nitrogen is immaterial, as far as agriculture and landscape use of the nutrient are concerned. Ammonia and nitrate are equally available forms for plant uptake. Any organic nitrogen will gradually decompose in the soil environment and convert to the more mobile, mineral forms, available for plant uptake and utilization. Where fruits and flowers are grown for harvest and marketing, yield of the crop may be adversely affected by nitrogen in the irrigation water—at the maturation stage of growth. However, for vegetables, where the green leaves are harvested and sold, higher nitrogen levels are actually beneficial. Application of commercial fertilizers should be curtailed to account for the presence of nitrogen in the irrigation water.

The treatment plants in Kuwait are very efficient in removing nitrogen from the wastewater. From an environmental perspective, this is a very good practice. From a resource conservation perspective, however, this is wasteful in two ways: first, the treatment plants spend large amounts of energy to nitrify-denitrify the effluent; second, nitrogen is a macro-nutrient required by all crops irrigated with recycled water. If left in the effluent it would make it unnecessary for farmers and landscape managers to purchase and apply expensive chemical fertilizers. Figure 2 shows a typical nitrogen removal history obtained from the Sulaibiya WWT&RP monitoring data. Nitrogen levels in the influent stream (about 50 mg/L) are dramatically reduced to levels below 1 mg/L consistently.



Source: Calculated from raw monitoring data provided by the respective WWTPs

Figure 2. Historical Pattern of Nitrogen Removal at Sulaibiya WWTP

Disinfection

Disinfection by chlorination, at the end of the treatment process, is a standard practice in the profession, both for reuse and for discharge. Recently, several manufacturers of ultraviolet equipment have succeeded in producing equipment that economically disinfects reclaimed water competitively, while taking up a much smaller footprint. However, for long-distance transport of the reclaimed water that is disinfected by ultraviolet light, it is advisable to add a residual amount of chlorine to prevent microbial regrowth and slime formation in stagnant water lines.

CHEMICAL AND BIOLOGICAL RISKS ASSOCIATED WITH TREATED EFFLUENT REUSE AND DISPOSAL

The layperson would likely want a world in which risks are managed to the level of zero. This, of course, is impossible, for any human activity, standards and regulations, or water resources. However, risks can be managed to levels that are tolerable, cost-effective, and considered safe, based on background risks of daily life. The ideal way to determine the adequacy of standards for water reuse would be through a formal risk assessment process. The science of risk assessment is relatively young and evolving. Risk assessment specialists use sophisticated mathematical models to arrive at numerical measures used to compare various scenarios and recommend the most appropriate standards for a given situation.

Some countries—notably Australia—are working toward establishment of "risk-based" water reuse standards. The World Health Organization, the European Community and some of the States in Australia have pioneered the use of risk models on which to base their potable water standards and regulations. A prominent model, gaining gradual acceptance now is a calculated Disability-Adjusted Life Years, or DALY value[3]. According to the World Health Organization's definition:

> "DALYs for a disease are the sum of the years of life lost due to premature mortality (YLL) in the population and the years lost due to disability (YLD) for incident cases of the health condition. The DALY is a health gap measure that extends the concept of potential years of life lost due to premature

[3] For a more detailed definition and formulas for risk calculation, refer to the WHO website: http://www.who.int/healthinfo/boddaly/en/index.html

death (PYLL) to include equivalent years of 'healthy' life lost in states of less than full health, broadly termed disability. One DALY represents the loss of one year of equivalent full health."

Applied to water quality, human exposure to a given quality of water (based on a given treatment level) is calculated with a set of assumptions about the individual's consumption, ingestion or skin exposure to that water for a lifetime. For example, for chemicals that are known or suspected to cause cancer, the acceptable lifetime exposure is defined in the WHO Guidelines for Drinking Water Quality as that which will result in one excess cancer case per 100,000 people. The Australian Drinking Water Guidelines are ten times stricter and set limits based on one excess cancer case per million people. The World Health Organization has defined a tolerable level of risk of 1 millionth of a DALY (one microDALY) per person-year. This is equivalent to the loss of one DALY per million people per year. This could be interpreted as one person in a million losing one year of life, or it could be interpreted as a larger number of people suffering less severe impacts. For a pathogen causing watery diarrhea, this reference level of risk has been determined to be equivalent to around 1 in 1000 annual risk of diarrhea to an individual, or about 1 in 10 risk of contracting diarrhea over a lifetime.

Of course, the outcomes of these risks would not actually be observable. For example, the normal reported rate of diarrheal illness in Australia is about 0.8-0.9 cases per person per year. In other words, the average Australian gets (and reports) diarrhea just slightly less often than once per year. With this 'benchmark' risk level having been defined, concentrations of specific hazards, that are consistent with this benchmark, can be determined.

While the risk benchmarks are the same for recycled water as for drinking water, this doesn't mean that the actual risks are the same. A well managed comprehensive advanced water recycling system can be expected to achieve much better water quality for most hazards, compared with simply meeting the drinking water guideline. Water reuse standards adopted by European, Australian and US states for various applications of reclaimed water meet or exceed these risk benchmarks. A sample calculation of risk-derived standard (in this case for deactivation of *E. Coli* in recycled water) is shown in Table 3 (WHO, 2004[i])

Table 3 Removal of *E. Coli* as a function of tolerable risk of infection from rotavirus

Tolerable rotavirus infection risk per person per year	Corresponding DALY loss per person per year [a]	Corresponding required wastewater quality (*E. coli* per 100 ml) [b]	Corresponding required removal of *E. coli* (log units) [c]
10^{-1}	$\sim10^{-5}$	4×10^{5}	2
10^{-2}	$\sim10^{-6}$	4×10^{4}	3
10^{-3}	$\sim10^{-7}$	4000	4
10^{-4}	$\sim10^{-8}$	400	5
10^{-6}	$\sim10^{-10}$	4	7
10^{-8}	$\sim10^{-12}$	0.04	9

[a] Allowing for a disease-infection ratio of 10^{-1}.
[b] Median values derived from 10,000-trial Monte Carlo simulations based on the following assumptions: 100 g lettuce eaten per person per 2 days; 10−15 ml wastewater remaining on 100 g lettuce after irrigation; 0.1−1 rotavirus per 10^{5} *E. coli*; 10^{-2}–10^{-3} die-off from harvest-consumption; $ID_{50} = 6.17 \pm 25\%$ and $\alpha = 0.253 \pm 25\%$.
[c] Based on raw wastewater containing 4×10^{7} *E. coli* per 100 ml.
Source: WHO (2004). *Guidelines for Drinking-water Quality*, 3rd ed. Geneva: World Health Organization.

ADDITIONAL TREATMENT NECESSARY

The four wastewater treatment plants currently providing pollution control for Kuwait are serving more than adequately as reflected in the historical and ongoing plant performance monitoring data analyzed and reviewed during the conduct of this research project.

The areas where additional treatment is deemed necessary primarily concern industrial wastewater discharges to the public sewers. Based on informal inquiries, these discharges are neither pre-treated, nor are they currently regulated. It is, therefore, recommended that regulations be adopted to require industry-by-industry specification of treatment levels aimed at meeting the existing standards for discharge to sewers (shown in Table 7, further below in this report).

KUWAIT NATIONAL STANDARDS: REGULATORY MODIFICATION TO ENFORCE SAFE WATER REUSE

Existing standards for water reuse in Kuwait were reviewed and compared with similar standards in effect in neighboring countries, and in other regions of the world, with similar climatic and water shortage conditions. The European Community, Australia, various states in the United States, and several countries in the Middle East have adopted updated standards for water reuse in recent years. A comparison of existing water reuse standards in the various Middle East and North African countries, plus a few Western states, is presented at the end of this document. A discussion of the standards and guidelines for water reuse in other countries is also presented further below.

The list of reasons for revision of water reuse standards for full utilization of the TSE resource in Kuwait is summarized below:

- Periodic update of existing standards to keep up with advancing technology,
- Using the state of knowledge about reclaimed water use in other countries,
- Reflecting the importance of water reuse in Kuwait, as part of the country's integrated water resources,
- Focusing on safe implementation of water reuse, i., e., protecting the public health—recognizing that a minimum water quality can be produced fit for a particular use, without excessive and expensive treatment to the highest level.
- Holding wastewater treatment plant operators accountable for the quality of effluent produced,
- Compliance with uniform standards by all involved, and
- Simplifying and streamlining enforcement of the standards.

Adoption of Updated Water Reuse Standards

Three steps in adoption of criteria are recommended. The **first step** would encompass the legally enforceable water reclamation standards, primarily aimed at assuring treatment integrity and protecting the public health and the field workers' safety and health. This would be accomplished through regulation of parameters that:

(1) ensure optimal performance of the wastewater treatment plant,

(2) indicate microbiological and chemical safety of reclaimed water,

(3) can be controlled with available tools at the wastewater treatment plant used by the plant operators, and

(4) Can and will be enforced through regular monitoring, compulsory reporting, surprise inspections, warnings, and legally established fines and other punishment for repeat violations.

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. Numerical standards for intensive monitoring, control, and legal enforcement of the step 1 criteria are proposed to be limited to those in Table 4. 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.

Table 4. Proposed Step 1* Standards for Irrigation with Recycled Water in Kuwait

Parameter	Orchard, Fodder, Industrial Crops, Grains	Commercially Cooked, Processed Food Crops	Vegetables Eaten Raw, Public Parks, Other Urban Uses, GWR**
Total Coliform	200	23	2.2
Nematode Eggs	1	1	1
BOD	100	50	15
TSS	50	30	5
Turbidity	12	10	2
Total Nitrogen	45	45	30
Residual Chlorine	NR	NR	0.5

* Step 1 includes parameters that can be controlled directly, by wastewater treatment plant operators.
**GWR = groundwater recharge
NR=Not Required

Rationale for Recommendations of Step 1 Standards

There is no simple formula for establishing standards for safe use of reclaimed water. Each country decides on its set of standards based usually on a qualitative analysis of risks, capability of treatment systems available, economic strength for sustained operation and maintenance of treatment systems, and the willingness of its citizenry to accept recycled water produced for reuse under those standards. As a result, there is a wide divergence of standard limits in the selected criteria of various countries as shown elsewhere in this document. Recommended standards in this paper are based on professional judgment of the author and the experience gained from close observation of water reuse systems in operation in numerous countries in the world. Further, they are based on the assumption that Kuwait aspires to err on the side of safety rather than on the side of savings with regard to treating wastewater for production of recycled water for beneficial reuse. In the following paragraphs, the rationale for each parameter is discussed for setting limits and for allowances—where appropriate—for occasional exceedance from the standard.

Total Coliform This indicator is used widely and is recommended to be used as the standard indicator for destruction of pathogenic microorganisms. It is recommended that total coliform be assessed on a daily basis. This indicator is selected also because of the relative ease of analysis and its good correlation with the level of pathogen destruction in the wastewater stream. The correlation has been established over many years of experience in operating wastewater treatment plants in various parts of the world. A five-year research project on use of disinfected tertiary recycled water for irrigation of vegetable crops documented this relationship with actual analyses for viruses, pathogenic bacteria and protozoa[ii] (Sheikh *et al*., 1990).

The total coliform limit values recommended are based on the most stringent standards in existence in various parts of the world, especially in the more developed, economically prosperous regions. It is felt that Kuwait fits well in that category and can afford such high standard of public health protection, even though it may be overly conservative. The maximum values are set at 2.2, 23, and 200 MPN/100 mL for raw eaten crops, commercially processed crops, and for orchards and industrial crops, respectively. For the food crops eaten raw, the median concentration of total coliform bacteria measured in the disinfected effluent should not exceed an MPN of 2.2 per 100 mL based on the bacteriological results of the last seven days for which analyses have been completed and the number of total coliform bacteria does not exceed an MPN of 23 per 100 mL in more than one sample in any 30 day period. No sample shall exceed an MPN of 240 total coliform bacteria per 100 mL. Similarly, for the other two categories of crops, tolerable exceedances can be set within a reasonable statistical range.

Nematode Eggs Because of the prevalence of intestinal nematodes in some of the countries from which expatriates arrive in Kuwait, it is recommended that this analysis also be performed on a daily basis. The standard of one egg per litre is almost universal and there is no reason to recommend a different value. With the treatment systems currently in operation in Kuwait, there should not be a problem meeting this standard.

Biochemical Oxygen Demand (BOD) is used to monitor plant performance and the level of removal of organic compounds in the water. The limits recommended are comparable with other countries' standards and will ensure that other indicators also fall within the standards. Since the greatest removal of BOD takes place in the secondary, biological treatment process, the values obtained should be quite stable over time as long as plant operations are not upset by an inflow of toxic industrial waste discharge into the sewerage system.

Total Suspended Solids (TSS) generally follows the pattern of BOD in the effluent. The recommended standard for TSS is slightly more stringent than the current guideline values for use in irrigation of raw-eaten food crops and less stringent for other uses. The selected values reflect what can be readily accomplished with tertiary treatment and are consistent with the most protective of the existing international standards.

Turbidity is an excellent indicator of the proper operation of the wastewater treatment system. It is also an extremely inexpensive and reliable indicator that gives instantaneous feedback to the plant operators regarding the efficacy of the treatment processes in removing contaminants from water. Recoded charts of turbidity can provide proof of historical performance of the treatment plant to gain public confidence in the product water and its safety for public contact—especially for the most intimate uses involving exposure of children and older people.

The values recommended for each category of irrigation use are consistent with those of Japan, California, and Jordan—found to be reliable based on long-term experience. Because of the immediate availability of turbidity data, the operator should be able to make quick adjustments whenever the turbidity value begins to approach the standard limit. Therefore, there is no need to provide a formula for allowable exceedance from this standard limit. Well-operated tertiary treatment systems almost never exceed their established turbidity standards.

Total Nitrogen Nitrogen is a fertilizer element of great importance for growing crops, ornamentals, greenery, and other cultivation. Therefore, its concentration in the recycled water is only limited by the established public health standards to protect against methemoglobenemia. These standards are internationally adopted and treatment processes can meet them easily. (For discharge to waterways and the sea, much lower nitrogen limits are necessary, because of the eutrophication potential.)

Residual Chlorine Whether disinfection is achieved with chlorine or with ultraviolet light, it is necessary to inject and maintain a minimal chlorine residual in the distribution system so that regrowth of bacteria is prevented. The selected minimum level of 0.5 mg/L for irrigation of raw-eaten crops is lower than the current standard of 1 mg/L, but is consistent with practice in other countries enforcing residual chlorine as a standard.

Implementation of Standards in Kuwait

There is no procedure at the present time to implement the existing or any future standards and to enforce them. A possible implementation plan may include the following elements:

- Intensive monitoring of the effluent from wastewater treatment plants on a pre-set schedule of sampling, chain-of-custody routine, and analysis using published standard methods for every analyte at a certifies laboratory.
- An approved quality assurance and quality control (QA/QC) program to ensure the veracity, credibility, and reliability of monitored data.
- Ready and easy availability of monitoring data for public inspection. The current practice of confidentiality of wastewater treatment monitoring data is counter to gaining public confidence in using the water for irrigating their gardens and crops.
- Oversight by an independent agency (such as KEPA or the Ministry of Health) to ensure accountability and responsibility in the water reuse system.
- Fines and other punishment for repeat violation of standards, imposed upon persons responsible for plant operation and treatment efficacy
- An administrative and/or judicial process for resolution of instances of violation of standards and their final settlement.

Intensive monitoring of the primary control parameters (total 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 parameters should be frequent (at least daily) and regular, to give quick feedback to treatment plant operators about problems that need correction and adjustment. Criteria in the last column of Table 4, if adopted, would remove the restrictions imposed in the current standards on irrigation of raw-eaten vegetables. In case of conflict with discharge standards, the more stringent (protective) criteria should govern.

RECOMMENDED WATER REUSE GUIDELINES

A **second step** is aimed at protection of the soil and crop yields, important concerns in sustainable water reclamation and reuse for landscape (greenery) irrigation, and for sustainable agriculture. 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 wastewater treatment plant. They are best managed technically and legally by source control, and with appropriate irrigation and soil amendment. Users of reclaimed water, in collaboration with the appropriate governmental agencies, including those producing reclaimed water, can play an important role in ensuring a sustainable irrigation operation with the use of recycled water. It would be an unreasonable (if not impossible) burden on the treatment plant operations personnel to hold them 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 many constituents and parameters. It is recommended that the existing guideline parameters of the Ministry of Public Works (MPW) be coordinated with the standards of the Kuwait Environmental Public Authority (KEPA). In this process, several changes will be necessary to create one set of guidelines for the country:

1. Delete the parameters covered in the standards recommended above from the guideline parameters,
2. Delete any parameters that have no significant impact on the customers (users) of recycled water, such as Total Solids, Fluorides, Hydrocarbons, Arsenic, Barium, etc.,
3. Consolidate parameters that can be covered with just one of them, such as the various components of nitrogen,
4. Consolidate biological parameters that can be covered with just one of them or with a standard parameter,

5. Select the higher of the two values (MPW's and KEPA's) as the new limit, unless there is a compelling reason to use the lower value of a compromise value.
6. Publish and adopt the new list as guidelines for users of recycled water to determine suitability of the recycled water for their own particular needs.

Guideline Parameters

Salinity

Salinity (total dissolved solids) is an important agronomic parameter and must be controlled. However, treatment plant processes are incapable of reducing TDS (except in circumstances where advanced treatment processes, e.g., reverse osmosis, are employed —such as at Sulaibia WWT&RP). Therefore, control of salts, and most common cations and anions should *not* be included in the primary set of standards. Their control, *at source*, is the proper responsibility of governmental agencies with powers to regulate industrial discharges, and regulate the use of residential and commercial water softeners. Water softener regeneration cycles are responsible for addition of significant quantities of salt into the sewers, as are industries that discharge their wastewater into the sewers without pretreatment, and without governmental controls. It is expected that this situation will change in the future as KEPA takes on a greater role in controlling environmental discharges from industry.

Other Guideline Parameters

Other important parameters are placed in the second step, or "guidelines", sampling and monitoring for which would be conducted by other governmental agencies, such as the Ministry of the Environment, Ministry of Health, Kuwait Institute 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 reclaimed water (TSE). Secondary, guideline parameters should be monitored monthly by agencies other than treatment plant operators. The guideline levels of these parameters, as given in the current standards appear to be consistent with USEPA recommended guidelines, and should be maintained as such.

From the point-of-view of customers of reclaimed water, it is important to set the guidelines at levels that do not harm plants irrigated with recycled water over a long period of time—many years, in case of perennial crops. Table 5, derived from the USEPA Guidelines for

Water Reuse (2004)[iii] and from the agronomy literature, provides the limits above which various constituents might be harmful to the irrigated fruits or vegetables.

Table 5. Concentration of chemical compounds that may harm or damage a fruit or vegetable

Constituent	Recommended threshold (µg/l)	Constituent	Recommended threshold (µg/l)
Zinc	2,000	**Copper**	200
Arsenic	100	**Nickel**	200
Boron[4]	3,000, 330, 750	**Selenium**	20
Iron	5,000	**Lead**	5,000
pH	6.5 - 8.4	**Fluoride**	1,000
Chromium	100	**Cadmium**	10
Molybdenum	10	**Cobalt**	50
Manganese	200		

Source: USEPA Guidelines for Water Reuse, 2004 and the general agronomic literature

MICROCONSTITUENTS

Finally, the **third step** addresses relatively new concerns, often called "emerging contaminants of concern" or microconstituents, 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. There is also concern about the environmental impact of microconstituents on aquatic life that is in constant contact with water. Their relevance in non-potable 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, pharmaceutical take-back programs, and public education to prevent disposal of left-over drugs to the toilets.

PUBLIC ATTITUDES TOWARD WATER REUSE

In many parts of the world, the general public is initially suspicious, sometimes hostile, to the concept of using recycled water, especially for those applications where close contact with people is involved—such as irrigation of residential gardens. More advanced treatment systems now make it possible to produce recycled water that is of better quality than any

4 Sensitivity of plants to Boron—an essential nutrient at very low concentrations—varies widely from species to species.

potable water available in nature. Even with that level of treatment, there have been instances of resistance from the public to these types of water reuse proposals. For example, in recent times, the town of Toowoomba in Australia voted against a proposed indirect potable reuse project. Similarly, in San Diego, California, the City Council voted against a proposal to augment a surface reservoir with very highly treated recycled water. These objections are principally motivated by the atavistic fear of waste ingrained in the human brain from childhood—irrespective of region, religion, or nationality. The only discriminator in this attitude is the level of education and technical knowledge of the processes that lead to the production of recycled water for these intimate uses (Reuten, 2004)[iv].

In Kuwait, Irrigation of residential gardens accounts for approximately 70 percent of the domestic water consumption, according to information provided by the Ministry of Public Works. A dual distribution system provides brackish groundwater to residences in most parts of Kuwait for irrigation of their gardens. The Sulaibiyah reverse-osmosis treatment system was constructed with the plan to replace groundwater with this highly treated RO effluent for garden irrigation. However, after the plant was completed, local residents refused to be switched to recycled water due to psychological aversions associated with the origins of recycled water. This indicates the need for a strong public education campaign coupled with transparency of wastewater treatment systems, monitoring data, and decisión-making processes affecting water reuse. Withour public support, urban and indirect potable reuse are not possible[v].

STANDARDS FOR DISCHARGE TO SEA

According to personal communication with the Ministry of Public Works personnel, an important environmental protection goal in Kuwait is to prevent "*even one drop of untreated wastewater"* from being discharged to the Gulf. It is believed that the waters of Kuwait Bay can no longer absorb any pollutants. Current discharges due to line breakage and stormwater overflows are being addressed by eliminating numerous pump stations and replacing them with a few major pump stations. Also, older sewer lines are being replaced on a regular basis.

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 emissions from treatment plants to the environment would be aimed at preventing bio-stimulation, accumulation of heavy metals, and protection of beaches against pathogenic microorganisms. Parameter concentrations specified in existing standards are appropriate. In case of conflict with water reuse standards, the more stringent set of criteria should govern. For example, as long as any amount of TSE is discharged to the sea, at least that portion of the discharge should be subjected to nutrient removal. The remainder of the flow, sent for reuse, can contain significant concentrations of nitrogen and phosphorus, beneficial nutrients for landscape (greenery) and agriculture alike. However, if and when Kuwait embarks on groundwater replenishment with highly treated reclaimed water, then nutrient removal to a low level, determined by the applicable standards, will become necessary for that purpose.

KUWAIT INDUSTRIAL DISCHARGES

A proposed industrial discharge standard was published in 2001 in the Kuwait Sanitation Master Plan, reproduced in Table 6. If enforced, these standards would be highly protective of Kuwait's marine and groundwater environment.

Table 6. KEPA Proposed Maximum Limit for Industrial Discharges to Kuwait Waters

Parameter	Standard	Parameter	Standard
Color	Free of pollutants	Aluminum, mg/L	5
pH	6 to 8	Arsenic, mg/L	0.1
Temperature, ◦C	10	Barium, mg/L	2
BOD, mg/L	30	Boron, mg/L	0.75
COD, mg/L	200	Berrylium, mg/L	0.1
Oil & Grease, mg/L	5	Cadmium, mg/L	0.01
TSS, mg/L	10	Cyanide, mg/L	0.1
TDS, mg/L	1,500	Total Chromium,	0.2
PO_4, mg/L	2	Nickel, mg/L	0.2
NH_4, mg/L	3	Mercury, mg/L	0.001
NO_3, mg/L	30	Cobalt, mg/L	0.2
TKN, mg/L	5	Iron, mg/L	5
Total N, mg/L	30	Antimony, mg/L	1.0
Total Phenol, mg/L	1	Copper, mg/L	0.2
F, mg/L	25	Manganese, mg/L	0.2
S, mg/L	0.5	Zinc, mg/L	2.0
Residual Cl_2, mg/L	0.5	Lead, mg/L	0.5
DO, mg/L	>2	Lithium, mg/L	2.5

Parameter	Standard	Parameter	Standard
Turbidity, NTU	30	Molybdenum, mg/L	0.01
Hydrocarbons, mg/L	5	Vanadium, mg/L	0.1
Floatables, mg/L	none	Silver, mg/L	0.1
Total Coli, MPN/100 mL	1,000	Pesticides, mg/L	0.2

Source: Kuwait Environmental Public Authority

The current KEPA standards applied to industrial discharge to the public sewers are shown in Table 7. The principal intent of these standards is to protect against excessive salts and other contaminants lowering the mineral quality of reclaimed water.

Table 7. KEPA Proposed Standards for Industrial Discharge to Sewer

Parameter	Standard	Parameter	Standard
BOD	500	Cu	0.5
COD	750	Pb	0.5
TSS	300	Hg	0.002
EOG	30	Ni	0.2
FOG	20	Ag	4
Tar and Tar Oil	0	Zn	2
SO4	1,000	Total Coli, MPN/100 mL	1,000
H2S	10	Fecal Coli, MPN/100 mL	100
CN	0.1	Parasite Eggs, #/L	0
As	0.1	Worm parasites, #/L	0
Cd	0.1		

Source: Kuwait Environmental Public Authority

It will be necessary to enforce these standards effectively in the future based on monitoring, surprise samplings, and quality assurance program for the collected information. Also, it will be useful to conduct a study of the actual quality of effluent typically discharged by each industrial sector (e.g., tile manufacture, auto assembly, paint manufacture, etc.) into the public sewerage system.

It is recommended that especially salt-laden brines (from cooling towers, ion-exchange regeneration units, desalination plants, and from other sources) be treated and disposed of separately. Solar drying ponds, lined to prevent groundwater contamination, would be a viable low-cost option in Kuwait and should be evaluated as a serious alternative to ocean discharge. The current practice of diluting the Reverse-osmosis concentrate (containing all the pollutants in the feed water plus the brine) with desalinized product water before discharge to the sea is wasteful and counter-productive.

EXISTING KUWAIT NATIONAL STANDARDS FOR WATER REUSE

Currently, there are two sets of standards in effect in Kuwait for water reuse for irrigation of non-food crops and landscaping. There are significant differences between these two standards and they merit simplification in order to obtain uniformity of standards for Kuwait. The guidelines of the Ministry of Public Works are, in some cases, several orders of magnitude more stringent than the standards of the Kuwait Environmental Public Authority. These comparisons are shown in Table 8.

Table 8. Comparison of Standards of Kuwait Environmental Public Authority (KEPA) for Use of Treated Wastewater in Restricted Irrigation in Kuwait to Ministry of Public Works (MPW) Guidelines for Wastewater Reuse in Kuwait.

Parameter	Symbol	Unit	KEPA Standards*	MPW Guidelines**
Temperature	---	ºC	---	31.9
Hydrogen ion concentration	pH	---	6.5-8.5	7.6
Electrical Conductivity	EC	dS/m	---	2.057
Biochemical Oxygen Demand	BOD5	mg/1	20	3
Chemical Oxygen Demand	COD	mg/1	100	54 (dichromate)
Oil/grease	-	mg/1	5	---
Bicarbonate	HCO_3	mg/l	---	---
Floatable	-	mg/l	0	---
Total Suspended Solids	TSS	mg/1	15	8
Volatile Suspended Solids	VSS	mg/l	---	6.2
Total Volatile Solids	TVS	mg/l	---	688
Total Dissolved Solids	TDS	mg/1	1500	1040
Total Solids	TS	mg/l	---	2009
Ammonia Nitrogen	NH_4–N	mg/l	15	15.1
Nitrate nitrogen	NO_3-N	mg/l	---	1.13
Nitrite nitrogen	NO_2-N	mg/l	---	0.77
Kajeldah Nitrogen	KJN	mg/l	35	---
Organic nitrogen	Org-N	mg/l	---	0.73
Total Nitrogen	TN	mg/l	---	17.3
Total Phosphate	PO_4	mg/1	30	18.75
Potassium	K	mg/l	---	---
Phenol	-	mg/1	1	---
Sulfates	SO_4	mg/l	----	270

Parameter	Symbol	Unit	KEPA Standards*	MPW Guidelines**
Fluorides	F	mg/1	25	---
Sulfide	S	mg/1	0.1	---
Sodium	Na	mg/l	---	---
Chlorides	Cl	mg/l	---	345
Residual Chlorine	CL_2	mg/1	0.5-1.0	0.3, 1st Stage Free
Dissolved Oxygen	DO	mg/1	>2	---
Hydrocarbons	HCs	mg/1	5	---
Aluminum	Al	mg/1	5	---
Arsenic	As	mg/1	0.1	---
Barium	Ba	mg/1	2	---
Boron	B	mg/1	2	---
Cadmium	Cd	mg/1	0.01	0.0004
Chromium	Cr	mg/1	0.15	0.00195
Cobalt	Co	mg/1	0.2	---
Copper	Cu	mg/1	0.2	0.00025
Iron	Fe	mg/1	5	---
Lead	Pb	mg/1	0.5	0.00055
Magnesium	Mg	mg/l	---	---
Manganese	Mn	mg/1	0.2	---
Molobium	Mo	mg/l	---	---
Mercury	Hg	mg/1	0.002	0.0036
Nickel	Ni	mg/1	0.2	0.0282
Selenium	Se	mg/1	---	---
Vanadium	V	mg/1	---	---
Zinc	Zn	mg/1	2.0	0.0009
Total coliform	-	MPN/100ml	400	11
Echerichia coli	-	MPN/100ml	---	---
Fecal coliform	-	MPN/100ml	20	8
Total Count	-	CFU/100 ml	---	3.1E+4
Egg parasites	-	Egg/l	<1	---
Worm parasites	-	Egg/l	None	---
Salmonella	-	CFU/100 ml	---	10
Fecal Streptococci	-	CFU/100 ml	---	5
Fungi	-	CFU/100 ml	---	7

Sources: * Kuwait Environmental Public Authority (KEPA), *Kuwait Al-Youm*, Annex to Issue 533, Year 47, 2001. ** Ministry of Public Works (MPW), Kuwait, 2001. MPN = Most Probable Number

OTHER WATER REUSE STANDARDS

World Health Organization

The World Health Organization (WHO) guidelines are probably the most basic and the most widely adopted and emulated in the Middle East Region, since 1985, when they were first adopted. These guidelines are based on the ability of the treatment system to meet "microbiological quality guidelines for wastewater use in agriculture". The most important recommended guideline is to reduce the number of intestinal nematodes to a level below 1 nematode egg per liter. This level is achievable with a series of stabilization ponds, with a retention time of at least ten days. If the water is to be used for irrigation of crops likely to be eaten uncooked, sports fields, and public parks, an additional criterion is recommended; fecal coliform count (most probable number) should be equal to, or less than 1,000 per 100 mL. In situations where direct public contact is likely, this criterion is more stringent (less than 200 fecal coliform per 100 mL.) For localized irrigation of commercially processed crops, no limits are set, except for pretreatment as required by irrigation technology, but not less than primary sedimentation. These crops include cotton, sugarbeet, and seed crops, where exposure of the public and workers to the water is effectively prevented. WHO guidelines do not address viruses and bacteria, and they do not specify treatment process requirements.

JAPANESE WATER RECYCLING REGULATIONS

The current regulations and standards governing use of recycled water for various purposes is are summarized in Table 9, from a recent book chapter on global water recycling[vi].

Table 9. Japanese Criteria and Standards for Water Reuse

Parameter	Toilet flushing	Garden watering	Landscape water	Recreational water
E.coli.	Not detected	Not detected	See foot note [1)]	Not detected
Residual chlorine, (mg/L)	0.1 (free chlorine) or 0.4 (combined chlorine)	0.1 (free chlorine) or 0.4 (combined chlorine)	-	0.1 (free chlorine) or 0.4 (combined chlorine)
Turbidity, (NTU)	Less than 2	Less than 2	Less than 2	Less than 2
Appearance	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
Color(color unit)	-	-	Less than 40	Less than 10
Odor	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
pH	5.8 – 8.6	5.8 – 8.6	5.8 – 8.6	5.8 – 8.6
Minimum requirement for tertiary treatment system	Granular-medium filtration	Granular-medium filtration	Granular-medium filtration	Chemical coagulation and Granular-medium filtration

1) 1000CFU/100mL as Total coliform counts is used tentatively now

Source: Professor *Naoyuki* Funamizu, Hokaido University, Sapporo, Japan

JORDANIAN STANDARDS

The current regulations governing water reuse in Jordan are embodied in Jordanian Standards 893/2006 (Third Edition) for "Water—Reclaimed Domestic Wastewater." These standards, officially referenced as a mandatory technical regulation, provide maximum allowable limits for a range of organic, inorganic and microbiological indicators for

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

The public health limits for water reuse are based on the indicator organism *Escherichia Coli* (set at <2.2 for groundwater recharge, <100 for urban irrigation, and <1,000 MPN/100 mL for non-food crops irrigation), and on nematode eggs (<1 egg per L).

BRITISH COLUMBIA, CANADA—WATER REUSE STANDARDS

Canada is generally a water-rich country. Nonetheless, there are regulations, varying by province, that regulate reuse of reclaimed municipal recycled water. As an example, the water standards of British Columbia are summarized in Table 10.

Table 10. Permitted Uses and Standards for Reclaimed Water in British Columbia, Canada

Permitted Uses	Treatment Requirements	Effluent Quality Requirements	Monitoring Requirements
Unrestricted Public Access – agricultural, recreational and urban uses	Secondary, with chemical addition, filtration, disinfection and emergency storage	- BOD5 ≤ 10 mg/L - Turbidity ≤ 2 NTU - Fecal coliform ≤ 2.2/100 mL – pH = 6-9 - general considerations	Weekly Continuously Daily Weekly
Restricted Public Access – agricultural, urban/recreational, construction, industrial and environmental uses	Secondary, with disinfection	- BOD5 ≤ 45 mg/L - Total suspended solids ≤ 45 mg/L - Fecal coliform ≤ 200/100 mL pH = 6-9- general considerations	Weekly Daily Weekly Weekly

Source: British Columbia Ministry of Environment, Lands and Parks, 1999.

CALIFORNIA WATER RECYCLING CRITERIA (TITLE-22)

The current California standards[5] for water reuse were formally adopted in December 2000[vii]. These regulations are more stringent than the WHO guidelines. For example, they specify a coliform limit of 2.2/100 mL for reclaimed water used for landscape irrigation in urban areas and for the irrigation of food crops eaten raw. They also specify treatment trains needed to achieve the specified levels for a variety of uses. These regulations allow 43 specific uses and four different treatment levels. The scientific group that developed the WHO guidelines criticized these criteria as being too stringent, not based on epidemiological evidence, unattainable, and not appropriate for developing countries[6]. The California criteria are the basis of more than 250 currently ongoing water reclamation treatment works in that State.

[5] The full text of these regulations is reproduced as a PDF file in the CD that also contains the source file for the current document.

[6] Crook, J., "Water Reclamation and Reuse Criteria", Chapter 14 in "Wastewater Reclamation and Reuse", edited by Takashi Asano, Technomics Publishing Co., Inc., 1998.

These systems attain the standards routinely. The fact that such stringent criteria are in effect is the basis of the safety record established for water recycling in California. This in turn has resulted in public confidence in the existing water reuse systems and a lack of successful litigation against the agencies delivering recycled water. In recent years, there has been general agreement within the profession that these criteria are appropriate under the economic conditions prevailing in California. In Kuwait, local economic prosperity and adherence to high standards of hygiene—both from an Islamic imperative for cleanliness, and from a public policy point of view—are reasons for adopting similarly stringent water reuse standards.

WATER REUSE GUIDELINES IN QUEENSLAND, AUSTRALIA

Table 11 provides a summary of water reuse guidelines adopted in 2007 in Queensland, Australia. These guidelines were developed over a long period of time after thorough risk assessment, public consultation, peer review, and a formal adoption process.

Table 11 Queensland, Australia, Recycled water uses, recommended class, process monitoring and performance standards

Recycled water use	Class	Recommended monitoring	Recommended management response
Domestic and commercial property use • rainwater for potable use	Potable		
• rainwater for non-potable use • stormwater	A A	*E. coli*1 , turbidity after rainfall events	
• domestic and industrial wastewater • medium human contact • low human contact	A+ A	*E. coli* weekly, turbidity continuous (24 hr median), Chlorine residual continuous, pH weekly	Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L.
Public open space • above ground irrigation, uncontrolled access	A	*E. coli* weekly , turbidity continuous, chlorine residual continuous, pH weekly	Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L.
• controlled access or sub-surface irrigation	C	*E. coli* monthly, SS monthly, chlorine residual daily, pH monthly	
Food crops and retail nurseries • food crops consumed raw (including nurseries where ready to eat items are sold, e.g. herbs and salad vegetable plants).	A+	*E. coli* weekly, turbidity continuous, chlorine residual daily, pH weekly	Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L. For chlorine sensitive crops, an alternative disinfection method should be used.
• food crops processed or consumed cooked	C	*E. coli* weekly, SS weekly, pH weekly	
• retail nurseries not selling ready to eat items (e.g. herbs and salad vegetable plants)	A	*E. coli* weekly, SS weekly, pH weekly, chlorine residual daily	
Irrigating pasture/fodder and agricultural wash down • pasture/fodder for dairy animals without withholding period	B	*E. coli* weekly, SS weekly, pH weekly	Helminth control for cattle may be required.
• pasture/fodder for dairy animals with withholding period of 5 days	C	*E. coli* weekly, SS weekly, pH weekly	Helminth control for cattle may be required.
• pasture/fodder for other grazing animals except pigs with withholding period of 4 hours	C	*E. coli* weekly, SS weekly, pH weekly	Helminth control for cattle may be required.
• Wash down	B	*E. coli* weekly, SS weekly, pH weekly	

Recycled water use	Class	Recommended monitoring	Recommended management response
Irrigating non-food crops • silviculture, turf, cotton, wholesale nurseries	D	*E. coli* monthly, SS monthly, pH	
with controlled access etc		*monthly*	
Aquaculture • human food chain	A+	*E. coli weekly, turbidity continuous, Chlorine residual continuous, pH weekly*	Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L. For chlorine sensitive fish/shellfish, an alternative disinfection method should be used..
• non-human food chain	C	*E. coli weekly, chlorine residual daily, pH weekly*	
Industrial purposes • open system (medium human contact)	A	*E. coli weekly, turbidity continuous, chlorine residual daily, pH weekly*	Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L.
• closed system (low human contact)	C	*E. coli weekly, chlorine residual weekly, pH weekly*	
Fire fighting	A+	*E. coli weekly , turbidity continuous, chlorine residual continuous, pH weekly*	Agreement of firefighters must be obtained. Alarm should be activated if NTU exceeds 2 and supply shutdown if NTU>5 or chlorine residual falls below 1 mg/L.
Supplementing raw water • surface water/direct injection to aquifer from STP • surface water/direct injection to aquifer from stormwater	A+ A	*Site specific depending on the receiving water quality*	Project specific assessment should take place that includes contaminant monitoring, health and safety testing, and system reliability evaluation. This should include a health impact assessment including health risk assessment..
• percolation to aquifer	C	*Site specific depending on the receiving water quality*	Minimum 3 m depth to aquifer. Groundwater should comply with Australian Drinking Water Guidelines for raw water after mixing. Health risk and impact assessment as above.
Environmental/recreational purposes (no human contact)	C	*Site specific depending on the receiving water quality*	

Source: Gardner, T. 2006, Queensland Government Department of Natural Resources, personal communication

DIFFERENCES IN VARIOUS COUNTRIES' STANDARDS

The water reclamation standards of several countries, a few American states, and WHO are tabulated for comparative purposes in Table 12. It is clear that each set of standards is unique and there are not many common threads among them. Different states in the United States have widely varying water reuse standards. This is in part due to the varying level of conservatism of technicians and public officials adapting standards to local conditions. It is also in part a reflection of the absence of communication among officials setting standards for different states and countries. Each local authority decides what is important for them. Adaptation of standards to local economic conditions, societal demands, and technological capabilities is essential. Flexibility and dynamic revisions of standards can assure their evolution with the country's development in future years. As the economy in a given country improves, and as development of planned water reclamation and reuse claims a higher proportion of the available raw wastewater, changes in standards can be contemplated, with development of new (possibly more or less stringent) criteria.

Table 12. Summary of Selected[7] Water Reuse Standards, Provisions, and Controls for Protection of Public Health

Parameter or Requirement	Kuwait	Jordan	California	Arizona	Nevada	New Mexico	Texas	W H O	Japan	South Africa	Israel
Fecal Coliform, MPN/100mL											
unrestricted urban irrigation				25[8]	2.2	100	75	≤ 200	not det.[12]	--	12
restricted urban irrigation	20			200[9]	2.2	1,000	800	≤1,000		< 1,000	250
food crops eaten raw				2.2[10]			75	≤1,000		0	12
non-food crops				100[11]			800	--		< 1,000	250
toilet flushing, dust control										0	
Total Coliform, MPN/100mL											
unrestricted urban irrigation			2.2								
restricted urban irrigation	400		23								
limited public contact			2.2						< 50		
no public contact			23						< 1,000		
toilet flushing			2.2								
E. Coli									not det.		
urban irrigation		100									
non-food crops		1,000									
groundwater recharge		<2.2									
Viruses, pfu/100 mL	0			<1/1,000L							
Intestinal Nematodes, eggs/L	<1	≤1						≤1	--		
Turbidity, NTU	([13])										
limited public contact		10	2	5	3		3		< 2		
no public contact					5				< 2		
ornamental lakes, streams									< 2		

7 Standards presented are mostly from regions where climatic conditions are somewhat similar to those of the Middle East countries.
8 Arizona also imposes limits on certain pathogenic microorganisms and trace substances.
9 Arizona also imposes limits on certain trace substances.
10 Arizona also imposes limits on certain pathogenic microorganisms and trace substances.
11 Arizona also imposes limits on common tapeworm for pasture, and on trace substances.
12 Not detectable: E. Coli (count/100 mL) is the applicable criterion in Japan.
13 The Kuwait Environmental Public Authority (KEPA) has a "proposed máximum limit for industrial discharge to Kuwait waters" of 50 NTU; but not a water reuse standard.

toilet flushing								< 2		
groundwater recharge		2								
Chlorine Contact, minute										
food crops eaten raw			90							120
processed, peeled, cooked			90							60
Residual Chlorine			([14])							
raw-eaten vegetables	1									0.15
processed, peeled, cooked		0.5-1.0								0.5
landscape irrigation	1	0.5-1.0						≥ 0.1 [15]		
toilet flushing								≥ 0.1 [16]		
BOD, total, mg/L										
food crops eaten raw	10	15				30, 10[17]				15
processed, peeled crops		15				30, 10[15]				35
fodder, orchard	10	200				30, 20[18]				45
fiber, seed, trees		300				30, 20[16]				60
groundwater recharge		15								
Dissolved Oxygen, mg/L										>0.5
irrigation		>1								
groundwater recharge		>2								
Posting of Informative Signs			Required on all use sites							
Buffer Distance, meter			18[19]							
restricted urban irrigation				33						--
fodder, orchard										250
fiber, seed, sugarbeets, trees										300
Treatment Prescribed										
unrestricted urban irrigation			disinf. tertiary	disinf second	disinfection			coag, filt	advanced	--
restricted urban irrigation			disinf. second.	disinf second	disinfection			filt	tertiary	--
food crops eaten raw			disinf. tertiary	secondary[20]	disinfect[22]		ponds	filt	advanced	filt, disinf.
non-food crops			secondary	secondary[21]	Primary[23]	ponds	primary +	filt	tertiary	--
toilet flushing, dust control			disinf. tertiary					filt	tertiary	

Source: Adapted, partly from the EPA Manual: "Guidelines for Water Reuse", 2004, updated with other countries' more recently published water reuse criteria

[14] None required in the California criteria. However, a chlorine residual is generally maintained (at least 0.5 mg/L) in the distribution system to minimize regrowth of coliform bacteria.

[15] Free chlorine, 0.1 mg/L; combined chlorine, 0.4 mg/L

[16] Free chlorine, 0.1 mg/L; combined chlorine, 0.4 mg/L

[17] 30 mg/L with pond systems, 10 mg/L with other treatment methods. Spray irrigation not permitted on foods eaten raw.

[18] 30 mg/L with pond systems, 20 mg/L with other treatment methods.

[19] Distance from nearest water supply well. Other buffer distances are required by local health authorities for lesser-treated reclaimed waters.

[20] Only surface irrigation of fruit or nut bearing trees permitted.

[21] Disinfection is required if spray irrigation is practiced and the buffer zone is less than 280 meters.

[22] Only surface irrigation on food crops with no contact of reclaimed water on edible portion permitted.

[23] Except for pastures where milking animals feed; disinfection to a fecal coliform level of ≤ 100/100mL is required for irrigation of such pastures.

RECOMMENDATIONS FOR RESEARCH

KISR is at the forefront of scientific investigation in Kuwait. It would appear a logical role for the Institute to assume greater responsibility in the area of water recycling. To that end, the following recommendations are offered for consideration:

- Convene biannual workshops to assess research needs in the field of water recycling, inviting local and international experts, academics, and practitioners for a two-day brainstorming and production of prioritized lists of projects to conduct, or to fund for other institutes to conduct.
- Collaborate with other research institutes in Europe, Japan, and the United States for conduct of joint water reuse projects with mutual benefit. Examples of such organizations might include the National Water Research Institute[24] and WateReuse Foundation[25].
- Select from the following list of currently urgent topics for formulation of research proposals for near-term implementation at KISR, including:
    - Assessment of public attitudes in the Gulf countries toward using recycled water for various applications, as affected by demography, religion, education, knowledge of water, and other relevant factors.
    - Safety of use of disinfected tertiary recycled water for urban uses
    - Safety of use of disinfected tertiary recycled water for various agricultural and horticultural uses
    - Investigation of the potential for groundwater recharge with Sulaibiya reverse-osmosis effluent and its applicability to the hydrogeology of Kuwait's aquifers
    - Fate and transport of microconstituents in Kuwait wastewaters and their potential effect on various types of water reuse projects.
    - Potential for satellite water reclamation plants in Kuwait.

[24] http://www.nwri-usa.org
[25] http://watereuse.org/foundation/

- Investigation of appropriate data management systems for systematic and automated analysis of routine monitoring data emerging from wastewater treatment plants and for their ready accessibility to other researchers, regulatory oversight officials, and the general public. [Implementation of such data management systems would be a separate, non-research activity, most probably conducted under contract with a highly specialized data management systems contractor experienced with large data base management systems, such as those employed at financial institutions and/or security organizations]

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