

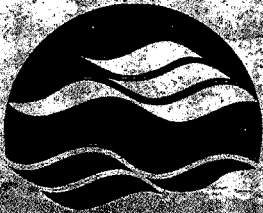
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Water Reuse in Canada: Oppor-
tunities and Challenges

BY:

K. Exall, J. Marsalek, K. Schaefer

NWRI Contribution No. 05-175

WATER REUSE IN CANADA: OPPORTUNITIES AND CHALLENGES

K. Exall, J. Marsalek and K. Schaefer

Abstract. Reclamation and reuse of various types of wastewater, including stormwater, greywater, and domestic wastewater, represents an important component of the urban water cycle helping close the loop between water supply and wastewater disposal. Safe and scientifically-based water and wastewater reuse has been practised for about a century, and a great wealth of practical experience with such practices has been reported in the literature. Essential elements of water reuse plans include the selection of categories of reuse (i.e., for what purpose), selection of water quality criteria for such specific reuses (in accordance with the existing regulations and guidelines), design of the treatment train providing the effluent of the required quality, and examination of overall feasibility. In Canada, water reuse is generally conducted on a small-scale or experimental basis. While no national guidelines exist at this time, a number of provinces have developed guidelines for specific water reuse applications. The current stresses on water supply, caused by growing population and increasing water demands, depletion of water sources, reduced supply reliability caused by climate change, ageing infrastructure and limited funding for its expansion, as well as the promotion of environmental sustainability and needs to reduce wastewater discharges to sensitive receiving waters, will contribute to further growth and expansion of water and wastewater reclamation and reuse.

NWRI RESEARCH SUMMARY

Plain language title

Water Reuse in Canada: Opportunities and Challenges

What is the problem and what do scientists already know about it?

Despite abundant freshwater resources in Canada on the whole, there are regions where demand exceeds supply. One solution to the challenge is water reuse, which facilitates the use of treated municipal effluents as a new source for non-potable water supply. Reuse or recycling of treated wastewater reduces effluent discharges into receiving waters and offers a reliable alternative supply of water for applications that do not require high quality water, freeing up limited potable water resources.

Why did NWRI do this study?

Water reuse is one element of integrated urban water resources management that promotes environmental sustainability through conservation of limited water resources, while supporting source water protection by reducing wastewater discharges to sensitive receiving waters. As competing water demands increase and existing supplies are strained, expanded water reuse is likely. Critical evaluation of past projects and experiences in other areas of the world can provide needed insight for planning future applications of water reuse in Canada.

What were the results?

The status of water reuse in Canada was reviewed in the context of international progress in this area. In Canada, water reuse is generally conducted on a small-scale or experimental basis. While no national guidelines exist at this time, a number of provinces have developed guidelines for specific water reuse applications; these were compared to other guidelines worldwide. Further opportunities and challenges in establishing new water reuse projects were identified, and essential elements of water reuse plans were discussed.

How will these results be used?

The paper will serve to communicate Canada's experiences in water reuse to an international audience and inform Canadian environmental professionals about the current and potential practices of water reuse. It serves as an update on the advances in water reuse in Canada since the 2002 CCME workshop on Water Reuse and Recycling and the follow-up articles; this information can be used by water managers and planners as a starting point in planning and implementation of new water reuse projects or guidelines.

RÉUTILISATION DE L'EAU AU CANADA : OCCASIONS ET DÉFIS

K. Exall*, B.G. Krishnappan, J. Marsalek et Q. Rochfort

Résumé. La régénération et la réutilisation des différents types d'eaux usées, comme les eaux pluviales, les eaux grises et les eaux domestiques, représentent une part importante du cycle de l'eau en milieu urbain et ferment la boucle entre l'approvisionnement en eau et l'élimination des eaux usées. La réutilisation de l'eau et des eaux usées se fait de manière scientifique et sécuritaire depuis près d'un siècle, et la documentation scientifique documente bon nombre d'expériences pratiques sur le sujet. Les éléments essentiels à l'élaboration de plans de réutilisation de l'eau comprennent le choix de la catégorie de réutilisation (objectif de la réutilisation), le choix des critères de qualité de l'eau pour des usages particuliers (conformément aux directives et aux réglementations existantes), la conception d'une chaîne de traitement fournissant des effluents ayant la qualité recherchée et l'étude de la faisabilité générale. Au Canada, la réutilisation de l'eau se pratique généralement à titre expérimental ou à petite échelle. Alors qu'aucune directive nationale n'existe à l'heure actuelle, un certain nombre de provinces ont élaboré des directives propres à certaines applications de réutilisation de l'eau. Les contraintes actuelles de l'approvisionnement en eau, liées à la croissance de la population, à l'augmentation de la demande en eau, à l'épuisement des sources d'eau, à la diminution de la fiabilité de l'approvisionnement causée par les changements climatiques, le vieillissement des infrastructures et la maigreur du financement destiné à son expansion, ainsi que la promotion de la durabilité environnementale et la nécessité de réduire les rejets d'eaux usées dans les milieux récepteurs sensibles, contribueront à la croissance et à l'expansion futures de la régénération et de la réutilisation des eaux usées.

Sommaire des recherches de l'INRE

Titre en langage clair

Réutilisation de l'eau au Canada : Occasions et défis

Quel est le problème et que savent les chercheurs à ce sujet?

Malgré les abondantes ressources en eau douce à l'échelle du Canada, il existe des régions où la demande dépasse l'offre. L'une des solutions à ce défi est la réutilisation de l'eau, qui permet l'utilisation des effluents municipaux traités comme nouvelle source d'approvisionnement en eau non potable. La réutilisation ou le recyclage des eaux usées traitées réduit le déversement des effluents dans les milieux récepteurs et offre une autre source d'approvisionnement fiable en eau pour les applications qui n'exigent pas une eau de qualité élevée, allégeant ainsi la demande exercée sur les ressources limitées en eau potable.

Pourquoi l'INRE a-t-il effectué cette étude?

La réutilisation de l'eau constitue un élément de la gestion intégrée des ressources hydriques en milieu urbain, qui encourage la durabilité environnementale par la conservation des ressources limitées et la protection des réserves d'eau en réduisant les rejets d'eaux usées dans les milieux récepteurs sensibles. Comme les demandes concurrentes augmentent et que les réserves actuelles sont très sollicitées, on peut s'attendre à un développement de la réutilisation de l'eau. Une évaluation critique des expériences et projets déjà menés dans d'autres régions du globe peut fournir des idées précieuses pour la planification d'applications futures en réutilisation de l'eau au Canada.

Quels sont les résultats?

Le dossier de la réutilisation de l'eau au Canada a été analysé dans le contexte des avancées internationales dans ce domaine. Au Canada, la réutilisation de l'eau se pratique généralement à titre expérimental ou à petite échelle. Alors qu'aucune directive nationale n'existe à l'heure actuelle, un certain nombre de provinces ont élaboré des directives propres à certaines applications de réutilisation de l'eau; nous les avons comparées aux directives en vigueur dans d'autres pays. Nous avons relevé d'autres occasions et défis dans le domaines des nouveaux projets de réutilisation de l'eau, et nous analysons les éléments essentiels des plans de réutilisation de l'eau.

Comment ces résultats seront-ils utilisés?

Ce document permettra de faire connaître à l'échelle internationale les expériences canadiennes en matière de réutilisation de l'eau et d'informer les professionnels canadiens en environnement sur les pratiques actuelles et potentielles en matière de réutilisation de l'eau. Il fait le point sur les avancées en réutilisation de l'eau au Canada depuis l'atelier du CCME de 2002 sur la réutilisation et le recyclage de l'eau et sur les articles qui ont suivi; ces renseignements peuvent être utilisés par les planificateurs et les gestionnaires de l'eau comme point de départ pour la planification

et la mise en œuvre de nouvelles directives et de nouveaux projets de réutilisation de l'eau.

WATER REUSE IN CANADA: OPPORTUNITIES AND CHALLENGES

SHORT TITLE: WATER REUSE IN CANADA

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Abstract. Reclamation and reuse of various types of wastewater, including stormwater, greywater, and domestic wastewater, represents an important component of the urban water cycle helping close the loop between water supply and wastewater disposal. Safe and scientifically-based water and wastewater reuse has been practised for about a century, and a great wealth of practical experience with such practices has been reported in the literature. Essential elements of water reuse plans include the selection of categories of reuse (i.e., for what purpose), selection of water quality criteria for such specific reuses (in accordance with the existing regulations and guidelines), design of the treatment train providing the effluent of the required quality, and examination of overall feasibility. In Canada, water reuse is generally conducted on a small-scale or experimental basis. While no national guidelines exist at this time, a number of provinces have developed guidelines for specific water reuse applications. The current stresses on water supply, caused by growing population and increasing water demands, depletion of water sources, reduced supply reliability caused by climate change, ageing infrastructure and limited funding for its expansion, as well as the promotion of environmental sustainability and needs to reduce wastewater discharges to sensitive receiving waters, will contribute to further growth and expansion of water and wastewater reclamation and reuse.

Keywords: Canada; water reuse; water recycling; wastewater treatment; reclaimed water quality; guidelines.

1. Introduction

1.1. DEFINITIONS

Throughout this paper, the term *reclaimed water* refers to wastewater or stormwater that has been treated to a quality that is suitable for a given reuse application; and *water reuse* refers to the beneficial use of reclaimed water. *Water recycling* or recirculation typically refers to industrial systems, in which the effluent is recovered, usually treated and returned back into the industrial process. Wastewater reclamation and water reuse is conducted on various scales: from decentralized systems, utilizing on-site treatment and reuse in single buildings, to the municipal level, with centralized treatment and distributed reuse applications.

1.2. RATIONALE FOR WATER REUSE

There exists a continuous water management challenge worldwide to provide a balance between water demand, water use and the protection of water resources quality. On the whole, Canada enjoys relatively abundant and high-quality water supplies. Annual precipitation in Canada averages 600 millimetres, although it varies significantly by region (Statistics Canada 2000). In fact, about 25% of municipalities with water supply systems reported water shortages during 2001, for reasons ranging from source water shortages to treatment and distribution system problems (Environment Canada 2005). There are therefore areas with limited water supplies, particularly in periods of droughts and high water demands, and high consumptive use in agriculture. At the most recently reported level of 335 L/capita/day (Environment Canada 2005), per capita residential water use in Canada remains well above that in advanced west European countries.

Many municipalities are thus faced with the challenge of providing water supply to their growing population, in competition with other sectors of the economy and relying on finite supplies, and controlling wastewater discharge into receiving waters. Within the holistic concept of integrated water resource management, water reuse provides an opportunity to ease the current stresses on water supply, caused by increasing water demands, depletion of water sources, reduced supply reliability caused by climate change, ageing infrastructure and limited funding for its expansion. Water reuse simultaneously promotes environmental sustainability through conservation of water resources and reduces wastewater discharges to sensitive receiving waters.

2. International and Canadian practice

2.1. INTERNATIONAL PRACTICE

Raw wastewater use for irrigation is still common in many low- and middle-income countries, although planned wastewater reclamation and water reuse is expanding in industrialised countries worldwide (U.S. EPA, 2004). The greatest water reuse occurs in regions suffering water scarcity, such as in the Middle East, the Mediterranean, Australia or the U.S. southwest. The field is also growing rapidly in regions with severe restrictions on effluent disposal, such as Florida, coastal areas of France, Spain and Italy, and densely populated countries, such as England and Germany (Lazarova *et al.* 2001).

Globally, the most common applications of reclaimed water are in agricultural and landscape (particularly golf course) irrigation. In Japan, urban water reuse is also common, with 8% of total reclaimed water used for such purposes as car washing, urban water features, firefighting or toilet flushing (U.S. EPA, 2004). Other common water reuse applications include on-site residential / greywater reuse, industrial water recycling and reuse, rainwater and stormwater collection and reuse, surface water augmentation and groundwater recharge, and potable reuse. The various water reuse applications have been discussed by Exall (2004), and numerous case studies are described in the U.S. EPA's *Guidelines for Water Reuse* (U.S. EPA, 2004) and the report, *Water Recycling in Australia* (Radcliffe, 2004).

2.2. CANADIAN PRACTICE

Water reuse in Canada has to date been largely conducted on an experimental basis. Decentralized wastewater reclamation and water reuse is practised for individual homes and clusters of homes, or isolated industries, service operations and institutional facilities. Under such circumstances, the most common types of reuse are landscape irrigation and toilet flushing. The Canada Mortgage and Housing Corporation (CMHC) has been involved in numerous research projects regarding residential greywater reuse applications (e.g., Canadian Water and Wastewater Association 2002; Waller *et al.* 1998). Case studies of residential recycling and reuse in Canada include the Toronto Healthy House system, a four storey duplex built in 1996, and the CMHC Conservation Co-op in Ottawa, an eight-unit apartment complex. Both sites reported initial difficulties in maintaining water quality and required process adjustments after start-up. Greywater reuse systems have also been considered

for areas in northern Canada to reduce dependence on trucked water supply and sewage disposal services (Waller *et al.* 1998).

The main applications of centralized wastewater reclamation and distributed water reuse in Canada are agricultural irrigation, and golf course and urban landscape irrigation (Exall 2004; CWRS, 1999). The practice of reclaimed water irrigation is quite well established in Western Canada, and experimental effluent irrigation projects have been conducted in Canada for over thirty years (Coote and Gregorich 2000). Since 1977, the City of Vernon has operated a water reuse system for all effluent disposal, irrigating agricultural, silvicultural and recreational lands during the irrigation season of April to October. Such effluent irrigation projects must take into account water use, nutrient loading, salinity, and the presence and persistence of pathogens and trace contaminants.

Industrial water recycling is fairly common in Canada. Canadian industry accounts for over 80% of the total water intake, and of this total intake, approximately 40% is typically recycled. Many industries employ recirculation of their own process waters for use in such areas as cooling tower make-up water. The recirculation rate, defined as the volume of water recirculated as a percentage of total water intake, varies considerably by the manufacturing sector, from a low of 22% in the wood products group, to a high of 292% in plastic products (Scharf *et al.* 2002). Other industries use reclaimed water as process water. In 2006, the City of Edmonton will begin supplying a local industrial partner with reclaimed municipal wastewater for use in hydrogen and steam production. As the water quality requirements for reuse can be specific to the industrial process and application of the water, advanced treatment systems are often required to produce water of acceptable chemical and microbiological quality.

Although results from a survey by the Canadian Water and Wastewater Association (2002) indicate that rainwater harvesting is rarely practised and almost never encouraged in Canada, stormwater reuse for golf course irrigation has been reported (Marsalek *et al.*, 2002). A recent workshop series held in six Canadian cities presented international rainwater harvesting practices and explored the potential for expanding its adoption in Canada (CMHC, 2005).

3. Opportunities and challenges

The extent to which water reuse is adopted depends on water availability, economic incentives, regulatory feasibility, and public acceptance. Among

these factors, water availability is probably the most important one; where water is scarce, water reuse is accepted by the general public, is economically feasible and a supportive regulatory environment is created.

In 2002, the Canadian Council of Ministers of the Environment (CCME) organized a national experts workshop on water reuse; a number of recommendations were made for further action in the areas of technology, policy and regulation, research, public acceptance, and coordination (Marsalek *et al.* 2002). Much can be learned from the experience of other jurisdictions, as well. California's Recycled Water Task Force produced a report identifying twenty-six issues relating to obstacles, impediments and opportunities for increased recycled water usage in that state (State of California 2003).

Careful planning is imperative in the implementation of new water reuse projects. Essential elements of water reuse plans include the selection of reuse applications, selection of water quality criteria (in accordance with the existing regulations and guidelines), design of the treatment train and infrastructure to store and convey the reclaimed water, and examination of overall feasibility. Common water reuse applications are listed above in Section 2.1; detailed descriptions of the categories can be found in the literature (e.g., Exall, 2004; U.S. EPA, 2004; Asaño, 1998). The other elements of water reuse plans are discussed below.

3.1. WATER QUALITY CRITERIA

Once the reclaimed water source and applications have been determined, water quality criteria must be established, taking into account the protection of both public health and environment. The standards or guidelines that have been developed by various jurisdictions generally include reference to reclaimed water quality, wastewater treatment processes, treatment reliability, distribution systems, and use area controls. The removal of pathogens is typically the prime objective in treating wastewater for reuse, although the suitability of reclaimed water for such uses as food crop irrigation, industrial applications, and indirect potable reuse may be affected by such chemical constituents as biodegradable organics, recalcitrant organics, nutrients, heavy metals, residual chlorine and suspended solids (Crook 1998). The removal of emerging trace contaminants such as endocrine disruptors and pharmaceutical residues is also of increasing concern (e.g., Khan *et al.* 2004).

The State of California adopted the first reclamation and reuse standards in 1918 to address the use of reclaimed water for agricultural irrigation; these have

been regularly updated and are used as a basis in the development of standards worldwide (Crook 1998).

Table 1. Comparison of general characteristics of various water reuse guidelines and regulations

| Jurisdiction | | Applications considered | Minimum treatment recommended | Unrestricted irrigation coliform limit (per 100 mL) ^a |
|----------------|--------------------------------|---|--|--|
| Canada | Alberta | Agricultural, landscape irrigation | Best practicable to achieve required quality | ≤200 FC (geo. mean), ≤1000 TC (geo. mean) |
| | Atlantic Canada (4 provinces) | Agricultural, landscape irrigation | Secondary with six months storage | ≤200 FC, ≤1000 TC |
| | Saskatchewan | Agricultural, landscape irrigation | Secondary | ≤200 FC (median), ≤400 FC (2 consecutive samples) |
| | British Columbia | Agricultural, landscape, urban, industrial, environmental | Secondary with disinfection | ≤2.2 FC (median), ≤14 FC (single sample) |
| U.S.A. | California legislation | Agric., landscape, urban, industrial, environmental, groundwater recharge | Secondary | ≤2.2 TC (MPN), ≤23 TC (single sample) |
| | U.S. EPA (national guidelines) | Agric., landscape, urban, industrial, environmental, groundwater recharge, indirect potable | Secondary ^b | No detectable FC (median), ≤14 FC (single sample) |
| Inter-national | WHO guidelines | Agriculture, aquaculture | Secondary+ ^c or waste stabilization ponds | <200 FC |

^a FC = fecal coliform; TC = total coliform; MPN = most probable number

^b Primary treatment for surface spreading for groundwater recharge only.

^c Secondary treatment followed by filtration and disinfection or by polishing ponds.

Canada does not have national guidelines on water reuse at present, although guidelines for the reuse of household greywater for toilet flushing are currently under consideration by Health Canada. Guidelines have also been developed for specific uses by a number of provinces. The scope of applications, treatment and quality criteria in the provincial guidelines (Alberta Environment, 2000; CBCL Limited, 1996 [Atlantic Canada]; Saskatchewan Environment, 2004; BC MELP, 2001) are compared in Table 1 with those of the State of California (2001), the U.S. EPA (2004), and the World Health Organisation (WHO, 1989).

3.2. TREATMENT, STORAGE AND DISTRIBUTION

The source of wastewater affects its level of contamination and the degree of treatment that must be employed to render the reclaimed water safe for the intended use. Numerous treatment technologies have been applied in water reclamation and reuse projects, and extensive reviews of such technologies can be found in Asano (1998) and Metcalf and Eddy (2003). The treatment processes applied at central facilities for wastewater reclamation and water reuse range from relatively low technology systems to advanced treatment systems. Many conventional treatment processes have been applied, including waste stabilization ponds, activated sludge, trickling filters, rotating biological contactors, filtration, and chlorination; the performance of many of these treatment technologies is relatively well known. Advanced wastewater treatment process combinations have also been applied in wastewater reclamation, including such membrane processes as membrane bioreactors and reverse osmosis, nutrient removal, and UV or ozone disinfection (Asano, 1998; Metcalf and Eddy, 2003).

For smaller on-site (or decentralized) systems, technologies exist and continue to be developed, although performance data are generally less well known and performance can be susceptible to upsets (e.g., influence of antiseptic and cleaning chemicals on small-scale biological treatment systems) (Marsalek *et al.*, 2002).

Storage system design requires consideration of evaporation and degradation of water quality by growth of microorganisms or pests such as mosquito populations, and odour problems, both of which may be controlled with appropriate management techniques or use of underground storage aquifers (U.S. EPA, 2004). Urban water reuse requires a dual distribution system, in which one system is used for potable water and a second for reclaimed water. The first dual distribution system in the U.S. was built in the

1920s to supply reclaimed water for landscape irrigation and toilet flushing in Grand Canyon Village in Arizona (Okun, 1997). Adequate labelling and signage of dual distribution systems is imperative and is often achieved through the use of coloured pipe or tape. Cross-connection controls and inspections are also essential in protecting public health (U.S. EPA, 2004). In Canada, standards on the design, installation, maintenance and testing of non-potable water systems using reclaimed water are currently in preparation by the Canadian Standards Association.

3.3. WATER REUSE PROJECT PLANNING

The overall project feasibility must be evaluated prior to initiating a wastewater reclamation and reuse project. Lazarova *et al.* (2001) discussed key economic, financial, regulatory, social and technical factors that contribute to the success of water reuse projects, and Mills and Asano (1998) described a planning analysis focusing on seven major feasibility criteria that should be considered:

- Engineering feasibility – includes considerations of water quality, public health protection, wastewater treatment and storage siting/design, and matching of supply and demand.
- Economic feasibility – the added treatment, distribution and storage costs for reclaimed water may be acceptable in urban, pollution-sensitive or water-scarce areas.
- Financial feasibility – issues of both financing construction/project implementation and generating revenue need to be addressed.
- Market feasibility – provides data needed to formulate project alternatives, including facility location, design criteria, and reclaimed water pricing.
- Institutional feasibility – involves the interaction of various institutions exerting influence at levels ranging from local to national.
- Environmental impact – water reuse projects change flows of water, wastewater and associated pollutants.
- Social impact and public acceptance – winning public support is of extreme importance in the case of water reclamation and reuse.

4. Conclusions

Despite abundant freshwater resources in Canada on the whole, there are regions where demand exceeds supply. Within the holistic concept of total

water cycle management, one solution to the challenge is water reuse, which facilitates the use of treated municipal effluents as a new source for non-potable water supply. Reuse or recycling of treated wastewater reduces effluent discharges into receiving waters and offers a reliable alternative supply of water for applications that do not require high quality water, freeing up limited potable water resources. As compared to other countries worldwide, water reuse is currently practised infrequently in Canada, and usually is conducted on an experimental scale. In developing new water reuse projects, consideration must be given to project feasibility and planning, water quality criteria, and treatment and infrastructure needs. Guidelines and regulations dealing with water reuse projects exist around the world, and a number of Canadian provinces have recently produced guidance documents for water reuse applications. Various treatment technologies for on-site and central wastewater reclamation facilities are available and have been well described in the literature. As competing water demands increase and existing supplies are strained, expanded water reuse is likely. Critical evaluation of past projects and experiences in other areas of the world can provide needed insight for planning future applications of water reuse in Canada.

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References

- Alberta Environment. April 2000. Guidelines for municipal wastewater irrigation. Edmonton, AB.
- Asano T (Ed.) 1998. Wastewater reclamation and reuse. CRC Press, Vol. 10. New York.
- BC MELP (British Columbia Ministry of Environment, Lands and Parks). May 2001. Code of practice for the use of reclaimed water: a companion document to the Municipal Sewage Regulation. Victoria, B.C.
- Canadian Water and Wastewater Association. 2002. Report on rainwater harvesting and greywater reuse for potable and non-potable uses. Report to Canada Mortgage and Housing Corporation, Ottawa, ON.
- CBCL Limited. 1996. Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment, and Disposal of Sanitary Sewage.
- CMHC (Canada Mortgage and Housing Corporation). 2005. Rainwater harvesting workshop. May 24, 2005. Toronto, Ontario.

- Coote, D.R. and L.J. Gregorich (Eds). 2000. The health of our water: toward sustainable agriculture in Canada. Research Branch, Agriculture and Agri-food Canada, Ottawa, ON.
- Crook, J. 1998. Water reclamation and reuse criteria, p. 627-703. In Asano T. (ed.) Wastewater Reclamation and Reuse. CRC Press, New York.
- CWRS (Centre for Water Resources Studies). 1999. Reuse of Renovated Municipal Wastewater for Golf Course Irrigation. Prepared for PEI Department of Technology and Environment. Dalhousie University, December. CWRS Internal Report No.99-11.
- Environment Canada. 2005. Municipal water use: 2001 statistics. Cat. No. En11-2/2001E-PDF, Environment Canada, Ottawa, Ontario.
- Exall, K. 2004. A review of water reuse and recycling; with reference to Canadian practice and potential: 2. Applications. Water Qual. Res. J. Canada. 39 (1), 13-28.
- Khan, SJ; Wintgens, T; Sherman, P; Zaricky, J; Schaefer, AI. 2004. Removal of hormones and pharmaceuticals in the Advanced Water Recycling Demonstration Plant in Queensland, Australia. Water Sci. Technol. 50(5): 15-22.
- Lazarova V, Levine B, Sack J, Cirelli G, Jeffrey P, Muntau H, Salgot M, Brissaud F. 2001. Role of water reuse for enhancing integrated water management in Europe and Mediterranean countries. Water Sci. Technol. 43(10): 25-33.
- Marsalek, J., Schaefer, K., Exall, K., Brannen, L., Aidun B.. 2002. Water reuse and recycling. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. CCME Linking Water Science to Policy Workshop Series Report No. 3. 39 p.
- Metcalf and Eddy, Inc. 2003. Wastewater engineering, treatment, disposal and reuse. McGraw Hill Inc., 4th edition, New York.
- Mills RA, Asano T. 1998. Planning and analysis of water reuse projects. p. 57-111. In Asano T. (ed.) Wastewater reclamation and reuse. Vol. 10, CRC Press, New York.
- Okun D. 1997. Distributing reclaimed water through dual systems. J. Amer. Water Works Assoc. 89(11) 52-64.
- Radcliffe, J. 2004. Water Recycling in Australia. Australian Academy of Technological Sciences and Engineering. Parkville, Victoria, 233 p.
- Saskatchewan Environment. June 2004. Treated municipal wastewater irrigation guidelines. Saskatchewan.
- Scharf D, Burke DW, Villeneuve M, Leigh L. 2002. Industrial water use, 1996. Environmental Economics Branch, Environment Canada, Ottawa, Ontario.
- State of California. 2001. California health laws related to recycled water. California Department of Health Services, Sacramento, CA. Located on the Internet at: <<http://www.dhs.ca.gov/ps/ddwem/publications/waterrecycling/index.htm>>.
- State of California. 2003. Water Recycling 2030: Recommendations of California's Recycled Water Task Force. California Department of Water Resources, Recycled Water Task Force, Sacramento, CA. 59 p.
- Statistics Canada. 2000. Human activity and the environment. Statistics Canada, Ottawa, ON.
- U.S. EPA (United States Environmental Protection Agency). 2004. Guidelines for water reuse. EPA/625/R-04/108, U.S. Environmental Protection Agency, Washington, D.C.
- Waller DH, Mooers JD, Samostie A, Sahely B. 1998. Innovative residential water and wastewater management. Report to Canada Mortgage and Housing Corporation, Ottawa, ON.
- WHO (World Health Organisation). 1989. Health guidelines for the use of wastewater in agriculture and aquaculture. Geneva, Switzerland.

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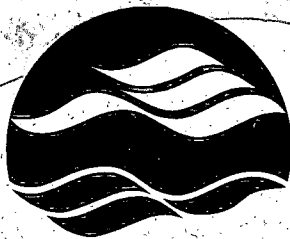


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