WATER REUSE FOR AGRICULTURE

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Contents

Summary

Increasing pressure on the world's water resources are matched by rising environmental expectations in the community to minimize the impacts of human interventions in the natural water cycle. As a result, water management strategies such as wastewater

UNESCO – EOLSS SAMPLE CHAPTERS

treatment and reuse (for agriculture and for other industries) are being driven, increasingly by a demand for cost-effective and sustainable solutions for reuse of water. Such trends are particularly evident in developed nations water reuse. Different countries adopt different water reuse standards for agriculture and adopt different investment strategies for managing irrigation system.

While water reuse has the potential to improve water usage and preserve global fresh water resources, a number of issues remain to be solved. Many of these issues involve assessment of environmental and health risk.

1. Introduction

Rising human population and industrialization have increased pressures on global water resources. Increasingly, there is a shortfall in the ready availability of high quality fresh water, particularly in many arid and semi-arid regions of the world.

A report by the secretary-general for the United Nations Commission on Sustainable Development has concluded that there is no sustainability in the current uses of fresh water by either developing or developed nations. The report stated that worldwide water usage has been growing at more than three times the world's population increase. The report also concluded that water shortages, combined with increasing pollution of water, was causing widespread public health problems, limiting economic and agricultural development (thus jeopardizing global food supplies), and harming a wide range of ecosystems.

Wastewater reuse has become an accepted part of the water supply system in several parts of the world. Reuse programs have been accompanied by public involvement campaigns (in the form of schools programs, visitor programs to reclamation facilities and active communications activities). The aim of water reuse for agriculture is to promote ecologically sustainable development, protection of environment by pollution, protection of public health and protection of community amenity.

Reusing treated wastewater is becoming a more valuable resource for industrial, agricultural, municipal and domestic purposes. Its reclamation allows a unit of water to be used for a number of purposes rather than once followed by discharge to the environment.

The disposal of effluent has caused problems both for the generator of the effluent and for the community. Community concern has led to a change in philosophy in dealing with effluent disposal in recent times. The primary focus now is on the most beneficial use for the effluent, which in many circumstances, is reuse by land application. Generally effluent or reclaimed water is a term broadly used to describe municipal wastewaters which have been purified to an extent suitable for the particular use. In recent times reuse of water extends to dairy sheds, dairy processing plants, intensive piggeries, wool industry, wineries and distilleries and tanning and related industries. Reuse of water also occurs to some extend in storm water runoff.

Use of reclaimed water as a resource is being encouraged on conservation, efficiency

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and environmental grounds. Only a small percentage of wastewater is currently processed and used worldwide. Current forms of wastewater reuse can conveniently be divided into:

- irrigation reuse;
- treatment and discharge to river for downstream needs;
- municipal reuse (potable and non-potable water supply and irrigation of parks, ovals, etc);
- industrial reuse;
- groundwater recharge.

The extent of reuse of wastewater for urban and industry purposes is driven by economics. This article focuses mainly on the reuse of municipal wastewater for irrigation reuse.

2. Treated Water Reuse by Irrigation

There has been worldwide expansion in recent years in the use of reclaimed water for irrigation of crops, urban "green spaces" and for industrial and domestic applications. Out of this, agricultural irrigation is the biggest user of recycled wastewaters. 41% of recycled water in Japan and 60% of Californian recycled wastewaters are used for this purpose. 15% of Tunisia's reclaimed wastewater is used for the irrigation of crops. Issues relating to the use of treated wastewater effluent for agricultural irrigation can vary between countries. Such variations depend on regulations controlling wastewater reuse, the percentage of wastewater recycled, the level of treatment prior to reuse, and, to some extent, the types of crops irrigated. The differences often depend on the dependence of the particular country for water, the political and social structure of the country, and the general availability of water.

For example, the use of wastewater for irrigation is considered a traditional practice in France, but is now strictly controlled by the health authorities with current trends moving away from agricultural irrigation and toward the irrigation of golf courses and landscaped areas. In the USA, California has been using recycled water since the early 20th century and wastewater reuse is now practiced in several other states. Current US EPA guidelines require that recycled wastewater undergo at least secondary treatment, and almost always that chemical disinfection is used prior to reuse of the wastewater.

The most common uses for reclaimed water are irrigation of:

- irrigation for agriculture (crops, pasture, orchards, and vineyards);
- irrigation for silviculture (forestry);
- irrigation for landscapes (sporting, land rehabilitation areas and recreation area).

Water used for irrigation need not be as high in quality as that used for drinking. The most advantageous reclaimed water projects are those that substitute lower quality water with minimum additional treatment for high quality potable water. The main benefits are conservation of water resources and pollution abatement.

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Nitrogen and phosphorus present in wastewater, which can cause eutrophication in receiving waters, can have beneficial effects on plant growth when used for irrigation in a planned and controlled manner. This benefit is of increasing importance where agricultural lands are nitrogen and/or phosphorus deficient.

The use of effluent will not be approved for drinking or other related domestic purposes, or for any body contact, recreational application, such as the filling of swimming pools. Special care needs to be taken in the application of effluent to fruit, vegetables and fodder crops, particularly those designated for human consumption. In developed countries applications primarily vary depending on the regulatory requirements. For example spray irrigation of fruit and vegetables that may be consumed raw or unprocessed, such as salad vegetables, will not be approved under the Australian regulation.

2.2. Principles

Best management practices on reclaimed water reuse may consider the following fundamental environmental performance objectives:

- **Resource utilization:** The useful resources in effluents, such as water, plant nutrients, and organic matter, should be identified. Agronomic systems for the effective utilization of these resources should be developed and implemented.
- **Protection of lands:** An effluent irrigation scheme should be ecologically sustainable. In particular, it should maintain the cropping capacity of the land, and should result in no deterioration of land quality through soil structure degradation, salinization, waterlogging, chemical contamination, or soil erosion.
- **Protection of groundwater**: Effluent irrigation areas and systems should be sited, designed, constructed and operated such that useable underground water resources do not become contaminated by either the effluent, or runoff from the irrigation scheme.
- **Protection of surface waters:** Effluent utilization schemes should be sited, designed, constructed and operated such that surface waters do not become contaminated by any flow emanating from irrigation areas including effluent, rainfall runoff, contaminated subsurface runoff, or contaminated groundwater.
- **Community amenity**: The effluent utilization scheme should be sited, designed, constructed and operated so as not to cause unreasonable interference with any commercial activity or the comfortable enjoyment of life and property off-site, and where possible to add to the amenity. In this regard, special consideration should be given to odor, dust, insects and noise above normal rural levels.

3. Public Health Aspects

Health concerns are frequently raised by the public, particularly in relation to residential reuse schemes, but also about irrigation of urban parkland and crops for human consumption. In many countries the public health aspects of the use of reclaimed water come under the control of state or local health authorities and environmental authorities, either through specific regulations under legislation or by more general measures such as guidelines. The health risks for the public from wastewater can come from microbial pathogens, toxic chemicals, and heavy metals. Bacteriological criteria are the most

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wide-ranging in application. These regulations are aimed at providing biologically safe direct use for agricultural irrigation and for irrigation of recreation areas. The most experience with large-scale reuse projects is in the USA, where documented public health investigations are available. The most general statement on the public health effects of reuse schemes in the USA is given in the USEPA Guidelines for Water Reuse, pp25:

Epidemiological investigations directed at wastewater-contaminated drinking water supplies, use of raw or minimally-treated wastewater for food crop irrigation, health effects to farm workers who routinely contact poorly treated wastewater used for irrigation, and the health effects of aerosols or wind-blown spray emanating from irrigation sites using undisinfected wastewater, have all provided evidence of infectious disease transmission from such practices. However, epidemiological studies of the exposed population at water reuse sites receiving disinfected reclaimed water treated to relatively high levels are of limited value, because of the mobility of the population, the small size of study population, the difficulty of determining the actual level of exposure of each individual, the low illness rate—if any—resulting from the reuse practice, insufficient sensitivity of current epidemiological techniques to detect low-level disease transmission, and other confounding factors. It is particularly difficult to detect low-level transmission of viral disease, because many enteric viruses cause such a broad spectrum of disease syndromes that scattered cases of acute illness would probably be too varied in symptomology to be attributed to a single etiological agent. The limitations of epidemiological investigations notwithstanding, water reuse in the U.S. has not been implicated as the cause of any infectious disease outbreaks.

In Australia at the national level, the National Health and Medical Research Council (NHMRC), Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zeeland (ARMCANZ) have published a series of guidelines for different effluents produced by diffuse and point sources under the National Water Quality Management Strategy. The Draft Guidelines for Sewerage Systems, *Use of Reclaimed Water*, outlines specific reclaimed water applications and requirements (Table 1).

Type of reuse	**Level of treatment**	**Reclaimed water quality**	**Reclaimed water monitoring**	**Controls**
Agricultural food production—crops in direct contacts with reclaimed water eg. via sprays	Secondary + Filtration; Pathogen reduction	pH 6.5–8.0 lesser or equal to 2 NTU 1 mg/L Cl_2 residual or equivalent level of disinfection <10 thermotolerant coliforms/100mL	pH weekly Turbidity continuous; Disinfection systems daily Thermotolerant coliforms monthly	Nutrients, toxicants and salinity controls

UNESCO – EOLSS SAMPLE CHAPTERS

Agricultural food production—crops not in direct contact with reclaimed water eg. via flood or furrow irrigation	Secondary; Pathogen reduction	<100 thermotolerant coliforms/100 mL	pH weekly BOD weekly SS weekly Thermotolerant coliforms weekly	Separation of edible product from contact with water, flood or furrow irrigation only nutrients, toxicants and salinity controls
Agricultural food production—crops sold to consumers cooked or processed which cannot be diverted to other uses	Secondary; Pathogen reduction	pH 6.5–8.0 <1000 thermotolerant coliforms/100 mL	pH weekly SS weekly Thermotolerant coliforms weekly Disinfection system daily	Nutrients, toxicants and salinity controls
Pasture and fodder; horticulture	Secondary	<1000 thermotolerant coliforms/100 mL	pH weekly SS weekly Thermotolerant coliforms weekly Disinfection systems daily	Nutrients, toxicants and salinity controls; Beef measles controls
Pasture and fodder for dairy cattle	Secondary; Pathogen reduction	pH 6.5–8.0 <200 thermotolerant coliforms/100 mL <10 thermotolerant coliforms/100 mL	pH weekly SS weekly Thermotolerant coliforms weekly Disinfection systems daily	Nutrients, toxicants and salinity controls, withholding period of 5 days No withholding period Beef measles controls
Silviculture, turf and non food crops	Secondary		pH weekly SS weekly	Restricted public access ; withholding period 4 hours

(Source: Australia, NHMRC, et. al., 1996)

Table 1. Guidelines for the use of reclaimed water

At the State level, in New South Wales (NSW) Australia, the Environment Protection Authority (EPA), as the regulator, has produced a Draft Environmental Guidelines for Industry, *The Utilisation of Treated Effluent by Irrigation*. This discusses the classification of the important constituents of effluent quality (Table 2) and the disinfection levels (measured in fecal coliform organisms/100 mL) for the operation of different irrigation systems (Table 3) based on minimum effluent bacterial levels. Considering health and environmental requirements, the irrigation application methods

UNESCO – EOLSS SAMPLE CHAPTERS

and disinfection requirements for the use of treated effluents vary as per Table 4. Drip or underground irrigation schemes, for example, have a reduced risk of human contact or ingestion than spray or sprinkler based systems and so can be used with water of a lower quality.

	Strength (average concentration mg/L)[1]		
Constituent	**Low[2]**	**Intermediate[3]**	**High[3]**
total nitrogen	< 50	50—100	> 100
total phosphorus	< 10	10—20	> 20
BOD	< 40	40—1 500	> 1 500
TDS	< 500	500—1 000	> 1 000—2500

Note:
1. Average concentrations established from a minimum of 12 samples, collected at regular intervals over a year.
2. The concentrations of N and P are set based on average quality of effluent generated by the inland STPs. Treatment plants using secondary treatment configuration are expected to produce effluents containing < 40mg/L BOD with an average TDS of less than 500mg/L. Based on these criteria, over 90% of inland STPs would be able to utilise their effluents.
3. The criteria for intermediate and high strength effluents are selected from a wide range of industries known to generate effluents that are much stronger than those produced by the STPs.

(Source: NSW Australia EPA, 1995)

Table 2. Classification of effluent

Level	**Minimum effluent bacteriological quality requirement[1]**	**Acceptable disinfection technique**
A	Geometric mean < 300 Upper limit < 2000	30 days pounding or other means acceptable to the EPA and Department of Health
B	Geometric mean < 750 Upper limit < 5000	20 days pounding or other means acceptable to the EPA and Department of Health
C	Geometric mean < 3000 Upper limit < 14000	10 days ponding or other means acceptable to the EPA and Department of Health

Note:
Measured in faecal coliform organisms per 100 mL. Faecal coliform levels may be determined by either the multiple tube fermentation technique or the membrane filter technique. The geometric mean and upper limit are to be calculated from the results of five samples collected at half-hourly intervals.

(Source: NSW Australia EPA, 1995)

Table 3. Disinfection of disinfection levels

UNESCO – EOLSS SAMPLE CHAPTERS

For example in Australia according to New South Wales government regulations, water used on crops for human consumption should achieve a minimum acceptable disinfection level "A". This means the effluent needs to have a minimum effluent bacterial count of <300 units geometric mean and <2000 upper limit. The effluent should be also detained for 30 days in ponding or other means acceptable to the EPA and Department of Health before reuse.

Applications	**Acceptable irrigation method**[1]	**Minimum acceptable disinfection level**[2]	**Provisos**
Grass and landscaped areas	Any	B	Public excluded during any spraying operation
Pasture lands for growth of fodder crops	Any	C B	Public excluded during any spraying operation and crops not harvested for 10 days Public excluded during any spraying operation
Pasture for sheep, cattle horses and other grazing animals	Any	C	Public excluded during any spraying operation and animals excluded for 10 days
Orchards and vineyard crops for human consumption	Furrow or trickle	C	Processing system approved by Department of Health
Crops for human consumption which will be commercially processed	Furrow or trickle	A	Processing system approved by Department of Health
Crops for human consumption which will be cooked before being eaten	Furrow or trickle	A	None
Forest areas and areas being rehabilitated after mining or quarrying	Any	C	Public excluded during any spraying operation

Note:
1: These methods are acceptable from a health perspective. From an agronomic perspective, certain methods may be less desirable than others. For example, trickle irrigation, where it is practicable, generally is preferable to furrow irrigation.
2: The minimum acceptable disinfection levels are defined in Table 3.

(Source: NSW Australia EPA, 1996)

UNESCO – EOLSS SAMPLE CHAPTERS

Table 4. Application, irrigation methods and disinfection requirements for the use of treated effluents

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Biographical Sketches

Krish Illungkoo is currently with the Department of Land and Water Conservation, Resource Assessment and Planning Group, Tamworth, Australia. He has extensive work experience in planning, research and information dissemination in aquatic resource environments. Presently, he is actively involved in the implementation of Water Reform processes in the urban and rural water resources sectors, in the Barwon Region of the New South Wales State, Australia.

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