# RESEARCH REPORT

# Innovative Residential Water and Wastewater Management

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# INNOVATIVE RESIDENTIAL WATER AND WASTEWATER MANAGEMENT

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## Wastewater Recycling and Reuse, Rainwater Cistern Systems, and Water Conservation


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Report to

**Canada Mortgage and Housing Corporation**

September, 1998

# INNOVATIVE RESIDENTIAL WATER AND WASTEWATER MANAGEMENT

## Executive Summary

The purpose of this report is to make those responsible for planning and management of water and wastewater systems aware of, and to provide information about, three technologies that have the potential to address water and wastewater problems that face, or will face, many Canadian communities: wastewater recycling and reuse, rainwater cistern systems (RWCS), and water conservation.

These technologies may be be used alone or in combination: all of them at the scale of individual buildings, conservation and recycling and reuse at the scale of municipal systems

Most of this report addresses recycling and reuse of wastewater for non-potable applications, because water conservation, and to a lesser extent RWCS, are more widely used and accepted and more completely documented. Many of the Canadian initiatives in this field have been initiated or supported by Canada Mortgage and Housing Corporation.

Section 1 provides the background to and methodology used in this project, and reviews terminology used in discussion of wastewater reclamation, recycling, and reuse.

Section 2 identifies areas and situations in Canada that might benefit from use of the technologies discussed here. Problems exist from coast to coast, from north to south, and in both urban and rural areas. They include water shortages in area of low precipitation or limited groundwater; increased demands to meet increased growth and expansion; contamination of surface and groundwaters by industry, agriculture, urban and rural wastewater, stormwater, and road salt; contaminated recreational waters and fish habitat in both coastal and inland regions; overloaded water transmission, treatment, and distribution systems, and wastewater collection systems and treatment plants; and construction moratoriums in areas with inadequate infrastructure. It has been estimated that Canada will need to spend 4 billion dollars annually over the next 15 years to simply maintain its water and wastewater infrastructure system, and that this amount could more than double if costs of anticipated system improvements are taken into account.

Section 3 deals with innovative on-site systems. Examples and references are provided for residential water conservation and RWCS, but the emphasis is on recycling and reuse in residential and other single buildings. Seventeen case studies are provided, of systems in Canada and internationally, and 15 treatment components or systems are described, which have been used, or have the potential for use, in small-scale wastewater non-potable recycling and reuse systems.

Section 4 provides examples of municipal innovations in water and wastewater management. A recent Canadian report provided a summary of Canadian municipal water conservation initiatives. Examples of wastewater renovation, recycling, and reuse are drawn from many references that provide examples from around the world.

Examples of direct and indirect potable reuse are reviewed, and information is included about systems where these options have been investigated or used; but most of the examples relate to wastewater reuse for non-potable purposes such as irrigation, or dual municipal systems for delivery of potable and non-potable water. Potential applications for dual systems include: areas where water resources are limited, and inter-basin transfer of raw water is less acceptable than in the past; locations where water demand is expected to exceed the yield from existing facilities, and non-potable uses can be met at lower cost by reclaimed wastewater; the possibility of treating raw water from a polluted source for non-potable uses; increasing treatment requirements to meet more stringent environmental standards; and the ready availability of wastewater as a potential source of reclaimed wastewater. Dual systems have been used for toilet flushing, and for other urban public, industrial, commercial, and residential uses that include irrigation, fire fighting, cooling and process waters, construction, street cleaning, and car washing.

Section 5 draws on many recent references to review issues, obstacles, and opportunities related to wastewater recycling and reuse. These include: arguments related to the need for potable reuse, and merits of non-potable reuse; health and other water quality considerations; system planning and design; management of small scale and large scale systems; legislation, regulations, and criteria; economic considerations; and research and demonstration needs.

INNOVATIONS EN MATIÈRE DE GESTION DE L'EAU D'ALIMENTATION
ET DES EAUX USÉES EN MILIEU RÉSIDENTIEL

Résumé

Le présent rapport a pour but de mettre au courant les responsables de la planification et de la gestion de l'eau d'alimentation et des eaux usées et de les renseigner au sujet de trois techniques susceptibles de régler les problèmes d'eau d'alimentation et des eaux usées auxquels font face ou feront face de nombreuses collectivités canadiennes : le recyclage et la réutilisation des eaux usées, les systèmes de citerne d'eaux pluviales et les systèmes économiseurs d'eau.

Ces techniques peuvent s'exploiter seules ou combinées; elles s'adaptent toutes au bâtiment individuel, alors que les techniques d'économie, de recyclage et de réutilisation visent plutôt les réseaux municipaux.

La majeure partie du rapport traite du recyclage et de la réutilisation des eaux usées à d'autres fins que l'eau potable, puisque les techniques d'économie de l'eau, et à un degré moindre, les citernes d'eaux pluviales, sont plus répandues et acceptées en plus d'être plus largement documentées. Bien des initiatives canadiennes dans ce domaine ont été amorcées ou appuyées par la Société canadienne d'hypothèques et de logement.

La section 1 livre le contexte et la méthodologie suivie dans le cadre de la présente recherche, en plus de revoir la terminologie utilisée dans l'exposé concernant la récupération, la recyclage et la réutilisation des eaux usées.

La section 2 caractérise les secteurs et les situations qui, au Canada, pourraient profiter de l'exploitation des techniques discutées ici. Des problèmes existent d'un océan à l'autre, du nord au sud et aussi bien en milieu urbain que rural. Il peut s'agir de pénuries d'eau dans les zones recevant peu de précipitations ou disposant d'une nappe phréatique peu abondante; de l'accroissement de la demande en vue de répondre aux besoins de croissance ou d'expansion; de la contamination des eaux superficielles ou souterraines par l'industrie, l'agriculture, les eaux usées en milieu urbain et rural, les eaux pluviales, et le sel de voirie; de la contamination des eaux de voies plansancières et de l'habitat des poissons autant dans les régions côtières qu'intérieures; de la surcharge des réseaux d'adduction, de traitement et de distribution; des systèmes de collecte des eaux usées et des usines de traitement; et des moratoires sur les travaux de construction dans les zones dépourvues d'infrastructures suffisantes. On estime que le Canada devra consacrer annuellement 4 milliards de dollars au cours des 15 prochaines années uniquement pour entretenir ses instrastructures d'eau d'alimentation et d'eaux usées et que cette somme pourrait plus que doubler si le coût des améliorations qu'on anticipe d'apporter aux installations entre en ligne de compte.

La section 3 traite des systèmes innovateurs individuels. Elle fournit des exemples et références à l'égard de systèmes économiseurs d'eau et de citernes d'eaux pluviales pour les bâtiments résidentiels, mais elle met l'accent sur le recyclage et la réutilisation dans les bâtiments résidentiels et d'autres bâtiments individuels. Elle traite de dix-sept études de cas portant sur des systèmes

implantés au Canada et à l'échelle internationale, en plus de décrire 15 éléments de traitement ou systèmes qui ont été utilisés ou pourraient servir dans des installations à petite échelle de recyclage et de réutilisation d'eaux usées à des fins d'eau non potable.

La section 4 fournit des exemples d'innovations municipales en matière de gestion d'eau d'alimentation et d'eaux usées. Un récent rapport paru au Canada résume les initiatives des municipalités canadiennes sur le plan de l'économie de l'eau. Elle fait état d'exemples de récupération, de recyclage et de réutilisation des eaux usées tirés de nombreux exemples dans le monde entier.

Des exemples de réutilisation directe et indirecte de l'eau potable sont revus et des renseignements sont fournis à l'égard de systèmes dont les options ont été étudiées ou utilisées, mais la plupart des exemples se rapportent à la réutilisation des eaux usées à des fins d'eau non potable, comme l'irrigation ou les réseaux municipaux à double usage assurant à la fois l'alimentation en eau potable et en eau non potable. Ces réseaux à double usage pourraient desservir les secteurs où les ressources en eau sont limitées, le transfert entre bassins d'eaux brutes étant moins acceptable que dans le passé; les endroits où on s'attend à ce que la demande en eau dépasse le rendement des installations en place, et les utilisations d'eau non potable pourraient être satisfaites à un coût moindre en récupérant les eaux usées; la possibilité existe de traiter l'eau brute d'une source polluée pour obtenir une eau non potable; d'augmenter les besoins de traitement pour répondre aux normes environnementales plus rigoureuses; et de disposer des eaux usées comme source potentielle de récupération des eaux usées. Les réseaux à double usage ont été utilisés pour la chasse des toilettes et à d'autres fins publiques, industrielles, commerciales et résidentielles, y compris l'irrigation, la lutte contre l'incendie, la climatisation et l'eau de fabrication, la construction, le nettoyage des rues et le lavage des autos.

La section 5 fait appel à de nombreuses références récentes pour revoir les enjeux, les obstacles et les possibilités de recyclage et de réutilisation des eaux usées. Il est question d'arguments se rapportant à la nécessité de réutiliser l'eau potable, des mérites de réutiliser l'eau non potable; de la santé et la qualité de l'eau; de la planification et de la conception des systèmes; de la gestion d'installations de petite et de grande envergure; de lois, règlements et critères; d'aspects économiques; ainsi que des besoins de recherche et de démonstration.

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**INNOVATIVE RESIDENTIAL**
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**INNOVATIVE RESIDENTIAL**
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## Abstract

This report is intended to provide an information and discussion source about innovative water and wastewater technologies that have the potential to address some of the infrastructure problems that face Canadian municipalities. These technologies, which may be employed alone or in combination, include reuse and recycling of wastewater, water conservation, and use of rain water as an alternative source.

The report begins with a review of situations in Canada that might benefit from the applications of innovative water and wastewater technologies. Following sections provide examples—from Canada and internationally—of the application of these technologies: at the scale of single unit dwellings or multi-unit residential systems, and at the municipal scale. The report concludes with a review of issues that may be involved in consideration or selection of these technologies.

This document is expected to serve as a resource for all of the stakeholders who have an interest in the planning, design, and management of water and wastewater infrastructure: municipalities and municipal utilities, provincial and federal planners and regulators, private investors and manufacturers, educators and researchers, and public, business and professional organizations.

**INNOVATIVE RESIDENTIAL WATER AND WASTEWATER MANAGEMENT**

## Acknowledgements

We are grateful to all of the individuals, companies, and agencies that provided the information on which this report is based.

Peter Russell, of the Research Division of CMHC, inspired the initiatives in residential wastewater recycling and reuse that CMHC has undertaken in recent years, which have resulted in this project and others that are reported herein.

Any reference to innovations in this area of technology and in connection with CMHC should not pass without acknowledging Sam Gitterman, who for many years, as a senior engineer at CMHC, championed the need to develop water recycling technology. In 1954 the Corporation first embarked on a long range set of R and D projects aimed at reducing the dependency of housing on piped sewer and water infrastructure systems. This culminated in 1978 with the construction of a large system termed CANWEL (Canadian Water-Energy Loop)[1], which was installed in a Toronto apartment building. It was able to treat all water from the building to a potable water quality. The system also recovered heat by incinerating the sludge and other waste. It worked, but eventually was scrapped due to formidable institutional obstacles and a market unready to accept such a radical advancement. It was an idea ahead of its time. A review of this project also illustrates that unless development of promising innovation is sustained competing technologies will overtake.

Ellen Youle was responsible for assembly and typing of this report.

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1. Canviro Consultants Ltd. and MacLaren Engineers Inc., 1984, "CANWEL, The Canadian Water Energy Loop", Summary Report, prepared for Canada Mortgage and Housing Corporation, 35 pp.

# SECTION 1

# INTRODUCTION

## 1.1 Background

Most Canadian municipalities face problems related to water and wastewater services.

It has been estimated that Canada will need to spend approximately 4 billion dollars annually over the next 15 years to simply maintain our water and wastewater infrastructure system. This amount could increase to 5.7 billion annually to account for anticipated expansion requirements (1). The scarcity of capital for this work has already caused a number of communities to place moratoriums on new development in areas where the capacity of existing infrastructure has been reached. In areas not served by central services, site or soil conditions may limit use of conventional on-site systems, and limit development or require very expensive central services.

The technologies discussed in this report may offer solutions to some of these problems. These technologies, which may be employed alone or in combination, include reuse and recycling of wastewater, water conservation, and use of rain water as an alternative source.

The objective of this report is to provide an information and discussion document that can serve as a resource for all of the stakeholders who have an interest in the planning, design, and management of water and wastewater infrastructure: municipalities and municipal utilities, provincial and federal planners and regulators, private investors and manufacturers, educators and researchers, and public, business and professional organizations.

Section 2 is a review of situations in Canada that might benefit from the applications of innovative water and wastewater technologies. The next two sections provide examples—from Canada and internationally—of the application of these technologies: Section 3 considers applications at the scale of single unit dwellings or multi-unit residential systems, and Section 4 describes applications at the municipal scale. Section 5 reviews issues that may be involved in consideration or selection of these technologies.

It was not considered practical or necessary to present in this report all of the information identified and reviewed in the course of this project. Readers who want to explore in more depth any of the information presented here should consult the references that are cited herein; attention is drawn in particular to important references ((2)(3)(4)(5)(6)) that have recently become available.

This project is one of several—related to wastewater recycling and reuse—that have been initiated by Canada Mortgage and Housing Corporation (CMHC):

- support of a number of projects, which are described in this report, that are intended to demonstrate the application of innovative residential water and wastewater technologies;
- a report that describes perceived regulatory barriers to on-site wastewater reuse in Canada, and discusses the implications of these barriers (7);

- a report prepared to assist persons seeking approval for wastewater reuse systems, and for regulatory agencies approving such systems (8);
- a computer program intended for the planning and design of innovative residential water and wastewater systems (9); and
- an examination of the potential for application of innovative residential water and wastewater technologies as alternatives to conventional servicing, in 3 case study situations (10).

### 1.2 Methodology

This project began with a detailed review of information, and potential information sources, in the Centre for Water Resources Studies' (CWRS) data base, which was supplemented by information provided by CMHC. Additional information was solicited by library and internet searches, and telephone, fax, and e-mail contacts, from sources that included public and private agencies, suppliers and manufacturers, consultants, and researchers in Canada, the United States, England, Japan, and Australia. All of the reference material has been catalogued for future use.

Information was assembled about areas and situations in Canada that might benefit from residential wastewater recycling and reuse.

Case studies were developed to describe examples of wastewater recycling and reuse in residential and in other relevant applications in Canada and elsewhere.

Descriptions of specific processes that have been used, or have the potential for use, in wastewater treatment for recycling or reuse were prepared. In addition to inclusion in this report, these descriptions were copied to Wastewater Technology Centre, Burlington, Ontario for inclusion in a computer program being prepared by that organization for CMHC. The format adopted for the process descriptions was based on that used in their program.

Municipal initiatives in water conservation and wastewater recycling and reuse were identified, and problems encountered and solutions adopted were summarized.

Issues and problems related to selection and implementation of the technologies discussed here were identified and described, based on the experience of the project team and many of the reference sources.

The foregoing tasks benefited from the knowledge and experience of two companies that have extensive first-hand experience in the planning and design of systems for wastewater recycling and reuse: the project descriptions and case studies were reviewed, and supplementary information provided, by the firm of totten-sims hubicki, under a parallel contract with CMHC; A.R. Townshend of Blue Heron Consultants collaborated with the Centre for Water Resources Studies in providing a review of planned and potential applications of wastewater technologies, which is Appendix C of this report. CMHC also arranged for the Canadian Water and Wastewater Association to review parts of the report, and to prepare most of Section 2.

## 1.3 Terminology

Most of the terminology used in this report is unambiguous, but several terms related to innovative wastewater management are defined here to provide a consistent usage for the balance of this report.
**Wastewater reclamation** - treatment or processing of wastewater to make it suitable for recycling or reuse. (There is no consistent use in the literature of the terms " reclaimed water" or "reclaimed wastewater"; the latter term is used in this report.)
**Wastewater reuse** - use of reclaimed wastewater for a purpose other than that for which it was initially used. e.g., reuse of greywater for toilet flushing or for irrigation.
**Wastewater recycling** - return of reclaimed wastewater to be used again for the purpose that generated the wastewater, e.g., treatment and recycling of all household wastewater for toilet flushing and other non-potable uses.

The distinction between reuse and recycling is illustrated in Figure 1.1. Reuse is uni-directional; recycling involves repeated passage of water through the system.

Two implications of this distinction are:

- The amount of water that can be reused is limited by the amount that is available from the source, but there is theoretically no limit to the amount that can be recycled. In Figure 1.1.(b) the minimum input from the source is 75, which is required to meet the demand for reuse. In Figures 1.1.(c) or (d) the input from the source is 30, which could be reduced to 25 (the irrigation demand) with complete recycling.
- Because recycling involves repeated passage of water through the system, the concentration of any wastewater constituent that is not completely removed by treatment will build up in the system, which may have water quality implications, e.g., salt buildup in irrigation water.

Notwithstanding the above distinction, the term *recycling* is commonly applied only to industrial wastewater recycling, or to building systems such as those in Section 3 of this report. For large-scale and municipal systems such as those in Section 4, the term *reuse* is applied to whether the water is reused (e.g., for irrigation) or recycled (e.g., returned to replenish the supply of the community that generated the reclaimed wastewater).

The following terminology, applied to large scale and municipal systems, is based on that used in recent reference sources, e.g., (3) and (6):
**Direct reuse** - reuse where there is a direct piped link between the treatment system and the reuse application. Commonly applied to *direct non-potable reuse* .
**Indirect reuse** - reuse where reclaimed wastewater is discharged into a reservoir, stream, or groundwater aquifer, from which water is withdrawn for use. Commonly applied for *indirect potable reuse.*
**Unplanned indirect reuse** - situations where downstream supplies are drawn from sources to which wastewater is discharged, and source water quality and quantity is not controlled by the user. Common worldwide.
**Planned indirect reuse** - situations where downstream supplies are withdrawn from sources to which reclaimed wastewater of managed quantity and quality is discharged.

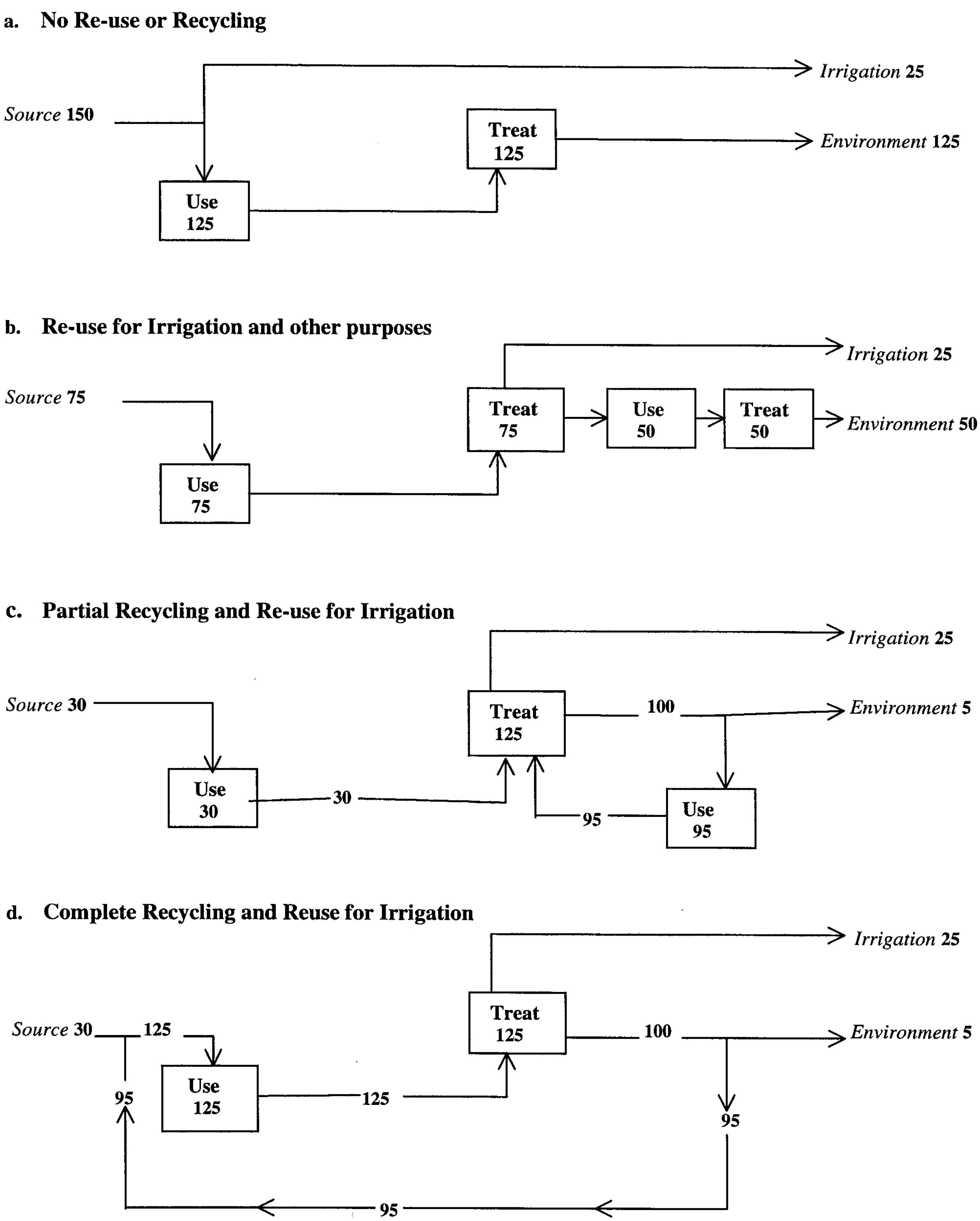


**Figure 1.1 Reuse and Recycling**

## 1.4 References


(1) Canadian Water and Wastewater Association, 1997, "Municipal Water and Wastewater Infrastructure – Estimated Investment Needs 1997-2012," 33 pp.

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(4) American Water Works Association and Water Environment Federation, 1998, Water Reuse Conference Proceedings, Lake Buena Vista, Florida, 757 pp.

(5) Crites and Tchobanoglous, G., 1998, "Small and Decentralized Wastewater Management Systems", McGraw Hill, 1084 pp.

(6) National Research Council, 1998, "Issues in Potable Reuse, The Viability of Augmenting Drinking Water Supplies with Reclaimed Water", National Academy Press, Washington, 263 pp.

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(9) Waller, D.H., J.D. Mooers, M.A. Salah, and P. Russell, 1997, "WATERSAVE - Planning for Water Conservation and Reuse in Residential Water Systems", proc. 7th National Conference on Drinking Water, August, 1996, Charlottetown.

(10) Waller, D.H., and M. Salah, 1998, "Innovative Residential Water and Wastewater Technologies", report to Canada Mortgage and Housing Corporation, Centre for Water Resources Studies, DalTech, Dalhousie University.

## SECTION 2

## AREAS IN CANADA THAT MIGHT BENEFIT FROM INNOVATIVE WATER AND WASTEWATER TECHNOLOGIES

### 2.1 Introduction

Many Canadian municipalities now face, or will encounter, serious problems related to water supply and wastewater management. Solutions to some of these problems may lie in adoption of technologies discussed in this report: wastewater recycling or reuse, water conservation, and rainwater cistern systems.

*Rainwater cistern systems* (RWCS) can provide an alternative or supplementary water source in situations where conventional sources are not available or inadequate, are contaminated, or are too expensive. Used in conjunction with water conservation and recycling or reuse, they can be applicable in areas where rainfall alone would not otherwise supply all residential demands.

*Water conservation* can reduce demands on a water source, transmission main, or distribution system. It can also reduce loads on wastewater collection and treatment systems. For on-site systems it can reduce water demands on wells and hydraulic loads on on-site wastewater disposal systems.

*Wastewater reuse* for irrigation or other purposes can reduce both water demands and hydraulic loads on wastewater treatment plants, and reduce or eliminate effluent loads to sensitive receiving waters.

*Wastewater recycling* in residential, commercial, and industrial applications can reduce water demands and wastewater flows, and expand options for effluent disposal because of improved effluent quality.

The purpose of this section, which draws on Appendix C and monthly bulletins of the Canadian Water and Wastewater Association, is to identify areas or situations in Canada that might benefit from use of these technologies. Sections 3 and 4 review examples of specific water and wastewater problems that have been addressed by these technologies – at the scales of individual buildings and municipal systems.

### 2.2 Background

Although fresh water is a renewable resource, it is also a finite one. The water cycle makes available only so much each year in a given location. One of the clearest signs of water scarcity is the increasing number of countries in which population has surpassed the level than can be sustained comfortably by the water available. Water scarcity problems may also stem directly from human activities - deforestation, over grazing, over farming, or urban development. Degraded land increases flash runoff decreasing seepage, and thus aquifer recharge.

Canada uses more water per capita than any other country except the United States. Despite an apparent abundant supply, clean water may be in short supply or inaccessible at specific locations at certain times of the year. Water problems across Canada involving both surface and ground water threaten the quality of life of people across Canada.

Pollution is more often the cause of water problems for Canadians than any absolute scarcity of supply. Wastewaters from municipalities on the Great Lakes and St. Lawrence River contain toxic chemicals that are not removed by treatment. Pollution from various sources including agriculture leads to contamination of the groundwater on which more than one-quarter of all Canadians rely for their water supply.

There is an ongoing population shift on a national basis from water rich areas in the East to water poor areas in the West. People choosing to leave metropolitan areas for small town and rural living are putting new demands on small water and wastewater systems.

As a result of global warming the earth's temperature is expected to rise somewhat, altering the hydrological cycle. Sea levels will rise, rainfall patterns will shift, and drought areas, such as those that developed in California, will develop in the Prairies.

Increased precipitation is projected for the Arctic and south eastern Canada. Summers will be drier with more frequent droughts except in the Arctic and in the St. Lawrence Atlantic region. Demands on water for irrigation in the West will increase and intensify.

Whether local rainfall decreases or not, warmer weather will increase evapotranspiration boosting water demands for crop irrigation, lawns and gardens. More winter precipitation will fall as rain and the snow will melt earlier reducing river flows during the summer when they are needed most. With diminished surface water supplies even more reliance will be placed on ground water.

Increasing pressures on available supplies, conflicting demands, and new threats to water quality from climate change are converging to make Canadians aware that they can no longer take plentiful supplies of clean water for granted. Many fear that our present water policies are inadequate to cope with the emerging pressures on our water resources. Such anxieties have produced a mood for change.

Experience in California has demonstrated that large-scale water transfers are not necessarily the most cost-effective solution to increasing water demands, and that wastewater reclamation and reuse is an alternative solution that may be less costly and more reliable than imported water.

Much of Canada's existing water and wastewater infrastructure needs major upgrading or replacement to meet existing and expanding demands. Inadequate and poorly maintained wastewater infrastructure reduces water quality in surface water bodies and in groundwater.

Many water shortages around the world stem from the widespread failure to value water at anything close to its true worth. Under pricing water perpetuates the illusion that it is plentiful. In Canada, unmet water and wastewater infrastructure capital requirements; population growth with location shifts; and government fiscal constraints are driving the move towards full cost, user pay direct consumer charges. Future new user pay pricing policies will increase demand for cost- competitive and more efficient environmental technologies, including wastewater renovation, recycling and reuse systems.

## 2.3 Potential Applications by Region

Even in a water wealthy country like Canada, physical signs of water stress already exist. Wastewater recycling and reuse systems may have some application in the regions of Canada where surface or groundwater supplies are in short supply, inaccessible or contaminated. Such systems may also extend the life of existing infrastructure in communities that have reached, or are approaching, the full capacity of their water or wastewater treatment systems. Whether or not a recycling or reuse systems is applicable to a given situation, the reality is that no region in Canada can consider itself immune to water quality or quantity challenges. Numerous examples which serve to reinforce this point can be found in communities from coast to coast.

### *British Columbia*

On the west coast, British Columbia has the greatest flow of water among the provinces, with half of its supply coming from the coastal and inland mountain ranges. Despite the relatively wet climate, the province does have many local water short areas in the southern interior (the Okanagan Valley) and in urban growth areas such as Surrey. Peak summer demand for water creates most of the demand-side problems in coastal BC. The provincial capital of Victoria has funded innovative water conservation projects which focus on reducing outdoor water use for gardens; this rainy coastal area would certainly support rainwater cisterns to help meet water demands. (1) The Victoria Capital Regional District continues to promote the inclusion of water saving fixtures in the provincial plumbing code (2). Due to the high water demand in the area, developers now face increased charges to help pay for the expansion of the water supply system. The extra charge will add about $900 per door to a Victoria Region developer's cost on a multiple unit. (3)

The Greater Vancouver Regional District has been studying water meter installation in all residential buildings. The Region estimates that a user-pay system would result in a 10 per cent reduction in water consumption. This might allow the regional district to postpone costly expansions to the system: the water department's 10 year capital plan includes $813 million in new infrastructure. This would fund plans ranging from dam works to increase water capacity to a new water filtration plant.(4) Even in 1997, after the Region had just endured the wettest 10-month period on record, Greater Vancouver residents were urged to conserve water. "The summer restrictions are about conservation as well as limiting the strain on our existing water supplies" according to a water planner at the Greater Vancouver Regional District. The Regional District's twice-weekly lawn sprinkling restrictions were established a few years ago to preserve treated water supplies during dry summers. (5) All of these examples serve as evidence that even water-rich areas must consider ways to reduce runaway consumer demand for water resources or face the high cost of expanding infrastructure.

Increasingly, water quality problems are surfacing in BC. As recently as 1997, a series of reports prepared by provincial officials sounded the alarm over a 600 per cent rise in the number of boil water orders in BC since 1986. (6) An Environment Canada study revealed low levels of pesticide contamination and high nitrate levels in the ground water beneath the Fraser Valley. (7) This contamination has already affected the town of Abbotsford, which has had to decommission community wells. (8)

For years now, cities in the interior of British Columbia have recognized the need to make their water supplies go further. Many have already embraced water reuse at a municipal level. It is practised mainly in the Okanagan Basin by communities such as Vernon, Osoyoos, Oliver, Armstrong and Penticton, as well as in the Cranbrook and Kamloops areas.

***Prairie Provinces***

As a rule of thumb, hydrogeologists designate water stressed countries as those with annual supplies of 1,000-2,000 cubic metres per person or 2,740-5,480 litres per person per day. The major area in Canada approaching this limit is in the southern Prairies, particularly the basins of the South Saskatchewan, Red and Assiniboine rivers due to agricultural activity. On a seasonal basis, those basins have less than 2,500 litres per capita per day. There is not always enough water available for crop irrigation and residential use.

More than half of Canada's irrigated land is in Alberta. Alberta (and to a lesser extent Manitoba and Saskatchewan) account for 95 per cent of all agricultural irrigation demand in Canada. In Alberta, experts estimate that the province's feedlots, combined with the other types of "industrial" farming, create sewage equivalent to that of 46 million people. Largely untreated manure runoff and nutrient-rich effluent threaten the water supplies of many Alberta communities. (9) As recently as Spring of 1998, widespread public concern about manure management practices and water quality prompted the Alberta Cattle Commission to create an industry task force to address the issues. (10)

In rural areas of the Prairie provinces, there is a lack of surface water, with dugouts drying up or contaminated with toxic algae blooms by the month of July. Blue green algae and its toxic by-product, microcystin-LR, are becoming an important water quality problem across the Prairies. Manitoba Environment has found that the toxin is widespread in rural municipal water supplies. (11)

The often isolated and far-flung First Nation communities of the prairie region are particularly affected by deficits in both water and wastewater treatment. (12) Consider the example of the Shamattawa First Nation; located 650 km north of Winnipeg, MB, this reserve of 827 people has suffered extremely high levels of methane in their community wells. In early 1997, the Department of Indian and Northern Affairs committed almost $6 million for a combination of new housing and a traditional central water treatment facility. (12)(13) Yet, with some innovative thinking, this site might have offered an ideal opportunity for a combination of alternative water sources and water reuse technology. The new and renovated housing might have been designed to incorporate the plumbing requirements and reuse technology needed to significantly reduce the community's water needs, and addressed some wastewater treatment needs at the same time.

More than 50 per cent of Saskatchewan's population is served by groundwater which tends to be expensive and of poor quality in that province, being deep and saline. Alternatives to the traditional centralized water and wastewater systems would seem to be ideal in these rural areas of the Prairie provinces which face so many water related challenges.

Urban areas in the Prairies are also affected by questions about water quality and supply. A 1997 report from Alberta Environment found that the water downstream from Calgary, AB, is "unacceptable for direct contact recreation" largely due to stormwater discharges. (14) The City of Calgary is faced with a rapidly growing population and with drinking water plants already operating at almost full capacity. Demand management techniques such as awareness campaigns and water metering are practised by the city in an ongoing effort to reduce water consumption. (15) Winnipeg, MB, has tackled water consumption with awareness campaigns as well, and, over the last 5 years, has increased water rates by 9 to 11 per cent every year. The rate increases are intended to build up Winnipeg's reserve fund to allow for anticipated repairs, upgrades and expansion of the water system (16). In Saskatoon, SK, demand is growing for the municipality's treated water outside the city limits. In 1998, through an arrangement with the Sask Water Corporation, Saskatoon agreed to supply water to two pilot projects in a nearby rural municipality involving about 30 residential units and 13 farmsteads. (17)

Finally, the economy of the Prairie region is based on other large and growing water-use activities - energy and mineral developments. New demands are expected for deep-well injection to maintain pumping pressure in depleting oil fields and for tar sand development.

***Ontario***

Ontario is Canada's most populated province, with 11,258,400 residents in 1996[1]. As such, there are numerous examples of Ontario communities, both large and small, which are experiencing water supply and/or sanitation difficulties. The Regional Municipality of Waterloo, with a population of 350,000 is Canada's largest metropolitan area dependent on ground water for its supply. Faced with a limited supply and the high cost of obtaining surface water from the nearby Grand River or Lake Huron, some 120 kilometres to the west, the Region has conducted a vigorous conservation program to reduce water demand.

On the tiny Ojibwa reserve of Ontario's Pays Plat First Nation, residents collected their drinking water from distillers set up at the community hall in 1994, when their existing filtration system was deemed inadequate for treating the polluted water of the Pays Plat River. The First Nation community received $2.5 million to build a water treatment plant, which draws water from Lake Superior and pumps to about 25 households and administration buildings (about 70 residents) located one kilometre inland. The new plant became fully operational in summer of 1998. Leaky septic fields were to blame for the original pollution, which caused some families who drank the water from the river to fall ill. The next project for the band is to install a proper sewage treatment plant. (18)

The Gull Bay First Nation is a community located about two hours north of Thunder Bay that has been riddled with financial difficulties, school closures and undrinkable water. Emergency funding is being used to complete a much needed sewer project on the reserve; there are several homes in the reserve that are not connected to the sewage system. (19)

Small communities, it seems, are often afflicted with water quality problems or sewage treatment systems which are inadequate or malfunction. The Goulbourn Township village of Munster Hamlet, for example, may be at risk of a serious environmental problem. The village's sewage lagoons are in poor condition and not large enough to serve the 1600 inhabitants. It is likely that the village will call for an expansion of the lagoons and their accompanying spray irrigation system, although more innovative solutions are being explored. (20)

A significant proportion of the homes in the hamlet of Ruthven, ON, are leaching raw human wastes into Lake Erie, according to environmental and Township of Gosfield South officials. In a 1994 pollution survey of hamlet drains leading to Lake Erie, every one of 21 water drain samples tested

1. Source: Statistics Canada, CANSIM, matrices 6367-6379

showed faecal coliform counts above acceptable levels set by the province. The pollution problems in the storm sewers result from inadequate private septic tank systems and they pose a health risk to area residents. Engineering consultants were engaged to present residents with remediation options by early June. The task will then be to convince residents to pay for what may be an expensive solution, including perhaps the need to construct a separate sewage treatment plant for the hamlet. The township is in need of a solution in the near future so that a 20 year development freeze in the area can be lifted. (21)

In St. Catharines, ON, a city of 127,000 residents, city officials have identified at least a half dozen homes across the city from which raw sewage is known to be discharged directly into the environment. These older homes have never been connected to the sewage system. One home in particular releases sewage into a canal in a public park where children play, creating a potential health problem for local residents. (22)

Developers are currently being refused permits until the City of London's existing sewage treatment plant undergoes an $8 million expansion. London's Pottesburg plant has the ability to treat 28.2 million litres of sewage daily. It is currently processing 26.8 million litres daily, and the city has approved development that will move the total up to 29.4 million litres. The City of London is planning for future growth as it attempts to choose a location for a Southside sewage treatment plant. The planning process has met with a great deal of resistance from home owners in the Lambeth area, which has been designated as a preferred site for the new wastewater plant. Residents of the Lambeth area have been trying to identify alternatives to what they fear will become a mega-plant in their backyards. (23)

A 1997 probe by York Region found 5 of 17 homes on a King City street illegally sending wastewater into roadside ditches. The King Township community is facing increasing septic tank system failures. As a result illegal discharge of wastewater is widespread. The Region has approved hooking the community - one of Ontario's largest without sewers - into the York-Durham sewer system, a move opposed by many residents. Residents are divided: on one side are the traditionalists who want to keep King City, a village northwest of Metro Toronto, a quaint little community of some 5,000 inhabitants. On the other side are those who are in favour of "*the Big Pipe Solution*", hooking into the York-Durham sewer system. Village officials feel that pollution and the possibility of disease from the village's crumbling septic tanks is hurting property values and stifling growth. The region's Medical Officer warns that some waterways in King City have become "*open sewers*" and blames seeping septic tanks. Opponents of the sewer hook-up issue warnings about huge tax hikes to pay for the link, which could cost an estimated $29.5 million. York Regional Council has approved the "*Big Pipe*" route as well as a growth plan that could see King City grow to 12,000 by 2021. Those who oppose the plan vow to continue to seek alternatives. (24)

During the next 20 years the Greater Toronto Area will be home to two million new residents, with Halton's population expected to increase from 320,000 to 538,000. In order to provide water to these new residents, a plan to build pipelines that will carry water from Lake Ontario to north Oakville, Milton and Halton Hills will be phased in. While the Halton Urban Structure Plan is considered proactive by many in that it will allow the regional municipality to set the agenda for future growth, it's pricetag of up to $100 million makes it an expensive solution. The structure is expected to provide enough water to develop 6,200 housing units and up to 283 hectares (700 acres) of commercial and industrial land. (25)

However, water supply is not the only issue at stake: growth in Burlington could come to a halt by 2001, when it is predicted that Halton's Skyway wastewater treatment plant will reach capacity. By spending $28 to $63 million on plant expansions and improvements, however, new residents and businesses could be welcomed to the area until the year 2011 and beyond. The South Halton Wastewater Master Plan will focus on the Skyway plant. Along with demands created by population increase, staff at the plant are under pressure to meet targets for improved water quality in Hamilton Harbour. As a result, the staff recommended the plant's outfall pipe be relocated to Lake Ontario, between the intake pipes for Burlington and Hamilton's drinking water plants. This recommendation was based on the continued use of conventional technology ; members of Halton's planning and public works committee agree that state-of-the-art technology will be considered as plans to increase plant capacity and improve effluent quality develop. (26)

Halton Region is also developing an aquifer management program to protect existing ground water resources for the 85,000 residents who rely on wells. The Halton Aquifer Management Plan is seen as a progressive step intended to protect a crucial resource too many take for granted. It is an indication that communities are beginning to understand how vital water is and how easily its quality can be ruined by careless practices. Halton intends to protect all water that passes through the Region's territory; its journey through the Halton watershed, while possibly taking more than 100 years, may subject it to contamination from road salt, fertilizers, pesticides, herbicides, gasoline spills, etc. The Region's plan may in time demand very strict controls. Halton and Waterloo are taking the lead in Ontario developing local aquifer plans, followed by Guelph, Paris, Peel, York, Woodstock, Oxford County and Ottawa. (27)

Also in the Toronto area, Richmond Hill is examining the source of much of its water. At this time only one small swath of Richmond Hill, located on the Oak Ridges Moraine, remains free from designation as an area to be developed, but it is considered a crucial swath. About 35 square kilometers remain green on the Oak Ridges Moraine, a ridge of gravel, sand and silt that acts to absorb and filter surface water to underground channels or into streams. Streams from this small stretch of Richmond Hill feed the headwaters of Toronto's three great rivers: the Don, the Humber and the Rouge. Ten communities with an estimated 500,000 people draw drinking water from the Moraine. It is also a source for at least 25 rivers. How much, if any, of this corridor can safely be paved over before the quality of the groundwater is seriously affected is a controversial issue. Richmond Hill developers, experts, and citizens are to advise the municipality on how much housing should be permitted. If a mistake is made in determining the public interest, it could damage the watershed and affect drinking water for the whole region. (28)

More than 2.5 billion litres of raw sewage combined with storm water runs into the Toronto Harbour annually, according to a new report from the Toronto Bay Initiative. More than 1,000 storm sewers and 64 combined sewer overflow outlets spill into the harbour. (29)

Amherstburg and Colchester North must grapple with the question of whether future growth is an affordable option for their shared hamlet of McGregor. For almost a decade, a freeze on new development had covered the community of about 1,600 people. McGregor's sewage lagoons are at capacity, and during some heavy rainfalls they can discharge directly into King's Creek, which eventually flows into the Detroit River. Compounding the problem of raw sewage being sent downstream is an added local health concern, as the bed of King's Creek is occasionally dry during these overflows of contaminated water. (30)

Ontario's large cities must contend with demands from neighbouring municipalities to extend or expand water and wastewater services. For example, the town of LaSalle made a request in 1998 to purchase an additional 4.5 million litres per day of sewage treatment capacity at the City of Windsor West Pollution Control Plant. Without the additional capacity, development in LaSalle (Essex County's fastest growing municipality) could grind to a halt. Windsor has indicated that it is unlikely to grant the request, as the remaining capacity at the plant is committed to Windsor's growth requirements. LaSalle has a contractual right to buy an additional 13.5 million litres per day capacity when the city expands its sewage plant. The city has no plans for such an expansion at this time. (31)

In the case of a group of 250 homes in Long Beach, a community west of Brockville, contamination of the well water by road salt eventually forced the Ontario government to announce that it will pay for treated water to be piped directly to the residences. Road salt running off provincial highways contaminated the wells. Plumbing has been corroded, well pumps and appliances have been ruined, and bottled water for drinking has been the norm. Road salt has been spread on Highways 401 and 2 for at least 30 years, and has been found in the wells of at least 130 homes. The Ministry of Transportation has already paid out over $1.5 million in compensation to affected residents, and in 1997, the Ministry agreed to connect affected residents at no cost. (32)

One community's longtime battle with a health-threatening sewage problem idea is to connect the 80 homes and businesses in Campden to a sewer line. Waste would then be pumped to a treatment lagoon to be constructed on a nearby quarry property. Once treated to provincial standards, the effluent would be released to natural watercourses. Odorous septic scum has been oozing into backyards and ditches all over the area. (33)

In Manotick a developer received permission to build a small sewage treatment plant that will discharge into the Rideau River. The 100 unit proposal will create senior's housing the village needs, apparently adding to the pollutant load of the river. Without innovative sewage treatment, the village would not be able to grow: its network of septic systems is already overburdened. The Region of Ottawa-Carleton's official plan calls for pilot projects using such "communal services" in rural areas. Ontario's Environment Ministry approved the small sewage plant subject to a 12-page list of controls on sludge, phosphates, bacteria and volume of sewage. (34)

### *Quebec*

The province of Québec must hike its drinking water standards to existing international levels, or the health of a large part of its population will be in danger. Many of the province's residents currently consume water that has undergone no treatment, or has merely been chlorinated. According to government engineers, Québec residents mistakenly believe that their province and municipalities are providing high quality drinking water. "The current regulation is out-dated and compromises public health" stated the president of the Professional Association of Engineers of the Quebec Government (Association professionnelle des ingénieurs du gouvernement du Québec). For instance, while the province recognizes the carcinogenic properties of trihalomethanes (THMs), the drinking water standard is maintained at 350µg/L, compared to the Canadian drinking water guideline of 100µg/L.

The same is true of the lead guideline, which in Québec permits up to 50 μg/L in municipal drinking water while the rest of Canada and the U.S. recommended only a maximum of 10 μg/L. (51)

A large proportion of surface water in the province of Quebec, is badly polluted. The provincial government, in partnership with municipalities and the federal government, has spent hundreds of millions of dollars on improvements to municipal wastewater treatment. Despite this, rivers such as the St. Charles near Quebec City , the Chaudiere (which discharges to the St. Lawrence), and the Assomption are still too polluted for recreational uses.(35) Towns such as Repentigny, whose water supply comes from the polluted Assomption River, must pay a high cost to adequately treat their drinking water.(36) Saint-Gervais-de-Bellechasse is a community whose water source is so contaminated by nitrates that it has been declared unfit for human consumption. Agricultural activity is now considered to be the main source of water pollution in Quebec.(37) The agricultural sector has lagged far behind the urban and industrial sectors in pollution control, largely due to the non-point source nature of the pollutants. However, Quebec rural communities have demonstrated a willingness to work to improve and protect the quality of their water with innovative programs. For example, Sainte-Marie and Sainte-Anges area farmers have agreed to modify their agricultural practices based on an analysis and recommendations from an environmental consultant. The goal is to reduce contaminant levels in the Belair River. (38)

Quebec is a province of many small towns, and these small communities are often challenged by difficulties which are particular to their situation. Saint-Placide and Franklin, for example, are communities which draw water from artesian wells. In 1997, residents of both towns experienced great turmoil as bottled water companies attempted to establish bottling plants in these regions. In both cases, residents successfully fought these applications, spurred by the fear of watching their drinking water shipped away leaving locals with potentially severe water shortages.(39)(40) Other small Quebec towns have experienced more common difficulties; Georgeville's communal septic tank and two septic fields have proved to woefully inadequate. In April 1997, citizens of Georgeville were threatening to sue the township over fields so saturated that septic effluents was sitting above ground. (41)

In urban Quebec, towns such as Laval have actively pursued water awareness campaigns in an effort to educate the public on the topic of conserving water. Laval in particular faced the possibility of building the equivalent of a fourth drinking water treatment plant. The town began an awareness campaign in 1992 and has managed to reduce overall water consumption by 30 per cent over the last six years. This has at least temporarily postponed their infrastructure expansion needs. (42)

### *Atlantic Provinces*

Canada's Atlantic provinces experience their share of water-related difficulties as well. A Fredericton, NB, family and two of their neighbours are plagued every spring with raw sewage in their yards and basements. The homeowners share a septic system which is not approved by the New Brunswick Department of Health because it drains into the St. John River. With high spring waters, the sewage spills into their yards. The homeowners are unable to replace their ineffective systems because their lots are too small for conventional septic systems. The properties can not be sold because the current system isn't approved. The families no longer drink their well water, as they are afraid the frequent overflows have contaminated it. At one point, the city suggested that a satellite sewage system might be installed in the neighbourhood, but the funds simply could not be found. The City of Fredericton is actively investigating the viability and cost of different options for servicing of all unserviced areas in the city. (43)

Bathurst, NB, was forced to carefully review a controversial proposal to supply water to the Carron Point area of the city. The city had announced it was seeking funding to extend the municipal water system to Carron Point. However, the proposal called for significant financial contributions from the residents in the area. Under the proposal, the city would contribute $300,000 over two years and would seek $1,050,000 from the province. The residents would also be expected to contribute $300,000 - between $4,000 - $12,000 per household. A number of people in the area whose well water is plagued with a high mineral content, foul odours and high particulate matter, had been fighting to get connected to the city's water supply for almost 20 years, and were supportive of the plan. But others had experienced no difficulties with the quality of their water and while sympathetic to their neighbours' plight, were unwilling to pay the large sum of money.(44)(45) In another sector of the city, Bathurst must resolve a 20-year old sewage problem in a subdivision that was privately developed in the late 1950s. The subdivision's septic tank gradually deteriorated and raw sewage began flowing into a nearby brook and into Bathurst harbour. For two years the Bathurst Sustainable Development Project tried to find a solution to the problem, but there was confusion over responsibility because the developers were deceased. An agreement between the province, the city and the local homeowners was eventually reached and work on a new sewage system began just before Christmas 1997. Meanwhile, the city continues to explore options for solving another sewage problem in a separate subdivision where the septic tank that serves 22 homes pumps sewage directly into the Bathurst harbour through an overflow pipe. A hotel and several other properties served by yet another leaky septic system have already been connected to the municipal water and sewer services, resulting in reduced untreated discharges to the harbour. (46)

The Town of Woodstock, NB, agreed in 1997 to build a test plant in order to test an innovative biological water treatment process. The town's water supply is afflicted with high manganese levels, which combines with the chlorine in the treated water and results in brownish stains to fixtures, dishwashers and clothing. If the town decides to proceed with system based on the test results, the overall cost would be $670 000, including the $26 000 cost of the pilot plant. (47)

Small New Brunswick communities like the Village of Salisbury must weigh new developments carefully in light of available sewage treatment capacity. The Irving Oil company approached the village council to discuss a proposal to channel sewage from a new truck stop into the municipal sewer system. At a glance, the Village East sewer lagoons could easily accommodate sewage from the Irving Big Stop, provided output does not exceed the company's estimate of 30,000 litres per day. However, village councillors must estimate how much more commercial development this could lead to, as the municipality might be asked to handle more sewage in the future. (48)

Provincial and territorial governments are exploring new models for the management of their water and wastewater programs; the changes that may result from such examination will eventually affect individuals across the country. In Nova Scotia, rainwater cistern systems endorsed by the Provincial Department of Health have been used successfully for some time. The Centre for Water Resources Studies (CWRS) has provided the technical support for the development of this program. In wastewater management, the Nova Scotia Environment Department is proposing that home and subdivision owners be allowed to have their on-site sewage disposal systems designed by private engineering firms rather than the province. The proposal is currently out for public comment and consultation. Critics claim that this is a move to privatize the department and that the consumer will end up paying more. But the Environment Department emphasizes that the consumer will continue to have the option of using the province's design services or a private firm. The department will continue to inspect and approve each system regardless of who designs them. (49) Such a move may be to the benefit of the individual, as it may allow more innovation in on-site systems to occur.

With respect to community wastewater systems, the Town of Lunenberg, NS is exploring treatment options. Lunenburg Harbour receives approximately 2,250,000 litres of untreated sewage every day - the combined waste of 2,599 residents and 187 businesses. Sewage treatment in Lunenburg has been discussed for decades. In 1966, a study suggested a treatment plant would cost $679,000. In 1997, the price to clean up the harbour has grown. It will cost an estimated $5 million, a price that will require homeowners to pay $200 a year, even with government funding, to have a plant built and maintained. Sewer rates in 1997 were $42.87, a price that provides simply an underground collection system and outfall pipes that dump the raw sewage into the harbour. (50)

Water quality is excellent in certain Nova Scotia towns such as Amherst: Amherst was awarded third prize in 1997 for the fine taste of its water in a Canada-wide competition sponsored by the Canadian Water Resources Association. Yet other communities have cause for concern about the deteriorating quality of their drinking water sources. In 1997, water taken from wells just metres from the Sydney, NS, landfill showed trace levels of pollutants, but it still met all applicable guidelines. The Cape Breton Regional Municipality indicated that preliminary findings from a leachate study showed some changes occurring in the water, but it was still safe to drink. However, it was clear that the water is being influenced by the landfill site. The initial findings, which were later confirmed by a second study, showed trace amounts of contamination by sodium, calcium, chloroforms, manganese, ammonia, tin, heavy metals, barium and hydrocarbons. The water continues to meet the Canadian Drinking Water Quality Guidelines, but residents are cautious: in 1996, the municipality warned residents of six homes to stop drinking their water until tests could be performed. The study findings were to be assessed by the provincial Environment Department for it to consider lifting the ban on drinking the water. (51)

The entire population of Prince Edward Island relies on ground water for all of their needs. Although the water quality remains generally good in the province, depletion and contamination of aquifers from agricultural operations and from waste disposal site plumes are an ongoing concern. Some 18 per cent of the wells on Prince Edward Island are contaminated with pesticides.

Provincial environment studies have discovered that close to 1% of the province's residents drink water containing an unacceptable level of nitrates. Between 1 and 2% of domestic wells have nitrate levels exceeding Health Canada's acceptable guideline of 10 mg/L. At least half of all Islanders get their drinking water from domestic wells, meaning that there may be more than 1% of the population which is likely drinking water with nitrate levels exceeding national guidelines. Nitrate levels have been rising steadily over the last 20 to 30 years in the province. Some areas with intense cultivation on the island have unacceptable nitrate levels in 6 to 7% of domestic wells. Levels are also creeping up in surface water as a result of cultivation, heavy use of fertilizer, and manure seeping into the water. The increase in nitrate levels is characterized by the province as a serious issue, but not a crisis. (52)

In Stratford, PE, the town's central sewage treatment facility was operating at 105% of its design capacity, limiting the prospects for growth in Stratford. The overloaded sewer system was slated to receive an upgrade with funds from federal and provincial infrastructure grants. Expanding the capacity of Stratford's sewer service was considered a key to allow the town to meet its potential for economic development. (53)

In the recent past, some Murray River, PE, residents were flushing their waste directly into the river. This Kings County community was heavily criticized when it became known that about 20 residents were flushing waste directly into the river. Public anger was further provoked by the community's repeated rejection of proposals to install a sewerage system. In spite of the government funding made available for the project, and in spite of mounting public pressure to stop those residents who were flushing directly into the river, community officials could not muster the support necessary to commit to a central sewer system. Eventually, the province's Environment Minister imposed a deadline: violators had a year to install septic tanks or face penalties under the province's environmental regulations. As a result, individual and community septic tanks were installed in a few dozen homes to curb the pollution and bacterial levels in the water surrounding the village. (54)

The province of Newfoundland is home to a host of water quality related challenges. There are relatively few good quality surface water sources in the province. Many surface waters which rise in conifer/peat areas are dark in colour, contaminated by natural organic compounds including tannins. In some areas, there is a reliance on rainwater to fulfil domestic water requirements.

The capital city of Newfoundland, St. John's has tried to get a 10-year commitment from the federal and provincial governments for the $35 million first phase of the St. John's Harbour cleanup. The first phase would be a small step in the estimated 20-year, $150 -million St. John's Harbour cleanup. The city received $4.5 million under the 1997 Infrastructure Works program extension to begin the harbour clean-up. The first stage will begin centralization of the sewage flows, screening and possibly disinfection of the sewage entering the harbour from two streets. Diffusers will be added to harbour outfalls. Reducing the amount of sewage entering the harbour marks a new respect and recognition of the water environment. (55)

Conception Bay South is a Newfoundland town which has experienced a range of water related challenges. Development groups have been striving to create local employment in such areas as aquaculture, recreational trout and salmon fishing and trailer parks. While these have shown potential, they require a dependable supply of fresh water to maintain long-term jobs. Yet much of the fresh water supply is being polluted by residential sewage systems such as storm drains, and the disposal of household cleaning chemicals. (56) Conception Bay South, together with the town of Paradise agreed to jointly fund a study to explore alternatives to the way their raw sewage is treated. As the system approached full capacity, residents began to complain frequently of nauseating odours and noxious fumes related to the sewage system. The study report will address environmental implications, engineering considerations, physical constraints and cost-effectiveness. A preliminary design of the best alternative will also be included. Only 45% of the Conception Bay South is currently serviced with water and sewer. The harbour clean-up has been a prominent issue with local candidates for Parliament in the 1997 federal election, some of whom are calling for greater federal leadership in the initiative. (57)(58)

*The North*

The North is an Arctic desert with low precipitation. Reliable seasonal flows are relatively low in northern basins where freezing reduces flows significantly in the winter months. Many communities have difficulty getting dependable supplies of safe drinking water, drawing from lakes, rivers and constructed reservoirs below freezing depth.

These physical problems, combined with geographic isolation, small community size, high capital and operating costs and lack of technical back-up make water efficiency a key requirement in northern communities. Trucked systems are a cost-effective alternative to the high capital cost of buried, insulated, and heated recirculating or heat-traced water piping systems, and insulated wastewater collection piping systems constructed in permafrost, rock or low density areas. Truck fill stations are usually located centrally in the community, being supplied from a piped water system from the closest suitable lake or river.

Trucked water and sewage disposal systems permit rapid implementation at lower initial capital cost. They provide increased employment opportunities, using low-level technology familiar to local work forces. The main concern arising from community truck haul services is the long-term operational cost, which has risen significantly in the last few years, resulting in initiatives to demonstrate the efficacy of wastewater reuse and recycling in both Arctic and Sub Arctic communities.

## 2.4 Summary

It is clear from the examples in this section that water and wastewater problems exist coast to coast, and from north to south, in Canada. There are few communities that might not benefit from application of one or more of the technologies discussed in this report. Problems identified in this section include, in no particular order:

- increasing demands on water and wastewater infrastructue as a result of increasing population and population shifts
- water-poor regions with low precipitation
- limited capacity of existing surface and groundwater sources
- contamination of surface and groundwater sources, which limit their use for water supply, recreational, and other uses
- isolated communities with limited water and wastewater facilities
- groundwaters with excessive concentrations of naturally occurring chemicals that include salts and arsenic
- limited capacity of existing infastructure, including water transmission, treatment, and distribution systems, and wastewater collection and treatment systems
- limited assimilative capacity of receiving waters, and more stringent wastewater effluent standards
- inadequate or malfunctioning on-site sewage disposal systems
- wells contaminated by road salt, sewage, or other sources
- municipal water supplies whose water quality is known to exceed recommended limits for chemical contaminants
- surface and groundwaters contaminated by agricultural and industrial chemicals and organics.

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# SECTION 3

# INNOVATIVE ON-SITE WATER AND WASTEWATER SYSTEMS

## 3.1 Overview

### 3.1.1 Introduction

This section considers three innovative water and wastewater technologies that have been or might be used in single or multiple unit residential buildings.

These technologies

- residential water conservation
- rainwater cistern systems
- wastewater recycling and reuse

may be used alone or in combination to provide cost-effective alternatives to conventional services.

The emphasis of this section is mainly on wastewater recycling and reuse, because residential water conservation and rainwater cistern systems are more widely used and accepted, and have been more completely documented.

Section 3.2 presents case studies of innovative on-site water and wastewater systems. Section 3.3 includes treatment components or systems that have been used, or have the potential for use, for wastewater recycling or reuse in an on-site system.

#### 3.1.1.1 Residential Water Conservation

Residential water conservation has been increasingly embraced by water managers and water users. It has become an important part of the water demand management strategies of many Canadian municipal utilities. (1) It has been accepted by consumers of water who are motivated by an environmental ethic and/or the prospect of cost savings. It has also been advocated, and is sometimes used, where on-site services are involved, to reduce demands where well supplies are limited, or to reduce hydraulic loads on wastewater disposal systems.

#### 3.1.1.2 Rainwater Cistern Systems

Rainwater cistern systems (RWCS) have provided an alternative water source in situations where central services are not available, or where the quality or quantity of groundwater is inadequate (2). The best documented example is the island of Bermuda, which for 300 years has relied on RWCS as the primary source of residential water supply. (3)

In Nova Scotia traditional applications included lighthouses that were located on rock, and often on islands, and in areas of the province where gypsum deposits or saltwater intrusion made groundwater unusable. More recent examples include situations where RWCS have been installed to replace wells that have been contaminated by road salt. (2)

The Centre for Water Resources Studies (CWRS) at DalTech assisted the Nova Scotia Department of Health in development of guidelines for use of rainwater for domestic purposes (4), which deal with system sizing, treatment, and operation and maintenance of RWCS. A computer program for sizing of RWCS, developed by CWRS for departments of the Nova Scotia government, is included in WATERSAVE, a program developed for CMHC to assist in planning and design of on-site systems that include RWCS, conservation, and wastewater recycling (5).

A RWCS is the sole source of water for the Toronto Healthy House, which is described in Section 3.2.

Some Canadian communities have recognized that use of rainwater for irrigation can reduce demands on the public potable water supply, and reduce stormwater flows. The City of Toronto has implemented a downspout disconnection program that encourages residents to disconnect downspouts and gather rainwater in a rainbarrel, pond, or cistern. Since 1993 the city has helped to disconnect downspouts from 9,000 of the 130,000 homes in Toronto. (6)

Wilson (8) reviews rainwater harvesting in the United States, including pros and cons of rainwater use, system components and design, and costs.

#### 3.1.1.3 Wastewater Reuse and Recycling

Residential wastewater may be described as black water or grey water, or a mixture of the two. *Black water* originates from a toilet, urinal, or bidet. *Greywater*, which includes wastewater from all other sources, may be described as light grey, e.g. from a bathroom sink or shower, or dark grey, e.g., from a kitchen sink.

Wastewater reuse and recycling were defined and discussed in Section 1.3. Either grey water or blackwater or both may be recycled and reused.

The case studies introduced in Section 3.2 include examples of both wastewater recycling and reuse.

### 3.1.2 Effects of Water Conservation, Recycling, and Reuse

Figure 3.1 compares, for a typical dwelling, the relative effects on potable water use and wastewater discharge (to a sewer or on-site disposal system), of:

a. a conventional plumbing system without water conservation
b. a conventional plumbing system with water conservation
c. wastewater reuse
d. wastewater recycling.

In considering Figure 3.1 it can be noted that:

- Water conservation (Figure 3.1.b) significantly reduces both water demands and wastewater flows.
- In the situation assumed here (Figure 3.1.c) reuse can further reduce the water demand and sewage flow by one-half.

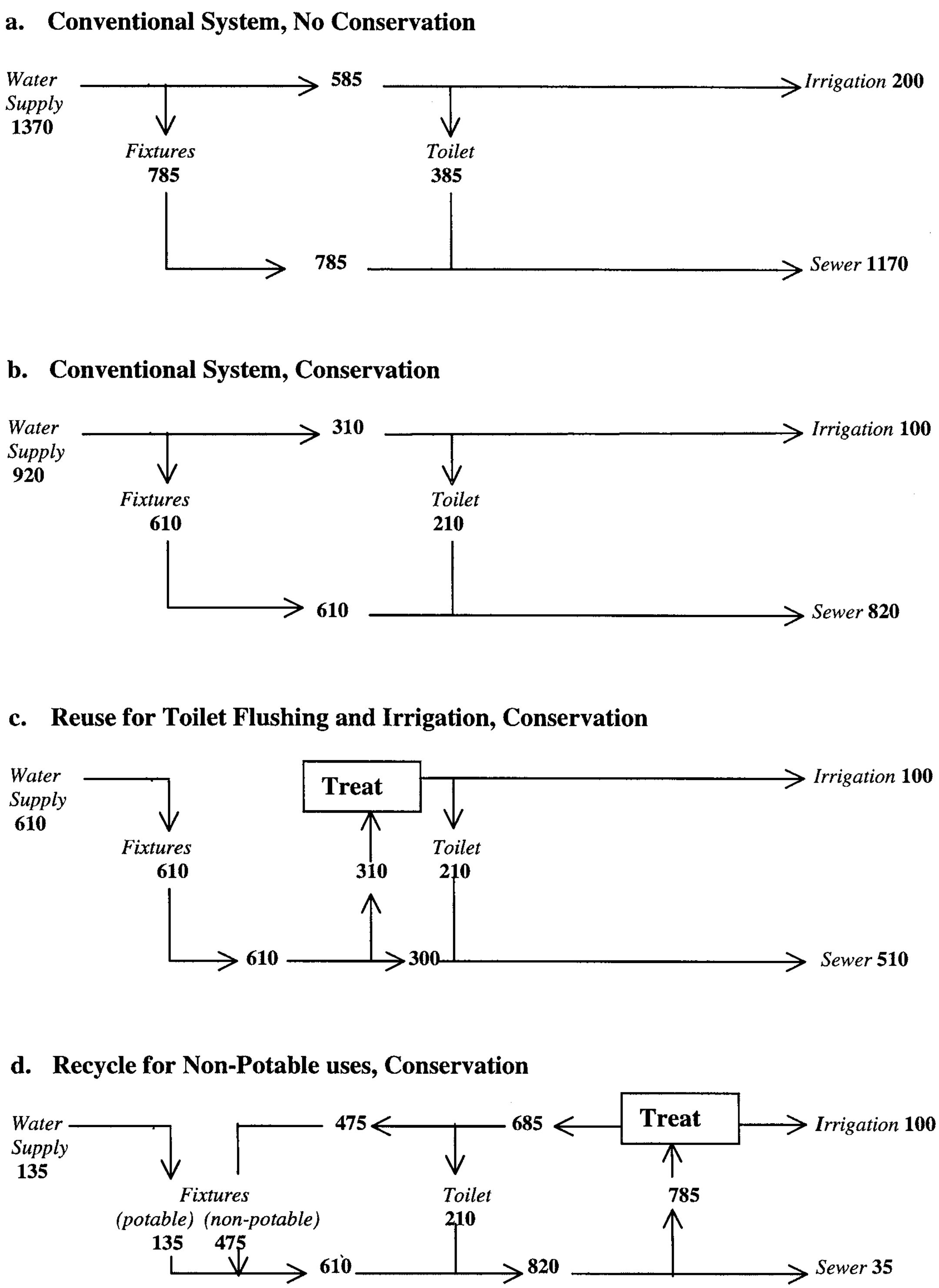


**Figure 3.1 Effects of Water Conservation, Reuse and Recycling in a Single Family Residence (L/day)**

- With complete wastewater recycling (Figure 3.1.d) the external water demand is reduced to that required to supply potable uses only, and water demand and wastewater flows are less than 10% of those required by a conventional system.
- Reduced water demand may make a rainwater cistern system a feasible water source in areas of low rainfall.
- The non-potable portion of the water supply might be met from another non-potable source such as stormwater.
- If the quantity of wastewater is significantly reduced, and the quality significantly improved by treatment, options for effluent disposal are greatly expanded.

### 3.2 Case Studies of Innovative Residential Water and Wastewater Systems

This section introduces 17 case studies that illustrate applications—in residential buildings—of the technologies that have been discussed above.

Most of the case studies deal specifically with residential wastewater reuse and recycling. Water conservation is included in many of these systems and rainwater cisterns are included in some; other examples of these technologies are provided in the references cited in Section 3.1.

The case studies introduced here are more fully described in Appendices A and C. The amount of detail in these case studies has depended on information available from published sources and direct contacts.

1) The Toronto Healthy House is a duplex dwelling in downtown Toronto, which is independent of municipal services and includes a rainwater cistern system, water conservation, and recycling of grey water and black water for non-potable uses (Appendix A, C).
2) Up to 7 single family homes in the Northwest Territories will recycle black water and grey water for all non-potable uses, using systems based on the technology in 1) (Appendix A, C).
3) Quayside Village is an 20-unit Cooperative Housing Project, in North Vancouver, that will be reuse grey water for toilet flushing, using a system based on the technology in 1) (Appendix C).
4) A demonstration Healthy House using the technology developed for 1) will be installed in 1998 by the Mohawks of the Bay of Quinte, Ontario (Appendix C).
5) The First Nations tribal councils will install 5 demonstration systems in northern Ontario, based on the technology in 1). These systems will be pre-assembled and delivered in container-based units (Appendix C).
6) The Conservation Co-op is an apartment building in Ottawa, in which greywater is reused for toilet flushing (Appendix A, C).
7) All wastewater from a provincial government office building in Sooke, British Columbia, is re-cycled for toilet flushing. The same technology has been applied in other situations that include systems serving 2 long-range radar sites in the eastern Arctic (Appendix A, C).
8) An installation at a Corrections Canada facility in Alberta recycles black water for all except potable use and fire protection (Appendix C).
9) Two low density commercial/office buildings at Friday Harbour, Washington, recycle black water and grey water for toilet flushing and landscape irrigation (Appendix A, C).
10) Eight hundred and eighty-eight units in an apartment complex in Japan recycle blackwater and greywater for toilet flushing and exterior uses (Appendix A).

11) Six homes in Canberra, Australia, recycle black water and grey water for toilet flushing and irrigation (Appendix A).
12) A single family home in Tucson, Arizona, includes water-conserving fixtures, and uses rainwater and recycled grey water for landscape irrigation (Appendix A).
13) A single family home in Phoenix, Arizona, includes water-conserving fixtures, and uses rainwater and recycled grey water for landscape irrigation (Appendix A).
14) A experimental system installed in two single family homes in Madison, Wisconsin, reused grey water for toilet flushing (Appendix A).
15) A student residence at the Campus Centre for Appropriate Technology in California reuses grey water to irrigate an organic herb garden (Appendix A).
16) A renovated dwelling in the Municipality of Aalborg, Denmark employs water conservation, grey water recycling, and a rainwater collection system (Appendix A).
17) A greywater recycling system was recently installed in a 23-student residence at Linacre College, Oxford University (Appendix A).

Systems like those in 1), 7), 8), 9), and 10) are permanent installations. Most of the others are demonstration systems that are intended to be permanent installations, subject to long term performance evaluation and possible modifications or replacement.

## 3.3 Water and Wastewater Treatment

### 3.3.1. Treatment Requirements

Typical water use in a four-person single-family residence might be, in L/day (5):

| | No Conservation | Conservation |
|---|---|---|
| Kitchen sink | 85 | 85 |
| Bathroom sink | 55 | 50 |
| Bath/shower | 350 | 240 |
| Dishwasher | 35 | 25 |
| Clothes washing | 260 | 210 |
| Toilet flushing | 385 | 210 |
| Irrigation | 200 | 100 |
| Total | 1370 | 920 |

The water quality requirements for each of these uses, and the quality of the source that is treated, will determine the nature and degree of treatment.

Potable water for drinking and associated uses obviously requires water of the highest bacteriological, chemical, and aesthetic quality, supplied from a municipal system, a well, or a rainwater cistern system. The minimum quality requirement for an external water source for potable use is probably that adopted for the Toronto Healthy House (Section 3.2), where treated rainwater from roof and yard surfaces is supplied to kitchen and bathroom sinks.

Treatment requirements for rainwater vary. Requirements in Canada, Bermuda, the United States, and the United Kingdom are summarized in references (2), (3), (7), (8) and (9) respectively. In Bermuda, where rainwater is collected from roofs that are painted and carefully maintained, treatment is not required. In Nova Scotia treatment is not required, but disinfection is recommended as a precautionary measure. In heavily urbanized areas atmospheric deposition may contribute chemical contaminants. In the Toronto Healthy House treatment by dual filtration and disinfection is provided for rainwater collected from the roof and yard surfaces.

Water quality requirements for reused or recycled water have been based on standards developed for surface water, swimming water, or potable water quality, depending on the application. Lower standards have been applied for toilet flushing and irrigation of crops not intended for consumption; highest standards have been used for household uses such as shower or laundry, and for consumable crops.

Wastewater treatment may depend on the type of wastewater being treated (greywater and/or black water) and the use to be made of the reused or recycled wastewater. Some systems have been constructed entirely on-site; others have incorporated proprietary elements in site-constructed systems; some involve adaptation and elaboration of a commercially available system to a particular application. Many of the systems considered here have involved customized site-specific design, but there is evidence of a market, and an industry response, that will in the future lead to production of standardized treatment systems aimed at specific applications.

Greywater treatment systems commonly include a strainer, sometimes preceded by a settling/flow balancing tank; these are intended to remove solid particles, hair, and grease. Further treatment has been provided by a sand filter, and/or biological treatment followed by membrane filtration.

Treatment of blackwater has included aerobic biological treatment, in some cases preceded by a septic tank. The biological treatment may be followed by one or more filtration steps.

Disinfection is incorporated in most systems.

### 3.3.2 Treatment Processes for Residential Recycling and Reuse

This section introduces 15 treatment components or systems that have been used, or appear to have the potential for use, for wastewater recycling and reuse in a residential system.

The information provided here complements the case studies in Section 3.2, by providing details about treatment processes used in some of the case study systems introduced in that section. Some of these components or systems are applicable at the scale of single unit dwellings. Other, more complex systems, may be applicable only for multiple unit residential systems. Some systems are applicable for grey water only; others require black water for effective biological treatment.

*System Components*
1. Septic Tank
2. Clivus Multrum Greywater Filter
3. Waterloo Biofilter
4. Polishing Filter
5. Ultraviolet disinfection
6. Ozone disinfection and oxidation

*Complete Systems*
7. AtlasCan
8. Biogreenp
9. Biokreisel
10. CleanFlush
11. Cycle-Let
12. Hydroxyl
13. Rotordisk
14. Aquatex
15. Proteus

These components and systems are described in Appendices B and C. Appendix B provides details about most items; Appendix C includes information about items 14 and 15, and supplements information about items 10 through 12.

All of the components or systems discussed here are proprietary, with the exception of the septic tank, which is a component of most of the case study systems in Section 3.2.

### 3.4 Summary

This section considers three technologies that may be used, alone or in combination, to provide alternatives to conventional water and wastewater services for single or multiple unit residential buildings:

- water conservation
- rainwater cistern systems, and
- wastewater recycling and reuse.

An example illustrates that a household's water supply might be reduced from 1370 L/day to 820 L/day by conservation, to 610 L/day by conservation plus reuse for toilet flushing and irrigation, or to 135 L/day by conservation and recycling for all non-potable uses, with corresponding reductions in wastewater flows. Reduced water demand may make rainwater an alternative source in regions where rainfall cannot supply normal demands.

Residential water conservation is an important part of the water demand management strategies of many Canadian municipalities.

Examples are provided of historic and current uses of rainwater systems as a potable source, in Nova Scotia, the Toronto Healthy House, and Bermuda. Many Canadian communities encourage use of rainwater for irrigation as a water conservation measure.

Residential recycling and reuse have been applied for non-potable interior uses and for irrigation.

Seventeen case studies of innovative residential water and wastewater systems, which are more fully described in Appendices A and C, are introduced. Most deal with wastewater recycling and reuse; most systems also include water conservation and some include rainwater cistern systems.

Treatment requirements for rainwater have varied from none to filtration and disinfection, depending on the intended use and the possibility of contamination of the rainwater before it is used.

Wastewater treatment for recycling and reuse may depend on whether greywater or black water is involved. Fifteen wastewater treatment components or systems that have been used, or have the potential for use, for wastewater recycling or reuse in a residential system, are introduced here and more fully described in Appendices B and C.

### 3.5 References

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4. Nova Scotia Department of Health, 1992, "The Use of RAINWATER For Domestic Purposes in Nova Scotia", 9 pp.

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# SECTION 4

# MUNICIPAL INNOVATIONS IN WATER AND WASTEWATER MANAGEMENT

This section provides examples of initiatives undertaken by municipalities, in Canada and internationally, that have faced and addressed some of the problems identified in Section 2. The initiatives summarized here involve both municipal water conservation and municipal wastewater reuse.

## 4.1 Municipal Water Conservation Initiatives

Canadian municipal water utilities have undertaken significant water conservation initiatives, which have been intended to reduce or defer capital and operating costs of water and wastewater management.

A 1996 study conducted for the Intergovernmental Committee on Urban and Regional Research (1) documented Canadian municipal water conservation initiatives. Responses to an initial survey included 65 municipalities, of all sizes, representing approximately half of Canadians served by municipal systems. Sixty-three of these communities have undertaken water conservation initiatives.

Twelve of these municipalities responded to a request for more detailed information. Summarized here are the reasons why water conservation initiatives were undertaken by these municipalities, and the nature of the initiatives that were adopted.

Table 1 summarizes, for each of the 12 municipalities, the problems that they have addressed in formulation of their water conservation initiatives. Table 2 summarizes water conservation initiatives that have been adopted or are under consideration by these municipalities.

The problems addressed, and the solutions adopted, by these 12 municipalities reflect circumstances unique to each municipality. But it is clear from these examples that significant water and wastewater problems face Canadian municipalities, and that water conservation can be a significant instrument addressing these problems.

## 4.2 Municipal Wastewater Reuse

Presented here are examples of municipal wastewater reuse from around the world. These examples have been selected to illustrate reasons why wastewater reuse has been adopted, and how the wastewater has been used. The information provided here is drawn from many recent and complete references; the reader is referred to these sources for detailed information.

## Table 1

## OBJECTIVES OF WATER CONSERVATION INITIATIVES UNDERTAKEN BY 12 CANADIAN MUNICIPALITIES

| Municipality | Objectives of Water Conservation Initiatives |
|---|---|
| Barrie, Ontario | reduce average water demands in order to defer an increase in the capacity of its wastewater treatment plant, and to defer construction of a new water treatment plant. |
| Edmonton, Alberta | reduce water demands resulting from population growth, in order to defer capital expenditures for water treatment plant expansion. |
| Kelowna, British Columbia | reduce average water demand in order to reduce anticipated capital and operating costs of water and wastewater systems. |
| London, Ontario | reduce average and peak water demands in order to meet long-term demand objectives and avoid or defer capital costs. |
| New Glasgow, Nova Scotia | defer capital costs of additional water treatment, and to avoid the need to develop a new water supply. |
| Ottawa-Carleton, Ontario | reduce maximum daily demands, recognizing that if current growth in maximum daily demand was maintained, consumption would exceed current production capacity by the year 2006 and would involve a total of nearly $300 million in capital projects over the period 1998 to 2011. |
| Rosemere. Quebec | reduce average and peak demands in order to reduce capital and operating costs for both water and wastewater. |
| City Of Toronto, Ontario | reduce or defer capital costs, and reduce operating costs, of both water and wastewater management, and to reduce energy consumption in the treatment and delivery of water, collection and treatment of wastewater, and in wasteful consumption of delivered water. |
| Vancouver, British Columbia | reduce average and peak demands, in order to avoid or defer capital costs for water storage and delivery facilities, and costs for purchase of water and disposal of wastewater. |
| Vernon, British Columbia | reduce peak demands in order to avoid capital and operating expenditures on water supply. |
| Winnipeg, Manitoba | reduce average demand in order to defer or avoid capital expenditures for a second 160-km aqueduct, or new source development. |
| Yellowknife, NWT | avoid or defer capital costs to reduce operating costs for water supply, to increase the capacity of an already overloaded wastewater lagoon, and to reduce effects of water main leakage on street pavements. |

**Table 2**

**Water Efficiency Initiatives Employed by Case Study Municipalities**

| **Municipality** | **Initiatives** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | New Meters | Infrastructure | Retrofit | Low-flow new | Rates | Rate Structure | Outdoor Regs. | Public Awareness | Collaborations | Other |
| | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) |
| Barrie | | | • | • | • | • | • | • | • | |
| Edmonton | | • | • | | • | | | • | | (1) |
| Kelona | • | | | | • | • | | • | • | |
| London | | • | • | • | • | • | • | • | • | |
| New Glasgow | • | • | • | | • | • | | • | • | |
| Ottawa-Carleton | | • | • | • | | | | • | • | (2) |
| Rosemere | | • | • | | • | • | • | • | | |
| Toronto | • | • | • | • | | | | • | • | (3) |
| City of Vancouver | | | • | • | • | • | • | • | • | |
| Vernon | • | • | • | • | • | • | • | • | • | |
| Winnipeg | | • | • | | • | • | | • | • | (4) |
| Yellowknife | | • | | | • | | | • | • | |

(a) New residential metering
(b) Infrastructure improvements
(c) Low-Flow fixture retrofit
(d) Low-flow in new construction
(e) Increase water rates
(f) Change water rate structure
(g) Regulate outdoor use
(h) Public awareness
(i) Collaborations
(j) Other

(1) Industrial water audits
(2) Pilot audit of large volume users; Pilot water treatment modifications.
(3) Water conservation plans required for new development; home water audits.
(4) Computer data base for program planning. Exploring industrial programs.

### 4.2.1 **Australia** (5) (6)

Water problems in Australia originate from low rainfall (80 percent of the country has a rainfall less than 600 mm per year), uneven distribution of runoff, and increasing water demands that accompany increasing population growth. Examples of water reuse include:

- The Earing Power Station in New South Wales will eventually provide up to 95% of its fresh water requirements by reuse of treated wastewater; a backup connection to the public supply will be retained. The water saved will be equivalent to the water requirements of 4000 homes. The power station will save the cost of purchased potable water, and the cost of demineralized water treatment is less because dissolved solids in the reclaimed wastewater are lower than those in the public supply.
- The Taronga Park Zoo in Sydney will recycle treated stormwater and wastewater, which will reduce the cost of purchasing potable water and of upgrading wastewater treatment to eliminate current pollution of Sydney Harbour.
- Primary treated wastewater from the city of Perth is being renovated and reused for cooling water and industrial use in a demonstration project in the Kwinana region, where demand is increasing and limited additional groundwater supplies may limit industrial development. Advantages are reduced water demand and wastewater volume.
- The Rouse Hill area of Sydney is expected to absorb much of that city's growth over the next 30 years: 9,400 ha will be developed to accommodate 235,000 persons and 1,400 ha of development. This is the first new urban development in Australia to provide all new homes with a dual water supply. Recycled water will be used for landscape irrigation, car washing, toilets, and other non-potable uses. The recycle system includes a tertiary treatment plant, 2 reservoirs, and 34 km of recycled water mains, which are sized for fire demand. Advantages of this system include an expected 40% reduction in water supply and wastewater, reduced size of the potable water system, and stream water quality that is as good as or better than pre-development quality.

### 4.2.2 **Belgium** (7)

The potable water source for the western Flemish coastal plain is an unconfined aquifer under the dune belt, which has reached its capacity; additional extraction would lead to groundwater intrusion. A feasibility study demonstrated that artificial recharge using both recycled wastewater and surface water from the polder area—after treatment by membrane filtration and reverse osmosis—was economically acceptable.

### 4.2.3 Canada

***Vernon, British Columbia*** (8) (9)

The city of Vernon, located at the northern end of the Okanagan Valley in south-central British Colombia, lies in semi-arid area in which water resources must be protected and wastewater treatment must be compatible with the environmentally sensitive designation for the area. For the past 20 years, Vernon has beneficially reused its treated wastewater on agricultural, silvicultural, and recreational lands. The program reclaims 100% of the wastewater after secondary treatment, chlorination, storage, chlorination again and finally pumping to irrigation sites in summer months.

The current population served by Vernon's sewage collection system is 32,000, with a projected population of about 70,000 in 15 years. Planning for this expansion is currently underway. A further reuse for the treated wastewater currently being examined is residential irrigation in new construction. With half of all residential water in the Okanagan being used for outside irrigation, the concept is to provide a second pipeline to each new home which would provide the highly treated reclaimed wastewater. Draft regulations have been prepared by the Provincial Ministry of Environment, Lands and Parks, to permit residential reuse based on requirements for treatment, quality and monitoring. These requirements are currently met by the City's program.

***River Hebert, Nova Scotia*** (10) (11)

The community of River Hebert is the site of a project intended to demonstrate the reuse of effluent from a wastewater treatment lagoon for wetlands that provide both a refuge for wildlife and tertiary effluent treatment. The project was carried out by Ducks Unlimited Canada with the support and cooperation of many municipal, provincial, federal, and private agencies. The project includes two wetlands—a 15.4 ac natural marsh and a 4.5 ac "highly engineered" wetland. Both wetlands are used by naturalist groups and by an area dog club for training and trials, dykes are used extensively for walking, and the marsh is used for skating in the winter. Effluent was discharged to the engineered wetland from June, 1996 to June, 1998, and tertiary treatment performance and wildfowl numbers and species were monitored over this period. The wetland reduced fecal coliform, suspended solids, BOD and phosphorus by up to 99 percent. During late winter, when lagoon effluent quality worsened, removals were lower but still significant. Recorded numbers of birds and muskrats increased substantially. Effluent is now discharged to the natural marsh, which is currently being monitored for comparison with the engineered system.

### 4.2.4 France (12)

Wastewater reuse in France is limited to irrigation. A survey by the Ministry of Health indicated that reuse is practiced at approximately 20 sites in that country. Only 4 or 5 sites use category A water, which is required for golf courses or sports fields. About 10 other agricultural projects are planned, including one that will require Class A water because the maize crop must be manually detasseled.

### 4.2.5 Japan (13) (14) (15) (16)

Although average annual precipitation in Japan (1,730 mm) is about twice the world average, the per capita supply of fresh water is low because of small land space and high population density. Wastewater reuse is one of the measures adopted to address potentially serious water and wastewater problems. Although reuse represents less than 1 percent of total wastewater, it is a locally important resource.

Forty-one percent of Japan's reclaimed wastewater is used for industrial purposes, and 32 percent is used for flow augmentation and environmental purposes. Irrigation accounts for only 13 percent, toilet flushing and urban non-potable uses for 8 percent.

Most recent examples of wastewater reuse have been for direct non-potable urban use, which has involved either (1) on-site reuse for toilet flushing in more than 650 large office buildings or apartment complexes, or (2) district-wide dual distribution and plumbing systems, supplied from public wastewater treatment plants.

Reuse initiatives in metropolitan Tokyo have included:

- Use of reclaimed wastewater for flushing is mandated in all new buildings with floor area greater than 30,000 $m^2$.
- Beginning in 1951, sand filtered secondary effluent has been used by paper mills, because of deterioration in river water quality and declining ground water levels.
- Other uses have included washing of passenger trains, and plant water at a refuse incineration plant.
- In 1964 a stream restoration project added reclaimed wastewater to a dried up irrigation channel to improve the local environment.
- A dual distribution system—which by 1994 provided reclaimed wastewater for toilet flushing in nineteen high-rise buildings in the Shinjuku district—serves a large scale redevelopment project that involved a huge increase in water consumption.

### 4.2.6 Singapore (17)

Secondary effluent from Singapore's wastewater treatment facilities is discharged to ocean outfalls. At one location the effluent was intercepted, filtered, chlorinated, and reused as the water supply to an industrial park, and for toilet flushing for some 25,000 residents in 12-storey apartment buildings.

### 4.2.7 South Africa (18)

Limited water supplies may be the most important factor that restricts South Africa's economic development in the 21st century.

- Mean annual rainfall is 483 mm, 56 percent of the world average, and varies between 50 mm and 1250 mm from west to east.
- Rainfall is highly variable, with regular extended and severe droughts.
- Mean evaporation varies from 3000 to 1150 mm, west to east.
- Groundwater supplies are very limited.
- Projected water demands will exceed supplies soon after the year 2020.
- High population growth and sustained agricultural and industrial development, and few rivers that are perennial to provide dilution capacity, pose severe pollution problems.

Against this background wastewater reuse is an obvious water management strategy. Provisions of the Water Act (1956) promote water use across the whole spectrum of planned indirect use, direct reuse, and internal recycling in industry. Examples of reuse initiatives include:

- In the late 1960's Windhoek, the capital of Namibia (then a mandate territory administered by South Africa), faced severe water shortages. In 1968, following pilot scale research, a potable reclamation plant was inaugurated. That plant has been upgraded on several occasions based on new research findings, and is currently being expanded to 21 ML/day. The project includes three equally important elements:

  - diversion of industrial and potentially toxic wastewater from the main wastewater stream
  - secondary treatment to produce an effluent of adequate and consistent quality
  - advanced treatment, which currently includes ferric chloride flocculation, dissolved air flotation, sand filtration, carbon filtration, and breakpoint chlorination.
- Potable reuse is recognized as a possibility for the Cape Town metropolitan area and the City of Port Elizabeth, and steps have been taken to segregate industrial effluents in the sewerage systems.
- Two major paper companies upgrade secondary effluent for use as process water.
- Major industries, under the pressure of limited water supplies, and with effluents upgraded to meet discharge requirements, have adopted internal recycling and intensive water conservation.
- In general irrigation using reclaimed effluent is discouraged, because in most instances more beneficial applications of this water are possible. Exceptions include irrigation of parks and sports fields where fresh water would have to be used, and at the coast where the effluent would be lost to sea.

### 4.2.8 United Kingdom

Current or anticipated water management problems in the UK include (19)

- In 1995-96, 22 percent of water customers were at risk of water shortage.
- Water demands are expected to increase: between 1995 and 2015 per-capita demand could increase by 21 percent, and if effects of climate change on irrigation use are considered could increase by 26 percent.
- Climate changes could reduce net precipitation minus rainfall, and rising sea levels could reduce available fresh groundwater.
- More rigorous surface water quality standards challenge the capabilities of wastewater treatment plants.

A total of 3.5 million new homes were built in Britain between 1972 and 1982, an estimated 4.4 million more will be required by 2016, 2.3 million to be built in the country's most drought-hit regions—the South-East and East. British water companies, which have an obligation to supply water to all customers in their areas, say that land use planners have not considered availability of water to meet the needs of this new development. The water companies have told government that new developments in dry areas should be refused, or fitted with new technology to reuse gray water. (20).

A major cruise ship terminal, which attracts 150 pleasure liners per year, opened at Dover; each ship can refill its tanks with up to 0.6 mL of water. This demand has placed enormous strain on the local water company, which was not consulted about the new development (20).

***Thames Water Utilities*** (21)

Thames Water Utilities is the largest in the UK, supplying 7.3 million customers with 1136 ML/day. The rivers Thames and Lee supply 75 percent of this demand; the remainder is supplied by groundwater.

At average river flows wastewater effluent represents 16.5 percent of the flow in the Lee, and 4.6 to 14.4 percent of flow at various abstraction points in the Thames. At minimum river flows these values increase to 81 percent in the Lee and 34 to 100 percent in the Thames.

This situation is considered to be one of planned indirect potable reuse, in that wastewater treatment has been improved to insure that abstracted water quality is appropriate to the degree of water treatment provided.

### 4.2.9 United States

#### 4.2.9.1 Arizona

Arizona reuses about 35 percent of the municipal wastewater produced in that state (15).

***Grand Canyon Village*** (15)
The first dual distribution system in the U.S. to use wastewater for the non-potable supply was built in Grand Canyon Village in 1926. Originally required to supplement a very limited groundwater supply, the system provided reclaimed wastewater for landscaping, toilet flushing in tourist accommodations, and boiler feed water for steam locomotives that serve the village. Although the water supply has been substantially increased, the reclaimed wastewater treatment and distribution system were modernised and enlarged in 1989, and 2.8 ML/d of reclaimed wastewater is now used for irrigating playing fields, toilet flushing, vehicle washing, and other construction uses as necessary. reclaimed wastewater costs $0.26/1,000 L, compared with $1.45/1000 L for potable water.

***Phoenix*** (15)(17)(22)
Phoenix supplies secondary effluent through a 58 km pipeline to a 340 ML/d reclamation plant at the Palo Verde Nuclear Power Plant, the largest cooling tower application in the U.S.

#### 4.2.9.2 California

The amount of wastewater reclaimed in California in 1996 has been estimated as 570,000 ML (23). Reclamation and reuse have been adopted to address a wide variety of problems.

Primary motives for reclamation and reuse, implied if not stated in many of the examples here, appear to be reliability of water supplies in water short areas, avoidance of the need to rely on imported supplies, and the cost of imported water. The nature of these problems is detailed in a recent article: In 1979 residents of Santa Barbara County voted against connection to the State Water Project. In 1991, after 6 years of drought, they voted to join the project. Larger cities in the County opted for small amounts of state water, which they were considered capable of using. But the small valley towns of Santa Maria and Solvang were committed to large amounts, and unexpectedly high costs that can only be recovered by increased growth or higher water rates; Santa Maria was committed to an annual state water bill of $14.5 million, and in Solsang's household water bills increased to $300 per month (24).

A study of the factors motivating establishment and continued use of large scale water reclamation facilities in California found that the most influential factors were: availability of substantial quantities of high quality effluent; opportunities to use reclamation as an alternative to treatment plant and effluent quality improvements; specific desires of local policy makers; and lack of water to supply new or growing water demands. Most motivating factors were found to have grown in influence in the past 40 years, but satisfactory cost of reclaimed wastewater declined as a motivating influence (25).

***Avalon*** (26)
The City of Avalon is the only California city that has a separate non-potable distribution system to deliver water for toilet flushing and fire protection to part of the city. Problems associated with the use of salt water led to a study to assess the feasibility of using reclaimed wastewater instead of salt water in this system. Conditions that favour reuse are the existing dual system, no interconnections with adjacent utilities, and customers who are accustomed to a non-potable source for toilet flushing.

The non-potable system serves about 1,100 connection, and anticipated non-potable demand is 2 ML/day. The capacity and condition of the current secondary plant require construction of a new 5.7 ML/day plant; the water reclamation facility would be built in concert with and adjacent to this facility.

An integral safety feature of this project would be maintenance of a significantly lower pressure in the non-potable distribution system, accompanied by an emergency response plan for an event such as a pipeline break.

A life cycle cost comparison indicated that the use of reclaimed wastewater would save the city several thousand dollars per year.

***Irvine Ranch Water District*** (15) (17) (22) (27) (28) (29) (30)
The IRWD, formed in 1964, provides water and sewer service to an 1,800 sq km area in southern Orange County. IRWD uses all of the wastewater from its reclamation plant through an intensive dual distribution system. IRWD began installation of a dual system for new construction in 1975, as a lower-cost alternative to ocean disposal. Reclaimed wastewater was 1/3 less costly than potable water from the Metropolitan Water District of Southern California. Savings became sufficiently great to justify retrofitting older parts of the city with reclaimed wastewater.

The reclamation plant produces 50 ML/d of reclaimed wastewater, which is used on over 2,400 ha of landscapes, 400 ha of agricultural fields, toilet flushing in high rise office buildings, and commercial uses. The system supplies ornamental impoundments, parks, golf courses, school grounds, common areas around condominiums, roadway mediums, and other open spaces.

Reclaimed wastewater accounts for 20 percent of water use in the district. A 1990 ordinance requires all new building over 17 m high to install a dual system for toilet flushing in areas where reclaimed wastewater is available. Use of reclaimed wastewater for toilet and urinal flushing began in 1991. In 1991 the first health department approved building in the United States to use water from a municipal reclaimed wastewater system for interior uses was put into service. In 1995 IRWD received a permit to deliver reclaimed wastewater to large lot single family homes for landscape irrigation. It is an IRWD policy that golf courses use reclaimed wastewater.

***Lake County*** (31)
A 75 km pipeline conducts treated wastewater from Lake County to the Geysers Geothermal steamfield, the world's largest developed steamfield. This will result in production of 70 MW of

electricity, of which 6 MW will be used to deliver wastewater to the site. The project provides an assured water source to recharge part of the steamfield, and provides a new method of wastwater disposal that allows lifting of a sewer hookup moratorium that has limited economic growth in several local communities.

***Livermore*** (32)
The City of Livermore, located about 40 km east of San Francisco Bay, experiences a semi-arid climate (average rainfall is 350 mm) and periodic droughts. The main source of potable water is imported through the State Water Project system. Water from a large groundwater basin that underlies the central portion of the Livermore-Anador Valley is used to supplement the water supply as needed. Water quality in the groundwater basin has degraded over time, due to high evaporation rates of urban irrigation and other recharge sources with high dissolved solids. Injection of water with low dissolved solids has been identified as a viable method to improve groundwater quality. The city also faces effluent disposal constraints, because the 64 km steel pipeline that transports treated effluent to San Francisco Bay is experiencing premature failure of the coal tar lining.

The City of Livermore has constructed a 2.8 ML/d water reclamation facility that treats wastewater to supplement the potable supply by injection into the groundwater basin. Tertiary effluent is treated by microfiltration and reverse osmosis.

***Los Angeles*** (33)
The City of Los Angeles uses local groundwater and imported water from the Mono Basin and the Metropolitan Water District of Southern California. During a period of drought in 1986-1992 these sources were not adequate to meet the needs of the city. Environmental challenges led to curtailment of exportation of water from the Mono Basin. The state Department of Natural Resources projected long term water supply shortages throughout the state. The city's Water Management Plan identified water conservation and recycling as alternatives that can meet up to 25 percent of the city's future supply.

The East Valley Water Recycling Project will use reclaimed wastewater for groundwater recharge, landscape irrigation, industrial applications, and direct injection of reclaimed wastewater for a seawater intrusion barrier. Up to 120 ML/d of tertiary treated wastewater effluent will be transported from the treatment plant to the spreading grounds; future facilities will include an additional pipeline to another basin.

***Los Angeles County*** *(17) (9) (34)*
The facilities of the Sanitation Districts of Los Angeles County include 6 water reclamation plants, with a total capacity of 722 ML/d. The district wholesales water to Los Angeles and cities throughout the county. The prime motivation for use of reclaimed wastewater is the fact that Los Angeles is essentially a desert, with a long-term average rainfall of 38 cm and no major rivers within 160 km. About two-thirds of the area's water supply is imported through 3 aqueducts that extend 320 to 800 from the area. Local groundwater supplies are very limited, and population increase in the region was predicted to increase by 40 percent between 1990 and 2010.

At each reclamation plant secondary effluent is treated by alum coagulation, chlorination, and filtration. Average distribution of reclaimed wastewater in 1996 was: groundwater recharge- 60 percent, landscape and agricultural irrigation- 22 percent, industrial process water- 9 percent, and supply to a man-made wildlife refuge- 9 percent.

The 6 reclamation plants, located high above the city, return their sludge via the trunk sewer to the water pollution control plant. Eliminating sludge handling means that the plants can be located in residential, commercial, or recreational areas without the odour or noise associated with sludge handling.

***Orange County*** (15) (35) (36) (37)
Orange County, in Fountain Valley, obtains 60 percent of its water from local aquifers, and buys the rest from the Metropolitan Water District of southern California. The population served by OCWD is expected to increase from 2 million to 3 million by 2020.

Water Factory 21, an advanced wastewater treatment facility operated by the Orange County Water District (OCWD), has been injecting reclaimed wastewater into coastal aquifers, to create a saltwater intrusion barrier, since 1976. A 57 ML/d reclamation plant treats secondary effluent from local plants.

OEWD and the County Sanitation Districts of Orange County are proposing a ground water replenishment system that by 2020 will produce 337 ML/d of reclaimed wastewater that would become part of the county's groundwater supply. This system would require half the energy required to import water to the county, reduce water discharge to the ocean by 337 ML/d, cost less or the same as imported water, and create local jobs.

Mission Viejo is a master planned, recently incorporated city in Orange County. Reclaimed wastewater is reused for landscape irrigation, including parks, schoolyards, residential greenbelts, arterial slopes, freeway corridors, and golf courses. The project's ultimate irrigation area is 770 ha.

***Salinas Valley*** (38)
The entire water supply of the Salinas Vally is currently met by groundwater pumping, which has resulted in seawater intrusion into the aquifer. The Castroville Seawater Intrusion Project, the largest application of reclaimed wastewater for irrigation in California, will provide tertiary effluent for irrigation of raw vegetable crops. The project includes a 113 ML/day treatment plant and 77 km of distribution piping.

***San Diego*** (39) (40) (41) (42)
San Diego is at the end of a system of pipelines that deliver water from Northern California and the Colorado River. San Diego has conducted years of research to determine if indirect potable reuse is a viable potable water source.

The San Diego Water Repurification Project (SDWRP) is the first in California to employ indirect potable reuse to supplement a surface water supply. Reasons for adopting wastewater reuse were:

- Concern about future water supply- 90% of the city's supply is imported, a severe shortfall is expected by 2010, and imported water from Northern California is increasingly unreliable because of increasing droughts and greater demands.
- Need for an emergency supply in the event of earthquake damage to canals and pipelines that deliver water to the area.

- Construction of a water reclamation plant is an alternative to a required upgrade of the city's wastewater treatment plant.

Wastewater effluent will undergo tertiary treatment at a 114 ML/day reclamation plant. Part of the reclaimed wastewater will be transported to a 76 ML/day advanced reclamation plant, which uses low-pressure membrane filtration, reverse osmosis, ion exchange for nitrate removal, and advanced oxidation . Water from this plant will be transported to the San Vincente Reservoir, where it will be blended with other water and stored. Reservoir water will be piped to San Diego's water treatment plant for complete treatment before distribution. The remaining reclaimed wastewater will be used for landscape irrigation and other non-potable uses.

#### 4.2.9.3 Colorado

***Colorado Springs*** (15) (22) (43)
In 1960 Colorado Springs constructed a large scale dual system for sale of tertiary treated wastewater to large scale customers such as college campuses, golf courses, and cemeteries, at about two-thirds the cost of potable water. Fire hydrants are located on the pressure lines. A total of 17 customers are currently supplied. The project was motivated by increasing demands on high quality water sources in this rapidly growing region.

***Denver*** (44) (46)
A direct potable reuse pilot project has been operating in Denver for 20 years. The plant is used to demonstrate the safety and reliability of potable reuse, to generate regulatory approval and public support for the process, as well as to provide data for implementation of a full-scale system. Although Denver has intensively studied direct potable reuse for 20 years, it has no plans to implement the practice. A reclaimed wastewater distribution system for non-potable reuse is being built around the new Denver airport.

#### 4.2.9.4 Florida (4) (57)

Although Florida is a water-rich state with annual rainfall of 1300-1500 mm, and over 7000 freshwater lakes, there are many areas in the state that are at or near the limit of available supplies. Average daily demand is 680 L/cap/d, almost twice the national average. Thirty percent of the water is consumed by households, 20 percent by industry, and 50 percent for irrigation.

The Florida legislature has established the encouragement and promotion of water conservation and reuse of reclaimed wastewater as formal state objectives. In 1996 a total of 444 domestic wastewater treatment facilities provided reclaimed wastewater for reuse, which represented nearly 40 percent of the permitted wastewater treatment capacity in the state. Reclaimed wastewater is used for the following purposes: irrigation of public access areas-40 percent; agricultural irrigation-24 percent; groundwater recharge-21 percent; industrial reuse-13 percent; other uses-2 percent.

***Arcata*** (47)
The City of Arcata reuses 8.7 ML/d of effluent from their constructed treatment wetlands in a 12.5 ha marsh that is an important bird refuge and a site for passive recreation, bird-watching and scientific study.

***Boca Raton*** (4)
During drought periods in 1989-1991 many counties in the Boca Raton region imposed restrictions on the use of potable water. Prior to restrictions consumption in Boca Raton was well over 1500 L/cap/d; water use restrictions reduced this use by 20 percent. Treated wastewater, normally pumped to an ocean outfall, was recognized as a alternative source of non-potable water for irrigation. A 10 year program, to be complete in 2001, will provide a 57 ML/d reclamation facility, which will reduce water demands and eliminate wastewater discharge to the Atlantic Ocean.

***Walt Disney World*** (48)
The Reedy Creek Improvement District (RCID) was created by the Florida legislature to provide municipal services to the Walt Disney World Resort. The RCID now makes beneficial use of all of the treated wastewater, via direct non-potable use and groundwater recharge. Current and potential use includes irrigation, fire protection, washdown of streets and sidewalks, water displays, and cooling water. Rapid infiltration basins provide beneficial recharge and have resulted in elimination of effluent discharge to Reedy Creek.

***Hillborough County*** (49)
Most of the wastewater from 4 treatment facilities, which is now discharged to Tampa Bay, is expected to be applied for beneficial uses by 2015. Reuse will include 61 percent for residential and golf course irrigation, 23 percent for wetland augmentation, and 16 percent for commercial applications. Maximizing reuse will reduce groundwater pumping by 50 ML/d. Excess reclaimed wastewater that accumulates in the wet summer season will be stored using aquifer storage-recovery wells, which will be pumped during the remainder of the year.

***Orlando*** (50)
WATER CONSERV II—owned by the City of Orlando and Orange County—is the first reuse project in Florida permitted to irrigate crops grown for human consumption with reclaimed wastewater. It is the largest water reuse project of its kind in the world. The project was born out of the necessity to stop the discharge of effluent from wastewater treatment plants into Shingle Creek. The program implemented the most cost-effective alternative, which includes irrigation of about 1800 ha of citrus and nurseries at 51 ML/d, and rapid infiltration basins that recharge the Floridan aquifer at 55 ML/d.

***Pinellas County*** (51)
Pinellas County, located on a peninsula, must import virtually all of its potable water from well fields located in adjacent inland counties, and water available from this source has been reduced. It was also necessary to find an alternative to disposal of effluent from the local 125 ML/d wastewater treatment plant, because of problems with existing deep injection wells. To reduce potable water demand and wastewater production, the County developed a master plan based on wastewater reuse for public access irrigation, and limited seasonal discharge to a local creek. Implementation of the plan involved installation of a transmission and distribution system for delivery of reclaimed water to residential users in 4 local communities.

***St. Petersburg*** (15) (17) (35) (52)
St. Petersburg operates one of the largest urban reuse systems in the world, providing a dual water supply system to more than 7000 homes and businesses. The 420 km dual system supplies 80 ML/d of

reclaimed wastewater for individual homes, condominiums, parks school grounds, golf courses, and for cooling tower makeup and supplemental fire protection.

The system was initially installed as a less costly alternative to an advanced wastewater treatment plant required for discharge into Tampa Bay and the Gulf of Mexico. It has also avoided increased demand on the city's limited potable source, a well field located 80 km from the city.

***Tampa*** (53)
Tampa receives more than 1300 mm of rainfall in a typical year, but 70 percent of this rain falls in the summer and is lost to runoff and evaporation. Periodic droughts and increased demands on the groundwater resource have prompted investigation of alternative water sources, including indirect potable wastewater reuse. A pilot plant began operation in 1986, with an associated health effects study, and regional agencies are cooperating in the Tampa Water Resource Recovery Project to examine reclaimed wastewater as a new water resource for the region.

#### 4.2.9.5 Kansas (54)

The first well-documented case of direct potable reuse occurred during a severe drought in 1952-1957, when Chanute, a town of 12,000, opened a valve that permitted mixing of treated, chlorinated secondary effluent with water behind the dam on the river. Although tap water met bacteriological standards, recirculation of reclaimed wastewater was estimated to have occurred 15 times during a five-month period, the taste, odour, and colour were unpleasant, and the water contained undesirable quantities of dissolved minerals and organic substances.

#### 4.2.9.6 Maryland

***Baltimore*** (15) (17)
One of the earliest example of large scale industrial reuse was construction in 1942 of a 7.2 km pipeline to carry 378 ML/d of chlorinated activated sludge effluent to the plant of thc Bethlehem Steel Corporation for process use. The results were significant reductions in demand on the city's limited upland water supply and its wastewater discharge to the local receiving water.

#### 4.2.7 Massachusetts

***Yarmouth*** (55)
The Town of Yarmouth decided to use a recently capped landfill site to expand a town-owned golf course. The expanded golf course requires an irrigation system, but the town's water supply is limited and cannot meet the additional demand. Effluent from the town's treatment plant, which is currently applied to a reed canary grass site for disposal, will be used for golf course irrigation, which will avoid additional demand on the water supply, and will allow the current land disposal site to be developed for other purposes.

#### 4.2.9.8 New York

***Onieda*** (55)
The Oneida Indian Nation is a federally recognized sovereign American Indian nation. The nation operates a number of resort facilities, and proposed the addition of a 40 ha golf course complex that will have a peak summer irrigation demand of 2.5 ML/day. This demand cannot be met from the potable source, and test wells indicated that groundwater was not an option. The City of Onieda agreed to a proposal that the city's wastewater treatment plant provide a water source for golf course irrigation. The nation will provide advanced treatment—filtration and disinfection—of the city's secondary effluent. Reclaimed wastewater will be produced only on an as-required basis. The nation has identified a number of other potential uses for the reclaimed wastewater, including car washing, other irrigation needs, and snow making for winter activities.

#### 4.2.9.9 Texas

***Cleburne*** (56)
Cleburne is a town of about 25,000 persons. A new power cogeneration plant, which burns natural gas to generate electricity and produce distilled water, under peak conditions requires up to 6.5 ML/d of cooling water. This water need will be met by reclaimed wastewater from a new tertiary treatment facility, that will meet the utilities need at one-half the cost of potable water.

***San Antonio*** (57)
Water needs for the city of San Antonio and surrounding communities have been met from the Edwards Aquifer. The aquifer may not be able to meet increasing future water demands. Water conservation programs have been implemented, but are not the total solution, and a Water Recycling Program has been developed. The primary goal of the program is to replace potable water use with reclaimed wastewater for irrigation by farmers, golf courses, cooling towers, and quarries. Peak flows will occur in the summer, when irrigation and cooling requirements are the greatest. The system includes additional treatment, a transmission pipeline, pumping, and storage facilities, at a total cost of $ 103.5 million.

### 4.3 Summary

This section reviews municipal innovations in water and wastewater management.

A review of municipal water conservation initiatives undertaken by Canadian communities, drawn from a recent report, presents objectives of initiatives undertaken by 12 case study municipalities, and summarizes those initiatives.

Examples of municipal wastewater recycling and reuse, from around the world, include:

- cooling water and other industrial uses
- public and private irrigation
- environmental enhancement in wetlands
- dual systems that supply irrigation, toilet flushing, fire protection and other uses
- direct potable reuse in a few systems, and
- planned indirect potable reuse from streams or aquifers supplied by reclaimed wastewater.

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# SECTION 5

# ISSUES, OBSTACLES, AND OPPORTUNITIES RELATED TO WASTEWATER RECYCLING AND REUSE

## 5.1 Introduction

Adoption and implementation of the technologies discussed here, and wastewater recycling and reuse in particular, have raised and will continue to raise issues that must be faced and addressed if these technologies are to play an effective and significant role in water and wastewater management.

The purpose of this section is to present and briefly describe issues that have been identified and faced by those who have considered or adopted wastewater recycling and reuse, and to provide appropriate reference sources to the reader who wants more complete information.

Some of the issues that are identified and discussed here apply to single building or to municipal scale systems, or to both.

## 5.2 Issues

Many of the references in this section discuss single issues, but a number of others help to provide an overview of the many issues that are of concern to those involved with wastewater reclamation and reuse. Van Riper and Gerebracht (1) provide a detailed review of recent literature related to wastewater reclamation and reuse. Reference (4) provides a review of the past, present, and future of wastewater reclamation, recycling, and reuse. An historical overview is also provided in (5).

A 1997 workshop convened by the Canadian Water and Wastewater Association (CWWA) concluded that reclamation, reuse, and recycling should be encouraged and extended for both on-site and municipal systems. Identified barriers to adoption were: lack of information for managers and politicians; regulatory barriers; liability issues associated with new technology; inertia in a system, which resists change and innovation; and separated administrations for water, wastewater, and stormwater. Research and demonstration projects, and public education, were identified as important needs.(6)

Other reports that have identified and addressed issues related to wastewater reuse include:

- A U.S. EPA report deals with the following issues: technical issues in planning reuse systems; types of reuse applications; regulations and guidelines; legal and institutional issues; funding alternatives; and public information programs. (7)
- Issues identified in the United Kingdom include the potential role of water reuse in meeting increased demands for water, and relative costs of reusing wastewater compared with costs of conventional water and wastewater systems. (8)
- Measures undertaken to overcome perceived impediments to use of reclaimed wastewater in Los Angeles County included technical obstacles, regulatory constraints, institutional barriers, economic deterrents, and public opposition. (9)

This section uses these and other references in an attempt to introduce issues associated with wastewater reuse, and to provide sources of further information.

### 5.2.1 Potable Reuse

A primary issue has been whether it is appropriate or necessary to use renovated wastewater for potable purposes.

This project did not identify any plans or proposals for use of renovated wastewater for potable use in individual buildings.

Section 4 cites examples of potable use at the municipal scale:

- world-wide examples of unplanned indirect potable reuse
- a few examples—San Diego, Ca., is one of the most recent—of planned indirect potable reuse
- three examples of direct potable reuse
  - a short-lived project to respond to an emergency situation at Chanute, Kansas in the 1950s
  - a long-term study at Denver, Co., which has not yet led to implementation proposals
  - a system at Windhoek, Nambia, that has operated since 1968.

In 1977 Shuval (10) identified concerns about potable reuse that appear to still be relevant. He pointed out that conventional drinking water standards were based on the assumptions that water would be drawn from groundwater or a protected surface source, and that a limited number of chemical parameters would be involved, but that these assumptions are rarely true for today's surface waters. He argued that most governments require the full toxicological evaluation of any new drug or food additive, and that requirements for evaluation of wastewater with its many and complex unknowns should be at least as rigorous, and proposed that epidemiological studies be conducted in situations where unplanned potable reuse already exists. Shuval pointed out that although unplanned indirect potable reuse might involve greater risk than planned direct potable reuse, those who propose and implement planned direct potable reuse must carry the responsibility of any adverse health effects, even if it can be shown that communities consuming polluted surface water may be exposed to equal or greater risks.

Asano and Tchobanoglous reviewed examples of unplanned and planned indirect potable reuse, and asked whether direct (pipe-to-pipe) reuse of "repurified" wastewater should be accepted. (11)

Okun (12) responded that the existence of examples of unplanned potable reuse should not be a basis for extending the practice, given recognized health risks from synthetic organic chemicals, disinfection by-products, and microbial contaminants such as cryptosporidium. He stated that because technology exists to make almost any water safe to drink does not mean that potable use is necessary, given that non-potable reuse has the potential for saving as much freshwater as does potable reuse. He cited 1976 U.S. EPA regulations that stated: "Because of human frailities associated with protection, priority should be given to selection of the purest source. Polluted sources should not be used unless other sources are not economically available.....", and pointed out that use of reclaimed wastwater for potable uses involved health risks from long-term ingestion of trace chemical contaminants, which would not be a problem with non-potable uses.

Asano and Tchobanoglous answered that they did not disagree with Okun's preference for non-potable use, but pointed out that the quality of natural water sources is not necessarily better than that of reclaimed wastewater (13). The San Diego project is demonstrating the ability of a wastewater treatment train to produce water of a quality better than that of the city's current raw water supply. (14)

A committee formed in 1996 by the National Research Council in the United States considered the planned use of reclaimed wastewater to augment potable water supplies to be a last resort when all other alternatives for non-potable reuse, conservation, and demand management have been exhausted. The report (15) reflects concerns previously expressed by others regarding the presence, identification , and health-significance of microbial and chemical contaminants, deficiencies in health effects testing and water quality monitoring, treatment reliability, and public health surveillance programs. It suggests measures to improve the safety of potable reuse, and concludes that planned indirect potable reuse may be a viable use of reclaimed wastewater on a site-specific basis after a thorough assessment and resolution of pertinent issues. (16)

### 5.2.2 Non-potable Reuse

Examples in Section 3 of the use of renovated wastewater at the scale of individual buildings include reuse of greywater for irrigation, toilet flushing, and other uses, and of recycling of grey water and black water for a variety of non-potable uses.

Section 4 includes examples of non-potable reuse at the municipal scale, for agricultural and urban irrigation, industrial applications, toilet flushing, and other non-potable uses. Non-potable use of reclaimed wastewater in urban areas is largely achieved by use of dual distribution systems, one for potable water and the other for reclaimed wastewater.

In 1994 the American Water Works Association published a revised version of a manual on dual water systems. The manual was offered as a starting point toward development of national standards for dual systems that could provide properly treated and distributed non-potable water. The main reasons why the use of dual distribution systems is becoming an acceptable practice are diminishing supplies of high-quality water resources, rapidly escalating costs for developing new sources or for treating poor-quality water, and the increasing costs involved in discharging wastewater to the environment. Developing a dual system may be less costly and less wasteful than use of potable water for purposes that do not require high quality water.(17)

Potential applications for dual systems include: limited water resources, and the fact that interbasin transfer of raw water is less acceptable than in the past; situations where water demand is expected to exceed the yield from existing facilities, and non-potable can be met at lower cost by reclaimed wastewater; the possibility of treating raw water from a polluted source for non-potable uses; increasing treatment requirements to meet more stringent environmental standards; and the ready availability of wastewater as a potential source of reclaimed water.(17)

Okun (18) argued that since only about one-third of water used in urban areas needs to be of potable water quality, a policy of wastewater reclamation for the other two-thirds make sense. He drew attention to a 1958 policy of the UN Social and Economic Council that "..no higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade." He cited advantages of urban non-potable reuse as (i) providing an additional economic source of water with little health risk, and (ii) reducing the cost of wastewater disposal. He also pointed out that in constructing a new dual system, reclaimed wastewater can be used for fire protection, thus reducing the size of the potable system and reducing stagnant water conditions that are often responsible for loss of chlorine residuals and development of troublesome biofilms. (12)

San Diego's need for an emergency supply in the event of earthquake damage to external delivery conduits is an example of another incentive for non-potable reuse.

### 5.2.3 Health and Other Water Quality Considerations

Water planning professionals view public health protection as a major constraint on the development of water reclamation projects. (10)(19) Epidemiological risk depends on both the degree of contamination and the degree of human exposure. (20) Cooper reviews the concentrations of various enteric bacteria that cause detectable disease in exposed humans. Although total coliform concentration is commonly used to indicate whether water is fit for human consumption, it must be noted that viruses and pathogens such as Giardia and Cryptosporidium may persist in treated water, even when coliform populations are acceptable. (14) Quality issues include the fact that not all trace or exotic contaminants have been properly assessed, and the need to avoid cross-contamination and provide fail-safe systems. (8)

The possibility of infectious disease and the presence of trace organic compounds are of particular concern in communities where treated wastewater is discharged to potable water supply reservoirs or used for groundwater recharge. (14)

Sakaji et al (21) discuss the multiple barrier approach, which consists of the ability to maintain a protected source, provide adequate treatment, and design and operate a distribution system. By understanding how the performance and reliability of treatment systems can be evaluated and compared, a risk manager can apply the multibarrier concept for the protection of public health in the development of public policy related to reclamation and reuse.

In order to identify the health risks of using reclaimed wastewater as a potable water source in San Diego, water quality tests were performed on both the raw water supply and the pilot treatment plant effluent. (14) The results indicate that the water quality of the treatment plant effluent was equal to or better than that of the existing water supply. (22) (23) Accordingly, blending reclaimed wastewater with raw water is not expected to increase the risk of disease. (14) As part of its direct potable reuse pilot project, the Denver Water Department is comparing the health effects of reclaimed wastewater and ordinary city drinking water, including animal testing for chronic and reproductive toxicity. (24)

Rowe and Abdel-Magid (25) provide a review of water-related diseases, and of pathogens, toxic chemicals, and radioactivity in reclaimed wastewater and treatment processes for their removal. A lengthy discussion of vector control in project management is also provided.

Crook et al (5) discuss pathogens and chemicals of concern in wastewater, and associated aerosols, and water quality considerations for non-potable uses of wastewater. Urban uses such as landscape irrigation or toilet flushing require essentially pathogen-free water, and wastewater treated to this level would not contain chemical constituents that would present risks from short term inadvertent ingestion. Use of reclaimed wastewater inside buildings requires that cross-connection controls be in place. Regulatory agencies have begun to require that a chlorine residual be maintained in a reclaimed wastewater distribution system, to prevent odours, slimes, and bacterial regrowth.

As indicated in Section 1.3, recycling of reclaimed wastewater will result in increased concentration of any contaminant that is not completely removed by treatment. Shuval (10) pointed out that if 90% of a wastewater containing sodium chloride or another refractory chemical is recycled the chemical concentration in the recycled water will be 10 times that in the incoming wastewater; if 50% is recycled, the concentration will be doubled; and if 30% is recycled the concentration will be increased by 40%. Actual examples are increased salt concentrations in recycled irrigation water, and Chanute, Ka., where recirculation of reclaimed wastewater occurred from 8 to 15 times during 5 months in 1956 when that community recycled municipal wastewater for potable use (11).

Even though toilet waste is excluded from greywater, some fecal contamination may be present. (20) Prolonged storage of untreated greywater should be avoided to reduce proliferation of both enteric bacteria and Legionella. (26)

### 5.2.4 Planning and Design

An application guideline for wastewater reuse systems, prepared for Canada Mortgage and Housing Corporation, discusses planning and design issues, and approval processes for reuse systems, as they apply to both on-site and large scale systems, drawing on examples from both Canada and the United States. (27) A report prepared for the U. S. EPA's Agency for International Development also discusses technical issues in planning water reuse systems (7), and reviews and discusses types of municipal reuse applications, with case studies.

On-site systems that reuse or recycle greywater and/or black water are described and discussed in reference (28), which discusses barriers and constraints to on-site recycling and reuse in the United States. These include: lack of statutory authority and regulations, restrictive and ambiguous plumbing codes, lack of a nationally accepted standard for on-site recycled water, lack of experience with procedures to control cross connections in dual water systems, and a preference for reclaiming water from municipal wastewater treatment plants.

Public health and building officials prefer use of reclaimed wastewater from municipal plants because they perceive that municipal systems offer superior quality and lower health risks, centralized operation offers better control over system operation and maintenance, and reclaimed wastewater from a municipal system can be a major revenue source.(28)

The following technical issues in planning water reuse systems are discussed in reference (7): planning approach; potential uses of reclaimed wastewater; sources of reclaimed wastewater; treatment requirements for water reuse; seasonal storage requirements; supplementary facilities (conveyance and distribution, operational storage, alternative disposal); and environmental impacts.

Reference (17) addresses determination of water quantity and quality to satisfy various non-potable uses, and considers engineering issues that include: non-potable sources, treatment, storage, distribution, and public health safeguards. Design and construction administration should include checking of plans, and inspection of, existing utilities, and preparation and updating of record drawings of the non-potable system.

Dual distribution systems that use reclaimed wastewater for fire protection were identified by a workshop group as one alternative to use of potable water, recognizing that fire protection is the most significant factor in municipal water system capacity from both the design and operational point of view. (6) In a new city or a major urban development in an existing city, the reclaimed wastewater system may well be designated for fire fighting (St. Petersburg, Florida, has hydrants on both systems); but sprinkler systems, because they use no water except during a fire event, might be better served from the potable system, in part because potable water is widely available in the building and its quality, being generally lower in nutrients, is better suited for pipelines with little or no flow.(5)

A retrospective assessment of 16 wastewater reclamation projects in California indicated that as a group these projects are delivering 63 percent of the water expected, and two-thirds are delivering 75 percent or less. Furthermore, the real costs of these projects are considerable higher than the costs used to justify them, and may be further increased if distribution facilities must be enlarged to reach new customers. The implications of these findings are that the amount of fresh water made available to serve other uses is significantly less than the expected demand on which project approval was based. The authors argue that the shortfalls are in large part the result of insufficient planning in advance of design and construction. Future planning can be improved by consideration of problems encountered by these projects, which relate to permit approvals, securing reclaimed water users, reliable data on the amount of wastewater available for reuse, and institutional issues related to resolution of the concerns of responsible government agencies. (29)

The principal advanced wastewater treatment (AWT) processes for water reclamation are filtration, nitrification, denitrification, phosphorus removal, coagulation-sedimentation, and carbon adsorption; other AWT processes include ammonia stripping, breakpoint chlorination, selective ion exchange for nitrogen removal, and reverse osmosis for reduction of dissolved solids and removal of organic and inorganic constituents. (5) The treatment process selected for Denver's direct potable reuse demonstration project, following secondary wastewater treatment, includes lime clarification, recarbonation, filtration, ultraviolet disinfection, activated carbon adsorption, reverse osmosis, air stripping, ozonation, and chloramination. (24)

### 5.2.5 Management Considerations

#### 5.2.5.1 Management of Small Scale Systems

Management, operation, and maintenance of innovative on-site systems involve special challenges in addressing many of the issues discussed here, if these systems are to provide continuous, reliable, and safe service.

Positive effects of an on-site recycling or reuse system include improved quality and reduced quantity of wastewater, which should be recognized in regulations governing minimum lot sizes and separation distances.

Consequences of the failure of an on-site system may be:

- direct, such as lack of water or a backed-up sewer;
- long term, resulting in deteriorated water quality or the necessity to repair or replace a failing or failed sewage disposal system; or
- off-site, such as contamination of surface or groundwater, where the effects may be unknown to, or ignored by, an owner or occupant.

Education of owners and occupants is important in motivating care of systems, by providing both information and an understanding of the consequences of failure to maintain and service a system. However, for some of the systems discussed here information and education may not be enough. Water conserving fixtures, once installed, require no more care than older fixtures, and a RWCS, unless it includes sophisticated treatment, can be cared for by a householder with possible occasional assistance from a plumber or handy-person.

But a treatment system for wastewater recycling or re-use requires a level of understanding, commitment, and capability that it is not reasonable to expect of an average householder. The treatment systems discussed here require a level of maintenance and service that is not required when municipal services are available, or when conventional on-site systems—which are relatively passive and can be looked after by a responsible owner or occupant—are involved. These systems should not be installed unless responsibility and authority for their long term operation and maintenance has been assigned to someone with the required knowledge and experience.

And these systems require adequate and reliable system management tools—sensors, alarms, and controls—to make it possible to remotely operate and control system performance and operation. Development of such systems has been rapid, and is expected to continue.

Two possible management models (there may be others) are:

(a) A Wastewater Management District (WWMD)—which is enabled by Nova Scotia and some other jurisdictions—may be established by a municipal unit to perform this function and recover associated costs from property owners;

(b) Legislation or regulations may require a property owner to employ a licensed service firm to perform specified monitoring, inspection, emergency response, maintenance, and repair, to report periodically to the regulating agency, and impose fines if the owner fails to comply.

Legislation administered by the Nova Scotia Department of Housing and Municipal Affairs enables establishment of municipal wastewater management districts to operate and maintain individual or cluster wastewater systems. The legislation and examples of its application are presented and discussed in (31) and (32). Provincial regulations for on-site systems require that where holding tanks are permitted (on older lots, unsuited for on-site systems, where municipal services are not available) the local municipality must have established a WWMD or another acceptable sewage management program.

A planning thesis (33) considered the role of clustered on-site systems to support clustered rural residential development, and reviewed options for management of on-site and clustered systems. The author proposed that privatization of the inspection function, in a manner analogous to routine inspection of motor vehicles, be adoption for inspection of on-site and cluster systems.

Reference (30) includes a comprehensive discussion of decentralized wastewater management, which involves collection, treatment, disposal and/or reuse of wastewater from individual homes, cluster systems, and isolated community and commercial facilities at or near the point of generation. Thirteen on-site WWMDs, most in California and Washington, are listed and compared; two examples–Stinson Beach and Georgetown Divide–are discussed in more detail. The reference includes discussion of needs for, types of, functions of, and financing of WWMDs.

#### 5.2.5.2 Management of Large Scale Systems

"Developing the institutional framework to implement a water reclamation system can be more daunting than the technology itself, as many communities and agencies with varying spheres of control must be involved. Agreements between cities, districts and private agencies are often needed to clarify the details of service and pricing structures. Many jurisdictional agencies need to negotiate an agreement that encompasses the cash value of all project benefits and then applies that value to the operational costs of the project, a complicated and difficult task. It is also difficult to accurately calculate and to obtain consensus on the real dollar value of these benefits, even though the benefits appear obvious to the average citizen. As an example of the potential complexity of these arrangements is the South Bay Water Recycling Program, which is implementing a nonpotable project in northern California. While the primary responsibility for the program rests with two cities, San Jose and Santa Clara, other partners include the city of Milpitas, five wastewater agencies, five water retailers, the Santa Clara Valley Water District, the state of California and the U.S. Bureau of Reclamation. The range of the required institutional, engineering and construction activities led to an interlocking set of complicated interagency relationships. Among the main issues of such an agreement are the specific ownership of pipelines, the ability for each water retailer to meet demands within its jurisdiction, the limits of system responsibility, the boundaries of service areas, and the potential duplication of services. An especially complicating factor is that existing rates for potable water are not uniform throughout the project area. Therefore, recycled water pricing is not straightforward and varies by jurisdiction and type of use, as crafted through a basic wholesale rate, wholesale discounts and varying retail markups. More often than not, the cast of players and agencies cannot reach a financial agreement, and these types of projects stall over the complicated fiscal arrangements." (23) In contrast: "We've found that the San Diego project has had a relatively smooth development, mainly because both water and wastewater services reside under one agency's jurisdiction. So there was little need for interagency agreements and negotiations." (23)

Most large scale reuse systems involve coordination of the activities of a number of agencies with differing responsibilities. In Los Angeles the Department of Water and Power (LADPW) will maintain ownership of recycled water and will be responsible for any treatment beyond disinfected tertiary treatment; Public Works will allow LADPW to build a pumping station in their plant at no land cost, and will credit to LADPW savings in using less dechlorination chemicals because chlorinated water is used for recharge; and County Public Works will have the right to curtail or suspend recharging with reclaimed wastewater during the storm season. (34)

### 5.2.6 Legislation , Regulations, Criteria

Regulatory barriers to the adoption of on-site water reuse in Canada–at the national or provincial level–are discussed in reference (35). The only restrictions that apply explicitly to wastewater reuse are those that deal with the quality of water applied to agricultural crops. Requirements that can influence the adoption of recycling and reuse systems are

- the National Plumbing Code and provincial plumbing regulations that require that every water system be connect to a potable supply, and prohibit discharge of non-potable water to any fixture where a potable supply is available
- requirements that all wastewater be directed to a sewer or an on-site disposal system.

Officials are generally concerned about health, reliability, and other issues that are identified here. The report concludes "As long as existing regulations are open to some degree of innovation there are no absolute barriers to on-site reuse. There will remain, however, administrative obstacles based on individual attitudes, interpretations, and other factors which in themselves can pose significant barriers. The solution may be to distill the successful experiences into a Code of Practice and case studies to provide guidance and confidence to decision makers facing approval of on-site reuse systems that practical and safe systems do exist." (35)

Examples of provincial initiatives that can impact acceptance of wastewater recycling and reuse include proposed amendments to the British Columbia Building Code and Municipal Sewage Regulations, and a policy for review of innovative on-site systems (Appendix 3 in (27) and (35)), and a provision in 1997 revisions of the Nova Scotia on-site regulations that provides for approval of innovative systems.

Cologne and macLaggan (36) provide an overview of legal aspects of water reclamation in the United States; Reference (4) also discusses legal issues, at the federal, state, and local level. Rowe and Abdel-Magid (25) discuss legal aspects of wastewater reclamation and reuse, including identification of the many U.S. federal agencies that have related responsibilities, and a review of federal legislation and examples of state regulations and local programs. They also devote a complete chapter to criteria, standards, and guidelines for reclaimed wastewater quality, in the United States and internationally.

Crook et al (5) review regulations related to wastewater reuse in all U.S. states, and discuss examples from four states. Reference (4) provides an inventory of existing state regulations, and suggests, for various categories of water reuse, guidelines for: type of treatment, reclaimed wastewater quality, monitoring of reclaimed wastewater, and setback distances from irrigation or other reuse locations to wells or public access areas.

Institutional issues identified by Crook et al (5) relate to assignment of responsibility for a reclamation and reuse plan, which involves water supply, sewerage, and wastewater treatment; determining the most appropriate institution to assume responsibility where water supply and wastewater services are separate; determining the responsible state agency and its role in regulation of reclaimed wastewater; and regulating reclaimed wastewater either as a waste or establishing separate regulations for the non-potable use of reclaimed wastewater. Legal issues include limits on the right of the utility to sell reclaimed wastewater, and liability for failure to deliver the required quantity or quality.

Reference (7) reviews the history of legislation related to non-potable use in four states, examines various state water reuse regulations, and introduces recommended guidelines that may aid in the development of more comprehensive state or eventual federal standards for water reuse.

Regulations related to handling of greywater in on-site systems in the United States, as of 1996, are listed in (37). Only sixteen states reported regulations that dealt specifically with grey water; most of these deal with the reduced hydraulic load on an on-site system when black water is not included.

Reference (7) provides a listing of state reuse guidelines and regulations in the United States, including quality, treatment, monitoring, and other requirements.

Mustow et al (20) review national and international water quality standards, for greywater reuse and rainwater use, and discuss water quality criteria and health and safety requirements appropriate for the United Kingdom. While there are currently no regulations or guidelines in the United Kingdom, this is likely to change quickly. (8) Recommended water quality criteria and conditions of use for RWCS and greywater reuse in the United Kingdom are proposed by Mustow and Grey. (38) Proposed conditions of use include anti-backflow devices, air gaps, and warning signs to protect potable water, use of corrosion-resistant materials, and filtration of greywater prior to reuse for toilet flushing or other non-potable uses.

Asano et al (39) review development of water quality criteria in the United States, and milestone events in wastewater reclamation, in order to establish a rational basis for comprehensive wastewater reclamation and reuse criteria, and estimates the risk associated with use of reclaimed wastewater for several of non-potable uses. Crook (40) provides a detailed review of quality criteria for water reclamation and reuse in the United States.

Van Riper et al (41) review the evolution of water reuse regulations in Washington State, and summarize proposed 1997 standards. Conte and Tuttle (42) review institutional and regulatory issues associated with implementing a water reuse project for the Oneida Indian Nation in upstate New York. Young et al (43) include a discussion of regulatory and internal standards, and associated monitoring programs, at the Irvine Ranch Water District.

Most jurisdictions in Canada do not have specific legislation that permits or requires the systems discussed here, or that establishes performance or design requirements for these systems. Provincial agencies in Canada appear to be feeling their way toward requirements that will exercise their responsibilities to protect public health and the environment, and will allow new technologies to be applied and evaluated.

In 1975, The World Health Organization concluded that conventional drinking water standards were not adequate for evaluating the health effects of using recycled wastewater as a potable water source. (10) However, others argue that there should be a single standard for drinking water quality, regardless of the source (11). Mustow et al. (20) include a comprehensive review of wastewater reuse standards, including guidelines established by the World Health Organization, U.S. EPA., National Sanitation Foundation, California, Florida, and Australia.

"The use of on-site water reclamation and recycling is relatively new and not yet widely used. In many states, lack of experience with such systems, and lack of specific standards and regulations, have restricted their use." (44)

There are no federal reclaimed wastewater regulations in the U.S. but the U.S. EPA has issued *Guidelines for Water Reuse* (7). California standards and regulations for reclaimed wastewater have provided a benchmark for similar regulations worldwide. (17) In both California and Florida, the regulations prescribe requirements according to the end use of the water. In addition, both states have mandated water reuse for certain non-potable purposes. (28) Okun (18) reviews the California requirements for unrestricted urban use of reclaimed wastewater. In 1993, the State of New South Wales, Australia released its Guidelines for Urban and Residential Use of reclaimed wastewater (45); the prescribed treatment train is based on systems in California and Florida. Wastewater reclamation criteria in Japan are outlined in the Ministry of Construction's Draft Technical Guidelines for Wastewater Reclamation and Reuse (19).

Adoption of uniform standards for greywater use on a state-wide basis offers a number of advantages, including public health protection, quality and availability of greywater systems cost savings and economies of scale due to increased market size, greater public awareness and education, and greater familiarity of local government inspectors and officials with these systems (46). California regulations and design specifications have been used as a model for regulations in other jurisdictions. The legislation permits the installation of greywater systems in single family dwellings for subsurface drip irrigation only. (46) In 1991, a bill was proposed to mandate dual plumbing for all new construction in Los Angeles, including residences. (44)

In 1996, the Urban Water Research Association of Australia published general guidelines for greywater reuse in Australia (28). The United Kingdom currently has no legislation that specifically regulates the use of greywater, although other water use regulations may apply. (28) Mustow et al. recommend that all systems, regardless of type or configuration, be required to meet established water quality standards, rather than restricting the types or uses of recycled greywater. (20)

### 5.2.7 Economic Considerations

Rowe and Abdel-Magid (25) devote a complete chapter to the economics of water and wastewater reclamation and reuse projects, including estimation of system costs, selection criteria and system evaluation, and finance and cost comparisons. Crook et al (2) discuss costs and cost savings associated with reclaimed water systems, and financing options. They conclude that the cost of a reclaimed water system should not be completely recovered from the sale of the reclaimed water, because cost savings in reduced potable use and wastewater disposal should be taken into account, and recognize that the price in a given situation will depend on the value of the reclaimed water in terms of availability. Reference (28) considers the economics of on-site treatment and recycling systems, and emphasizes that cost comparisons should be based on life cycle costs that take into account initial system costs and long term benefits. The economic life of an on-site system is typically 20 years. Cost of an on-site system can range from $500 for a basic greywater system to $5000 for a fully automated system; a complete wastewater treatment and recycling system might cost from $4,500 to $8,000. Operating costs are principally for electricity. Maintenance costs for a greywater system are up to $100 per year; costs for more sophisticated systems are about 2% of initial equipment cost. Benefits of on-site recycling and reuse can include reduced water demand and associated cost, the possibility of heat recovery from greywater, and the value of nutrients when reclaimed wastewater is reused for irrigation. An on-site system may make it possible to develop a site where municipal sewers are not available and site conditions prevent or limit installation of a conventional disposal system. (28)

The estimated cost of the treatment system and distribution pipeline for the San Diego direct potable reuse system is US $141.6 million. (47) The city expects to recover a portion of the costs through capital improvement fees included in utility bills, as opposed to increasing the normal water rate. (22) The project is expected to save $6.4 million annually versus the cost of imported water. (20) In 1991, Los Angeles planned to spend $800 million over a 10-year period to install a dual system to distribute treated wastewater for non-potable use. The system was to be funded by increased water rates. (44) In Japan, while government may subsidize the capital costs of district wastewater system construction, the systems are required to recover operating costs through reclaimed water sales. (19)

The total cost of the district system at Rouse Hill, which is designed to serve a population of 25,000, was AU$285 million, including land sewage treatment and reclaimed water distribution costs. The capacity and expansion of the reclaimed water distribution system will be required as development in the area continues. Law suggests that discharge of high-quality treated wastewater to Sydney's drinking water supply reservoirs may have been a more cost-effective option than the dual distribution system. (45)

Direct potable reuse may provide cost savings in areas where increased demand would otherwise require additional water supplies; (8); recycled water returned to a water supply reservoir supplants an equivalent volume of additional potable water supply capacity. A cost analysis indicated that the costs of water treatment for direct potable reuse are comparable to the costs of developing new water supplies for the City of Denver. (24) Reclamation also reduces the cost of wastewater disposal. The cost of complying with ever-more-stringent wastewater discharge standards has made reclamation a viable alternative. The St. Petersburg reclaimed wastewater treatment and distribution system is a noteworthy example.

Clearly, the cost of installing a district wastewater distribution system and dual plumbing within each structure will be greater than that of conventional systems. If reclaimed water is to be used for fire protection, the additional cost of building and maintaining elevated storage tanks separate from potable water supply tanks must also be considered. (17) However, Okun claims that the mere existence of unsubsidized dual systems is evidence of their cost effectiveness. Capital costs can be reduced if these systems are installed during construction of new business districts and residential subdivisions, such as Rouse Hill, or during major overhauls of the existing water mains. (8) (17)

Reference (7) discusses funding alternatives for water reuse systems, and provides case studies. Cost-effectiveness analysis should recognize environmental benefits that include discharge of cleaner effluents, conservation of fresh water supplies, and reduction of salt water intrusion, and economic benefits that include delay in or avoidance of expension of water and wastewater treatment facilities. Generally costs of a reuse program are recovered by reclaimed user fees and long-term bonds to finance capital costs. Alternatives for financing of operation and maintenance, and repayment of borrowed funds include: operating budget and cash resources of the utility; local property taxes and existing water and wastewater charges; special assessments or special tax districts; connection fees; and reuse user charges.

Consumer rates for reclaimed water have traditionally been lower than those for potable water to encourage use of reclaimed water.(19) (45) However, as demand for reclaimed water has increased, rates have approached those of drinking water. The market value of reclaimed non-potable water depends on the intended use: reclaimed water used for urban and industrial purposes is of greater value than that used for agricultural irrigation. Moreover, urban and industrial uses promise full recovery of reclaimed water treatment and distribution costs, whereas agricultural uses do not. (17)

Rates and fees may be used to recover costs of capital construction of a distribution system or development of future water and wastewater systems. Fees may be collected for review of drawings, to insure compliance with design and construction standards. Rates for sale of non-potable water can be based on metered flow if the water is considered a valuable resource, at rates of 25 to 100 percent of the potable rate. A flat rate may be charged where disposal of the non-potable water is the main objective.(17)

At the scale of individual buildings there are some situations, represented by northern Canadian communities now serviced by trucked water and wastewater, where economics will clearly justify adoption of wastewater reuse. As further markets develop, and the technologies mature, costs should decrease. Any realistic cost comparison should include all relevant life-cycle costs of the alternatives being compared. For those discussed in Section 3, these costs would include costs of alternative plumbing, the system itself, operation, maintenance, repair, and management. They should also recognize the value of space inside a building that is required to house the system.

### 5.2.7 Public Acceptance

References (5) and (7) cite studies of public attitudes about wastewater reuse for various purposes. Their conclusions include: a surprising degree of public support for reuse programs, apparent opposition to the disposal as wastewater of water that could be reclaimed, and a belief that public opinion surveys should be made in a community where a wastewater reuse project is proposed. The following is summarized from a table (quoted from (48)), that shows percentages of respondents opposed to use of reclaimed water in 7 surveys: drinking water or food preparation – 38 to 67%; bathing at home or groundwater recharge – 22 to 40%; swimming, and home or communal laundry – 15 to 30%; irrigation of dairy pasture, fruit, or vegetables – 1- to 27 percent; toilet flushing or lawn irrigation – 1 to 7%; other uses, depending on use – 1 to 14%.

Public acceptance of water reuse is closely associated with the quality and reliability of the reclaimed water supply. (19) The perception by both water industry professionals and the general public that "natural" water is purer and better than reclaimed wastewater may not be valid, as even "natural" water from snowmelt frequently contains organic compounds of anthropogenic origin. (10)

Social acceptability is not a limitation to the spread of greywater recycling in the UK, provided the systems are appropriately designed and operated. (20) A recognized accreditation system would likely increase the acceptability of these systems. Although a number of water utilities have conducted research and development, general interest in wastewater reuse in Britain remains low. (8) In

Germany, public opinion toward rainwater use is more favourable than opinion toward greywater reuse. (20)

Even people who are strongly motivated to practice a "green" lifestyle may find the inconvenience difficult to accept. In-home greywater reuse systems may require that residents stop using their preferred cleaning products (28) and alter their cleaning habits in general to prevent fecal contamination (California regulations (46) specify that soiled diapers must not be washed in fixtures connected to a greywater system.).

Many people still perceive use of treated wastewater for landscape irrigation and toilet flushing as "unappetizing" or unsafe. (44) As stated by Toronto Healthy House owner/developer Rolf Paloheimo, "It may be psychologically difficult for occupants when they are first presented with the opportunity to use reclaimed water for bathing and clothes washing, even if it is more hygienic than many untreated surface waters." "Reclaimed water reuse is controversial and will only be proven by informed advocates who understand the risks and benefits". (49)

Informed consumers are absolutely essential in obtaining support for development of a reclaimed water system. The public information program should be ongoing. Consumers asked to support a reclaimed water system and to use the water must be convinced that the product will not in any way endanger their health. (18)

The San Diego project has been relatively uncontroversial, because the city has thoroughly educated the public about its expected benefits, and has publicized results of tests and analyses confirming that the resulting water supply would be safe. (29)

Reference (7) provides an overview of public information programs, and offers case studies from four communities. Public participation not only builds support for a program; it can also provide valuable community-specific information to planners. The public might include the general public, public and private interest groups, and the economically concerned public whose interests may be directly affected by a program. In order to avoid difficulty associated with public acceptance, it is of paramount importance that the expected benefits of the proposed project be established. Public information and involvement initiatives should be tailored to the interests of each public sector.

Education programs and public involvement are responsible for the widespread acceptance of the San Diego Water Repurification Project. (47) The comprehensive water recycling program initiated by the City of Los Angeles has received enthusiastic support from residents, for whom the prospect of using recycled wastewater is preferable to mandatory water rationing during drought periods. (44) Drought in the eastern states of Australia has increased support for potable reuse; however, Law (45) questions whether such a scheme would receive political support. Although public education campaigns may successfully overcome negative public perception about planned direct use of wastewater as a potable water source (22), it may also raise concern about de facto indirect potable reuse which occurs when lakes and rivers contaminated by human wastes upstream are used as drinking water sources. (10)

Los Angeles' program of public consultation and information included focus groups, a public hearing, and provision of information via a telephone hotline and newspaper articles. (34)

Katz et al (50) examine similarities and differences in communications approaches used in indirect potable water reuse projects in Tampa and San Diego. Differences included: preference for "purified" or "repurified" as the name of the process; the viability and views regarding seawater desalting as an alternative; political issues; and the extent of previous studies and interaction with the public about recycling. Similarities included: implementation of public affairs efforts at the beginning of the project; use of citizen advisory groups; and the establishment of independent panels that comprised health, medical and water quality experts.

Reference (51) describes planning of a communication program that will help to reach technical objectives, obtain public support and win acceptance for water reuse projects, and presents results of the expertise and experience of public relations professionals from the Western United States.

Most of the references cited here address public acceptance of municipal-scale programs for wastewater recycling and reuse. Where innovative on-site systems are proposed, another issue that is of concern to individual property owners is the level of service.

Public water supply, and central sewage collection and treatment systems, are the accepted norm for urban populations in North America. Safe potable water and fire protection is expected of the water supply, wastewater disappears, and the costs are covered by taxes or user fees. The property owner has no responsibility for, or control of, the system.

Where central services are not available, on-site services—wells and septic tank systems—are the usual alternative. Fire protection by public hydrants is not available. Property owners are responsible, with their contractors, to maintain and repair their systems; wastewater management districts can provide this service. On-site systems occupy space on a property, and impose limitations on lot sizes and separation distances. Hopefully the reduced level of service is recognized in tax rates.

A program directed at public acceptance of on-site recycling and reuse could emphasize, where appropriate, that

- if the level of service is reduced it is recognized in tax rates
- recycling and reuse result in relaxed restrictions on lot sizes and separation distances when compared with conventional on-site systems.

### 5.2.9 Research and Demonstration Needs

A Canadian Water and Wastewater Association workshop group concluded that research and demonstration projects were needed to produce information and new technology to provide a basis for sound decisions about safe, reliable, and economical recycling and reuse.(20)

Sections 3 and 4 of this report include examples of extensive research that has addressed health and other concerns related to wastewater reuse, and of recent Canadian demonstration projects that have been initiated and/or supported by Canada Housing and Mortgage Corporation.

Research needs related to wastewater reuse are discussed at length in (2). Research needs identified by the project team were ranked by participants in a workshop; recommended projects are presented under the following headings: Microbial risk assessment modelling; identification of new indicators of pathogens; evaluation of effects of process selection on particle size distribution; seasonal storage; nonpotable water management, and evaluation of synthetic organics and metals in irrigation water.

Reference (22) identifies sources of information about wastewater reclamation and reuse research, potential sources of research funds, and research needs.

## 5.3 Summary

This section identifies and discusses issues related to wastewater recycling and reuse, at the scales of single buildings and municipal systems.

Although unplanned indirect potable reuse of renovated municipal wastewater is widespread, and examples exist of planned indirect and direct potable reuse, planned potable use has been considered as an alternative to be adopted with caution and care.

Renovated wastewater from individual buildings has been recycled and reused for purposes that include toilet flushing and other non-potable interior uses, and for irrigation. At the municipal scale, dual distribution systems have been used to deliver reclaimed wastewater for industrial uses, agricultural and urban irrigation, fire protection, toilet flushing, and other non-potable applications.

Incentives for use of reclaimed wastewater have included reduced demand for potable water, reduced dependence on imported water, and reduced cost of water supply and wastewater disposal.

Concerns about public health implications of reclaimed wastewater reuse include microorganisms and organic chemicals, and increased concentrations of contaminants in recycled water that are not completely removed by treatment. These concerns have led to extensive water quality testing, applications of the multiple banner approach to risk management, and measures such as cross-connection controls in dual systems.

Wastewater reclamation and reuse projects must be carefully planned and designed, and should draw on the experience of earlier projects that have not fully achieved their goals in terms of projected costs or savings in potable water use. Specific planning issues include accurate assessment of uses for, and demands for, reclaimed water (including fire protection), and of system costs, and resolution of institutional concerns.

Proposals for on-site recycling or reuse must address considerations related to regulations, codes, and standards, and control of operation and management.

Management of on-site systems will require regulations, technology, and public or private sector capacity, which a resident cannot be expected to possess, to insure long-term operation and maintenance of the system. The major issue in management of municipal systems may be coordination of the responsibilities and activities of responsible government agencies.

Examples of existing regulatory environments are reviewed. Absence of legislation, regulations, codes, and criteria that specifically address wastewater recycling and reuse is a barrier to implementation of these systems.

Economic considerations, including cost-benefit analyses, financing options, and pricing structures for reclaimed wastewater, with examples drawn from existing systems, are reviewed.

Public acceptance of reclaimed wastewater will depend on the timing and quality of programs for public consultation and information.

Research and demonstration projects will be an important basis for public information and for policy and planning decisions related to wastewater reuse.

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# Appendix A

## CASE STUDIES OF RESIDENTIAL RECYCLYING AND REUSE

### A.1 TORONTO HEALTHY HOUSE

### A2. PILOT WATER MANAGEMENT PROJECT, NORTHWEST TERRITORIES

### A.3 CANADA MORTGAGE AND HOUSING CORPORATION CONSERVATION CO-OP RESIDENTIAL LIGHT GREYWATER RECLAMATION PROJECT

### A.4 SOOKE, B.C. OFFICE BUILDING (B.C. MINISTRY OF SOCIAL SERVICES)

### A.5 SUSTAINABLE TECHNOLOGY CENTER, FRIDAY HARBOR, WA

### A.6 WASTEWATER RECLAMATION IN AN APARTMENT COMPLEX IN JAPAN

### A.7 SIX HOMES IN CANBERRA AUSTRALIA

### A.8 CASA DEL AGUA, TUCSON ARIZONA

### A.9 DESERT HOUSE, PHOENIX, AZ

### A.10 MADISON, WISCONSIN RESEARCH HOMES

### A.11 CAMPUS CENTER FOR APPROPRIATE TECHNOLOGY (CCAT) HUMBOLDT STATE UNIVERSITY, ARCATA, CA

### A.12 THE BLUE HOUSE, AALBORG, DENMARK

### A.13 STUDENT RESIDENCE, LINACRE COLLEGE, OXFORD UNIVERSITY, UK

## A.1 TORONTO HEALTHY HOUSE

### 1. Highlights of Findings

CMHC's Toronto Healthy House was one of the award winners of a National Healthy Housing Design Competition. The Toronto Healthy House has on-site potable and reuse water treatment systems which are completely independent of municipal water and wastewater services.

Potable water, supplied by rain and snowmelt, is treated and used for drinking water, food preparation and dish washing. Wastewater in the Healthy House is collected through a separate plumbing system, treated and reused for toilet flushing, bathing and clothes washing.

Rainfall and snowmelt is collected for treatment by a potable water treatment system. The rainwater is contacted with limestone, filtered through multi media filters and disinfected by an ultraviolet irradiation unit. The potable water treatment system is designed to provide treated water which meets the Guidelines for Canadian Drinking Water Quality.

Wastewater produced at the Toronto Healthy House is collected and treated through a water reuse treatment system. Water reuse unit treatment processes comprise a septic tank, recirculation tank, Waterloo Biofilter, combination slow sand activated carbon filters, and an ozone disinfection unit. The water reuse quality objective is to meet swimming and bathing use criteria based on Ontario's water contact protocol and other suggested guidelines for water reuse developed by the USEPA (manual: A Guidelines for Water Reuse).

### 2. House Description and Water Conservation

Canada Mortgage and Housing Corporation's (CMHC's) Healthy House in the City of Toronto is an award winning design in the National Healthy Housing Design Competition held to promote environmentally responsible housing. The Healthy House, a three bedroom, four storey duplex located in the heart of Toronto, was constructed in 1996.

The total water used in the Healthy House represents about half that used in an average Canadian household. Water conserving appliances and fixtures help reduce the water consumption. The Healthy House currently uses 265 L/day of potable water and 325 L/day of recycled water.

The house is equipped with water conservation devices including low flow toilets (6 L), water conserving faucets and shower head aerators. The shower heads are rated at 9.5 L/s. The washing machine in the Healthy House uses 25 litres per cycle which represents 1/3 of the water used by a conventional washer. The dishwasher uses approximately 40% less water than a conventional dishwasher.

In addition to water conservation, the house design is energy friendly. Solar energy provides 75% of the electricity needs of the home which is supplemented by a cogenerator on cold or cloudy days. Energy efficient appliances are used to conserve electricity. Recirculated water is heated by two glycol circulating solar panels on the south side of the house and stored in a 150 L potable hot water tank. When required, the water is heated by a heat exchanger powered by a back-up cogenerator.

There are two greywater heat recovery units included as part of the plumbing system. These exchangers recover heat from the wastewater leaving the bathrooms and the kitchen. It is reported that up to 70% of the energy in the wastewater is recovered.

## 3. Process Configuration and Attributes

Surface water draining from two patio surfaces and three roof areas is collected in a storage cistern for processing in the potable water treatment system. Surface water drains into a 20 $m^3$ concrete cistern where the water's pH may be adjusted from contact with limestone. From the storage cistern water is filtered through a combination slow sand-filter and activated carbon absorber. The treated water is then disinfected by ultra-violet irradiation before storage in a concrete tank. Potable water is disinfected a second time prior to circulation in the distribution system.

The wastewater reuse system comprises four unit treatment processes. Primary treatment through settling of suspended solids is accommodated in a septic tank. The water is then circulated through a biotube effluent screen located in the septic tank on its way to a recirculation tank. From the recirculation tank water is pumped to a biological filter (Waterloo Biofilter) where it undergoes secondary treatment. The Waterloo Biofilter aerobically biodegrades organic matter. From the biofilter water can return to the recirculation tank (multiple recirculation) for de-nitrification or sent to twin combined slow sand filters and carbon absorbers. Treated water from the filter is disinfected with ozone.

The wastewater reclamation system includes backwash and overflow features which help to capture and recirculate water. Similarly, surplus water from the potable water treatment process can overflow to the wastewater reuse system. Surplus water can also be wasted to a site gravel pack located under a garden.

Sampling taps are and pressure gauges are located throughout the treatment process for monitoring purposes.

## 4. Equipment Evaluation

### 4.1 Potable Water Treatment System

Components of the potable water unit treatment process are described in this section.

#### Rainwater Storage Cistern

Surface water is collected from three roof surfaces and two ground patio areas with a combined total area of 80 $m^2$. The water is directed to one of two 20 $m^3$ concrete cisterns Lime or limestone can be added to the cistern through an inspection and cleaning access chamber to adjust the water's pH. Overflow from the cistern drains into the wastewater reuse system or can be wasted through a ground disposal gravel pack.

The cistern tank bottom is lower than the outlet drain pipe to accommodate solids accumulation or suspended solids settlement.

### Multi Media Filter

The combined slow sand filter and activated carbon absorber represents the main treatment process prior to disinfection. The filter unit, a 300 mm in diameter cylinder by 1.2 m high, was produced by RAL Engineering Limited for use in the Healthy House.

The slow sand filtration rate is 5 L/min. The filter is multi media comprising four layers of material varying from coarse quartz on the bottom (13 to 19mm) acting as a roughing filter, to fine silica sand (0.35mm) at the top. Flow through the RAL filter is upwards with an activated carbon absorber suspended in a basket above the fine sand.

The slow sand filter develops a surface layer of biologically active microorganisms to break down organic matter and filter particulate, bacteria and cysts. Activated carbon removes dissolved organic compounds and some metals.

Air release valves in the treated water pipes are located on the discharge side of the filter unit. The valves serve to vent accumulated air which could interrupt hydraulic flow. The RAL filter is backwashed with potable water which is recycled to the wastewater treatment system. Flow reversals in the backwash line are prevented by double check valves acting as a backflow preventer.

### Ultraviolet Irradiation Unit

Ultraviolet (UV) treatment is provided before and after the potable water storage tank using an Aqua Advantage 5 water sterilizer manufactured by Trojan Technologies Incorporated. The unit includes a UV sensor to measure UV light intensity. When the ultraviolet light intensity is too low an alarm is triggered to automatically shut down the water supply.

### Drinking Water Storage Tank & Pressure Pumping System

A Grundfos JetpaQ pumping system pump, with pressurized tank, pumps water from the potable water storage tank. The pumping system is designed to deliver a constant preset discharge pressure. It has an electronic control system which incorporates a frequency converter adjusting the pump impeller speed to maintain a preset pressure. The potable water storage tank has a capacity of 600 L to provide 5 days storage of potable water.

## 4.2 Wastewater Reuse Treatment System

The reclaimed wastewater collection, treatment and distribution system is separate from the potable water plumbing system. Major components of the reclaimed waste water treatment system are described below.

### Septic Tank

The first component of the wastewater treatment system is a 3600 L septic tank.. The septic tank helps to retain oil, grit, floatable, settleable solids and removes some heavy metals. It also provides anaerobic digestion of settled and waste sludge.

The septic tank outlet is fitted with an Orenco Biotube effluent filter to filter suspended solids. The Orenco Biotube filter is a removable cartridge comprising a biotube screen unit, access handle and air vent.

**Recirculation Tank**

The recirculation tank is a precast concrete 2000 litre tank. The recirculation tank provides an anaerobic environment where denitrification can occur. A vent is provided to release nitrogen gas generated through denitrification.

Water from the recirculation tank is pumped intermittently to the Waterloo Biofilter (on for 30 seconds every 30 minutes) to provide water cycling through the biofilter. The process is designed to accommodate recycling of water from the recirculation tank to the biofilter up to five (5) times.

**Waterloo Biofilter**

The Waterloo Biofilter, an aerobic filter, was developed at the Waterloo Centre for Ground Water Research. It provides secondary treatment of wastewater generated in the Healthy House.

The filter medium comprises synthetic foam blocks contained in a geodrain grid baskets. Biofilter baskets are 750 mm in diameter and 1.2 m high. Each basket is housed in a waterproof stainless steel cabinet with a removable vertical access panel. Mesh cloth bags are used to contain the top portion of the filter media to facilitate removal for cleaning.

Synthetic foam blocks are placed randomly in the baskets to provide a large surface area, long retention times, and high porosity. The block physical characteristics provide for microbial attachment, separate flow paths for a forced air system and water treatment process. Microbes and bacteria remove suspended and dissolved organic solids from the wastewater in an aerobic environment.

Wastewater is sprayed on top of the filter media. The spray nozzles are designed to be self cleaning to minimize biological slime clogging. Air is provided to the microorganisms by a side-stream of forced air which is then vented to a heat recovery unit.

Water gravity draining through the filter media is collected in a bottom tray. Check valves direct water to either the slow sand and activated carbon filter (RAL filter) or return it to the recirculation tank.

**Combined Slow Sand Activated Carbon Filter**

Dual RAL multi-media filters are used to filter water. Each filter has a rated capacity of 25 litres/hr. An activated carbon basket is suspended in the filter to remove dissolved organic compounds The filters are backwashed with treated wastewater with wash water wasted to the septic tank.

**Ozonation Unit**

The final treatment process is a disinfection unit. Originally an ultraviolet irradiation unit was used for disinfection. During the first three months of system commissioning aesthetic problems with the water, colour and odour, were experienced. Changing the disinfection process from a UV unit to an Ozonation unit is reported to have solved this problem.

Ozone has high oxidation potential which is capable of reacting with a variety of impurities such as metal salts, organic compounds, and is effective in inactivating microorganisms. It is generally acknowledged the oxidation process can be effective in reducing colour problems associated with organic compounds. Process by-products can include the formation of solids referred to as microfloc, oxidized metal ions, and partially oxidized organic compounds. Initial reclaimed water sampling results have found low residual pathogen indicator counts.

The Ozonation unit used at the Healthy House is a forty watt corona generator. A PSA oxygen concentrator is used for the feed gas. The Ozonation system also includes an inductor, a diffusor and two contactors.

**Renovated Water Storage Tank and Pressure Pump**

The water storage tank used to store the reclaimed water has a volume of 1200 L. The average day reclaimed water use is reported to be 585 L. Treated water from the reclaimed water tank can be re-disinfected before entering the distribution system.

## 5.0 Water Quality Objectives

The water quality objectives for the reclaimed wastewater are outlined briefly in the following table.

**Table 1**
**Reclaimed Water Quality Objectives for the Toronto Healthy House**

| | |
|---|---|
| **E-coli:** | Mean < 2.2 cfu / 100 ml over 7 tests |
| | No sample exceeding 14 cfu < 100 ml |
| **Turbidity:** | Average < 2.0 ntu |
| | No sample > 5 ntu |
| **$BOD_5$:** | < 5 mg/L |
| **TSS:** | < 5 mg/L |
| **Colour:** | < 5 TCU |
| **No odour and no foam** | |

The wastewater effluent disposal objectives are BOD/TSS concentrations of 40/40 mg/L at all times. The following table provides reported water quality test results for the wastewater treatment system.

**Table 2**
**Water Reuse Treatment Performance**

| Component | Chemical Parameter Levels Expected (mg/L) | Concentrations Observed (mg/L) |
|---|---|---|
| Septic Tank | 250/100 (BOD/TSS) | 266/39 (BOD/TSS after 3 months) |
| Waterloo Biofilter | 10/10 (BOD/TSS) | 16/10 (BOD/TSS after 4 months with 3 to 5 recirculation cycles) |
| RAL Sand Filter / Activated Carbon | | < 5/4 (BOD/TSS after 3 months, UV)<br>< 5/4 (BOD/TSS after 4 months, Ozone) |
| Total Nitrogen | | now achieving 70 to 80% removal |
| Total Nitrogen<br>Total Phosphorus<br>(in Toilet Tank) | | 35 to 50 mg/L TN<br>10 to 20 mg/L TP<br>(with ozonation) |
| Water pH | 6.5 to 8.5 | 8.2 with UV and 6.9 using ozonation |

Reclaimed wastewater was originally used for toilet flushing, laundry, baths and showers. The hot water developed a noticeable ammonia odour due to insufficient nitrification. There was also a light yellow colour in the final effluent due to soluble recalcitrant organics from paper and cooking. As a result, the showers and baths were disconnected from the reclaimed water treatment system and reconnected to the potable water system after two months of use.

The septic tank, biofilter and sand filter all took time to become biologically mature. After three months of use it was decided to change the UV disinfection unit to ozonation to help break-up dissolved organic molecules. The colour and odour problems in the water cleared up with ozonation. The change in the disinfection system also resulted in a low pathogen detection count which may have indicated a low ozone generation and transfer rate.

## 6. Facility Operation and Maintenance

To help ensure good treatment performance, residents of the Toronto Healthy House have had to become involved in checking and monitoring water quality. Residents monitor the performance of the wastewater treatment system by observing aesthetics of the treated water.

The system may be upset if commercial disinfectants and cleaners containing naphtha, chlorinated germicides, etc are used. Phosphates in laundry detergents should also be controlled, it is ideal to use safe biodegradable products. Recommendations provided to the homeowner include using less paper, using biodegradable products, minimizing the use of disinfectants and keeping chemicals, paints and solvents out of the system.

The potable water storage tank is checked regularly for the buildup of solids. Access hatches and sampling taps provide points to collect water samples and check water levels. Lime can be added to the rainwater in the cistern collection tank to raise the pH if required.

The septic tank needs to be checked about every six months and be pumped out every 3 to 5 years. The Orenco Biotube effluent filter must be inspected and/or replaced annually. The biofilter medium will settle over time due to the weight of the water. The upper media is contained in removal baskets and may require replacement every five years.
Monthly inspection of the complete system is recommended. A monitoring program undertaken at the Toronto Healthy House for the first year of operation is outlined in the following table.

**Table 3**
**Toronto Healthy House Monitoring Requirements**

| | | |
|---|---|---|
| **Monitoring Equipment Requirements:**<br><br>Flow Measuring Devices<br>On-Site Monitoring Equipment<br>All equipment is to be calibrated at regular intervals not exceeding one year.<br>Equipment accuracy is to be within +/- 5%. | | |
| **Raw and Treated Water Quality Tests (Parameters and Frequency)** | | |
| Quarterly | | Weekly |
| Alkalinity | Conductivity | Total Coliform |
| Hardness | Chloride | Fecal Coliform |
| Calcium | Sulphate | Turbidity |
| Sodium | Ammonia & Ammonium | Colour |
| Iron | Total Kjeldahl Nitrogen | pH |
| Copper | | |
| Lead | | |
| Zinc | | |
| Arsenic | | |
| Aluminum | | |
| Manganese | | |

## 7. Monitoring Equipment and Costs

The total system capital cost for potable and wastewater treatment systems in the Toronto Healthy House is reported to be $15,000.00. The total operating costs are estimated at $800/year.

The following table provides a list of approximate component costs for the wastewater treatment system.

**Table 4**
**Principal Component Costs of Wastewater Treatment Components**

| Unit | Supplier | Model | Approximate Equipment Cost (exclusive of taxes and installation) |
|---|---|---|---|
| Control Panel with Timer | Simplex | | $ 556.00 |
| Septic Tank | | Precast Concrete Tank (3600 L) | $1000.00 |
| Biotube Effluent Filter | Orenco Systems Incorporated | 4" diameter | $89.00 |
| Recirculation Tank | | Precast Concrete tank (2000 L) | $700.00 |
| 2 Float Switches | | Super Single | $134.00 |
| Alarm Float | | | $45.00 |
| Pump | | BF33E 1/3 HP | $246.00 |
| Waterloo Biofilter Tank | Waterloo Biofilter Systems Incorporated | | $1000.00 |
| Waterloo Biofilter Inserts (Fan, dist. system, baskets) | Waterloo Biofilter Systems Incorporated | | $3250.00 |
| Pipe and Fittings | | | $200.00 |
| Roughing and Combined Sand Activated Carbon Filters | | | $2500.00 |
| Ozonation Unit | | 40 watt corona generator | $500.00 |
| **Total Equipment Cost (exclusive of monitoring equipment)** | | | **$10220.00** |

The estimated cost to provide full municipal services to this house was $205,000.

**References**

Townshend, A. R., E. C. Jowett, R. A. LeCraw, D. H. Waller, R. Paloheimo, C. Ives, P. Russell and M. Liefhebber. 1997. Potable Water Treatment and Reuse of Domestic Wastewater in the CMHC Toronto Healthy House.

Toronto Healthy House opens. September 1996. On the ground: Applications of CMHC's housing technology research.

Townshend, A. R. December 1996. Commissioning Guide for the Toronto Healthy Houses Water Systems. Blue Heron Environmental Technology.

Townshend, A. R. April 1996. Monitoring Program for the Toronto healthy Houses Water Systems. Blue Heron Environmental Technology.

Paloheimo, R. 1996. Reusing Treated Wastewater in Domestic Housing: The Toronto Healthy House Project. Creative Communities.

Factsheet: CMHC's Healthy House in Toronto
CMHC's Healthy House in Toronto is:
No Connections to Municipal Electricity, Water or Sewers.

Personal Communications

## A2. PILOT WATER MANAGEMENT PROJECT, NORTHWEST TERRITORIES

- **Number of buildings**
  Three units are under construction at the Ndilo and Dettah territories outside Yellowknife; four additional units are slated for installation in May, 1998 at Holman, Victoria Island, NWT.

- **Type of use**
  Single-family rental homes owned by the Northwest Territories Housing Corporation.

- **Purpose of implementing reuse / recycling**
  To provide a basis to assess the public health implications and safety of such systems; to obtain information to develop recommendations for permanent operation and maintenance of similar systems; to assess the appropriateness of onsite wastewater treatment and recycling in the North.

- **Current status**
  Under construction

- **What wastewater is reused**
  Blackwater and greywater.

- **Applications of reused water**
  Renovated water is to be used for toilet flushing, bathing, laundry, and garden hose faucets.

- **What wastewater treatment technology is used**
  The system installed at these locations will be identical to the system installed in the Toronto Healthy House project. The system will include a septic tank, recirculation tank, Waterloo Biofilter™, slow sand filter / activated carbon adsorber, and ultraviolet disinfection unit.

- **How excess wastewater is disposed of**
  Unlike the Toronto Healthy House installations, all wastewater will undergo the complete treatment and disinfection process, rather than being diverted to the leach field after passing through the Waterloo Biofilter. The treated effluent will be suitable for off-site uses, including firefighting, street cleaning, park and agricultural irrigation.

- **Daily water balance**
  Unknown.

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  Unknown.

### References

Bedinger, M.S., A.I. Johnson, J.S. Fleming, eds., 1997. *Site Characterization and Design of On-Site Septic Systems.* [ASTM STP 1324]. American Society for Testing of Materials.

Paloheimo, R. and A. Townshend, 1998. Terms of Reference for an Independent Monitoring Program. [Proposal to Northwest Territories Housing Corporation Pilot Water Management Project].

Townshend, A.R., E.C. Jowett, R.A. LeCraw, D.H. Waller, R. Paloheimo, C. Ives, P, Russell, M. Liefhebber, 1997. Potable Water Treatment and Reuse of Domestic Wastewater in the CMHC Toronto Healthy House. In Bedinger et al., 1997.

## A.3 CANADA MORTGAGE AND HOUSING CORPORATION CONSERVATION CO-OP RESIDENTIAL LIGHT GREYWATER RECLAMATION PROJECT

**TABLE OF CONTENTS**



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## 1.0 HIGHLIGHTS OF FINDINGS

The light greywater treatment system at Ottawa's Conservation Co-op incorporates screening, vortex suspended solids separation, sedimentation, multi media filtration and ozonation for the treatment of bath/shower wastewater. The research treatment facility is capable of meeting effluent criteria established by health and environment agencies. Several factors related to the unit processes have affected treatment reliability performance and modifications to the facility have been proposed. The facility continues to be monitored.

## 2.0 RESEARCH PROJECT DESCRIPTION

3.0

Canada Mortgage and Housing Corporation initiated a research project with a Conservation Co-op in the City of Ottawa for the design, installation and monitoring of a treatment facility for light greywater. The system uses treated bathtub/shower water for the toilet flushing within a cluster of eight units in the apartment complex.

## 3.0 CONSERVATION CO-OP COMPLEX AND WATER RECLAMATION PROJECTError! Bookmark not defined.

The Conservation Co-op is a four story 84 unit apartment building located at 140 Mann Avenue in the Sandy Hill district of Ottawa. The project was one of a small group of multi-unit residential buildings in North America to incorporate a wide range of environmental features within its design, while also paying attention to cost effectiveness, health and social impact issues.

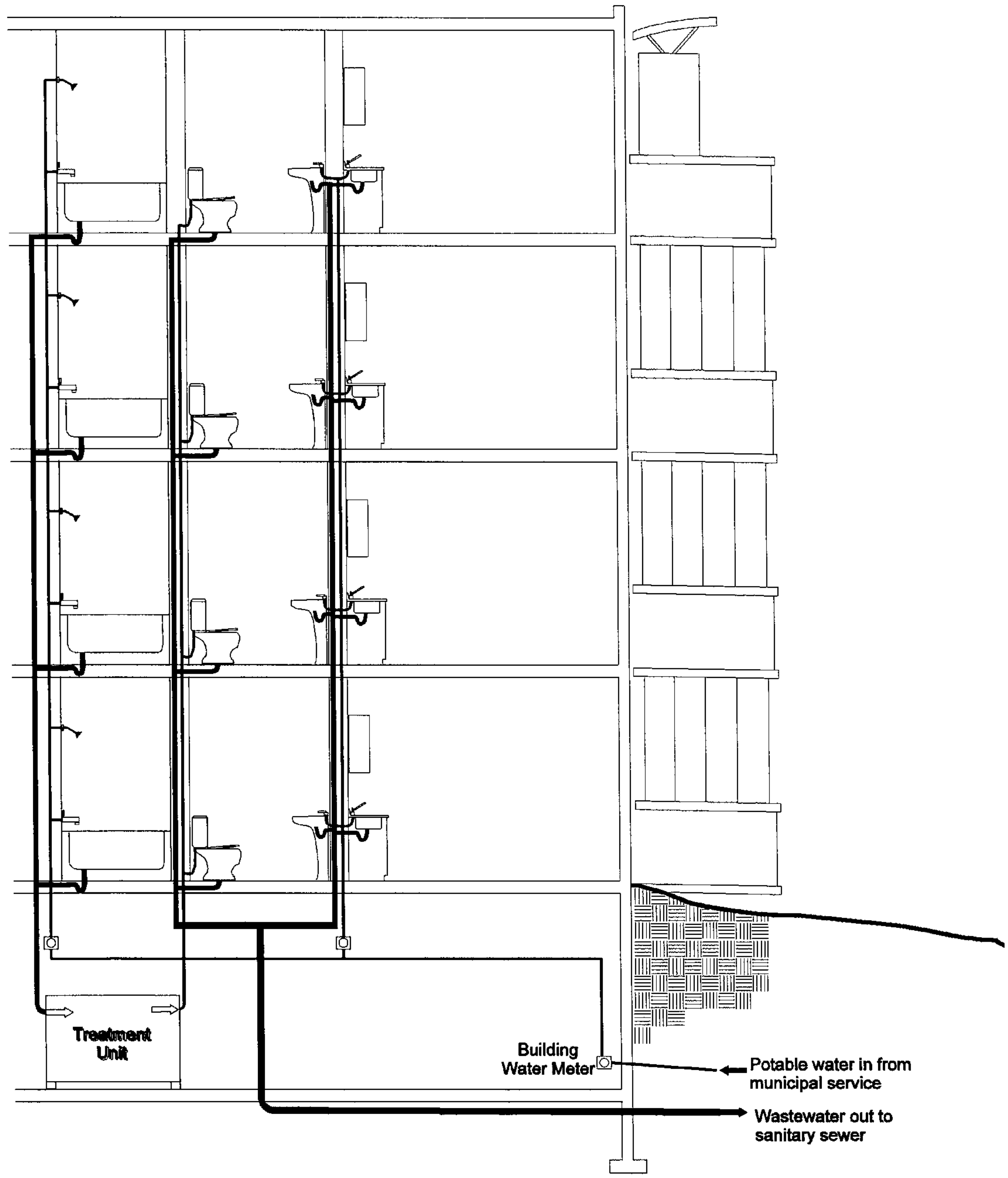
While the housing project's unique design and sensitivity to environmental issues is significant, there is even a greater commitment to developing a "green" project by the residents in the Co-op. They follow the Co-op Code of Environmental Practice that includes the following principles:

- a commitment to using "environmentally-friendly" cleaning products in the Co-op;
- acceptance of the limited availability of parking;
- acceptance and non-substitution of low-flow plumbing fixtures and energy-efficient lighting;
- the prohibition of air conditioners; and
- commitment to the separation and sorting of recyclable materials and use of the provided recycling rooms.

When the building was completed in 1995, eight units were constructed with dual plumbing systems so that a water reuse research and development project could be conducted in the future.

The dual systems consisted of one plumbing system for the light greywater from the bath or shower, and a second system for wastewater from the toilets and wash basins. The water supply to the units was also separated. One supply line was exclusively for toilet flush water and the second serviced all other sources of water in the units. The plumbing system is schematically illustrated in **Figure 1**.

CMHC SCHL




| totten sims hubicki associates<br>ENGINEERS ARCHITECTS AND PLANNERS | FIGURE 1<br>Plumbing Schematic<br>(Light Grey Water Treatment System) | Conservation Co-op | | |
|---|---|---|---|---|
| | | Scale: N.T.S. | Date: December 1996 | TSH No. 18-12432-DJK |

The research project, sponsored by Canada Mortgage and Housing Corporation, was set up in two phases. The first phase entailed:

- installation of meters to determine the amount of water being used for bath/shower and toilets in the eight units;
- determining characteristics of light greywater;
- development of design criteria for treatment facility; and
- assessment of potential treatment facilities and design of a system to provide safe, reliable water for the toilets.

The second phase included the installation of the designed treatment facility and monitoring of its performance.

In early 1997, Totten Sims Hubicki (TSH) completed Phase One. The metering information showed that approximately 500-550 L/day were used in the toilets of the eight units. Total daily water use was about 2,600 L/day. Since there are no laundry facilities in the individual apartments, it was assumed that the shower/bath water use was a high proportion of the daily use; perhaps in the range of 50-60% or 1,300 - 1,560 L/day. Based on this information a light greywater reuse water balance was developed for the design which is illustrated in **Figure 2**.

Since light greywater excludes kitchen and toilet water it was expected constituent level in the wastewater would be lower than normal wastewater. Monitoring of the light greywater at the Co-op showed a wide variance in its quality as presented in **Table 1**.

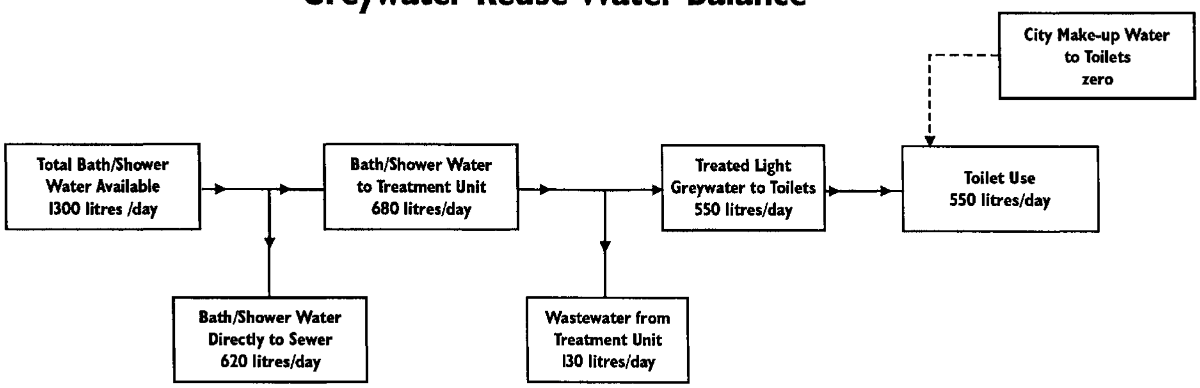
**Table 1**
**Typical Quality Values for Light Grey Water at Conservation Co-op**

| Parameter | Average Concentration | Range |
|---|---|---|
| BOD (mg/l) | 200 | 22-299 |
| T.S.S. (mg/l) | 48 | 2-284 |
| Colour (T.C.U.) | 3 | 2-5 |
| Turbidity (N.T.U.) | 68 | 17-116 |
| Total Phosphorus (mg/l) | 0.19 | 0.12 - 0.24 |
| Total Nitrogen (mg/l) | 8.3 | - |
| E. Coli (#/100 ml) | 564 | 0 - 23,000 |

A process designed by T.S.H. to treat light greywater from the showers/bathtubs in the eight apartments and recycle the treated water for toilet use is shown in **Figure 3**. Criteria used in the design of the pilot plant is noted in **Table 2**. To fabricate and install the pilot plant as designed was estimated to cost $35,000.

CMHC SCHL

## Greywater Reuse Water Balance




| | | | | |
|---|---|---|---|---|
| totten sims hubicki associates<br>ENGINEERS ARCHITECTS AND PLANNERS | FIGURE 2<br>Greywater Reuse Water Balance | Conservation Co-op | | |
| | | Scale: N.T.S. | Date: December 1996 | TSH No. 18-12432-DJK |

**CANADA MORTGAGE AND HOUSING CORPORATION CONSERVATION CO-OP**
**RESIDENTIAL LIGHT GREYWATER RECLAMATION PROJECT**

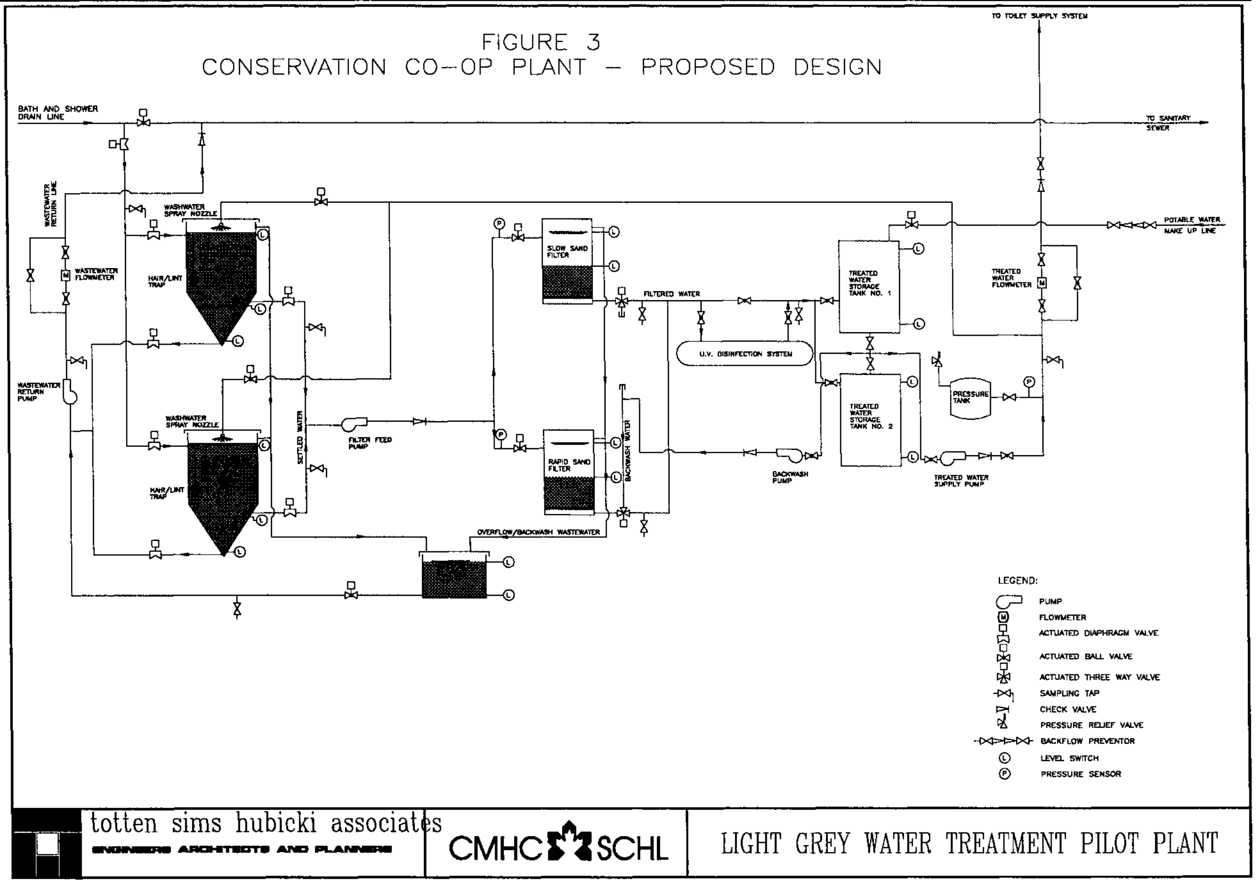
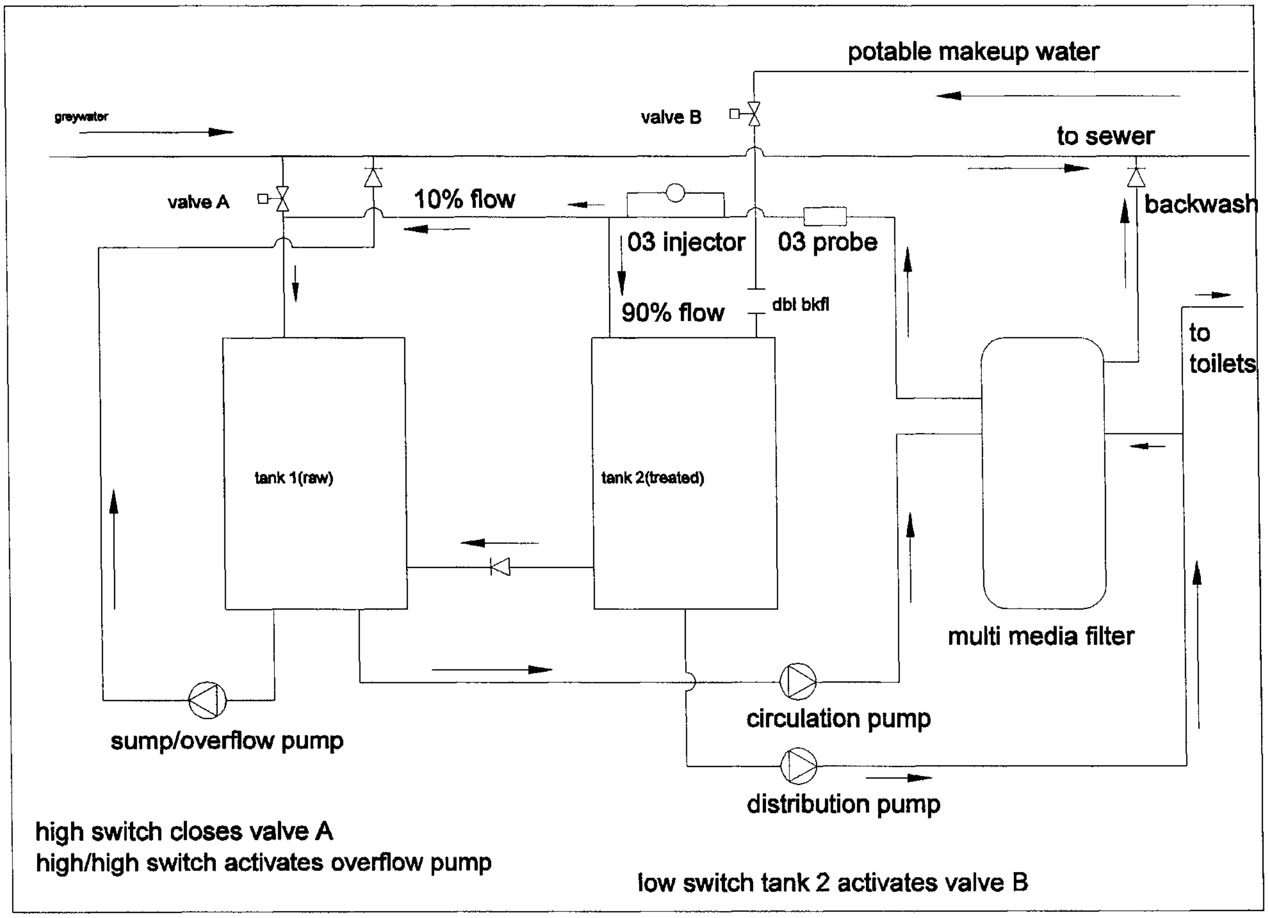


FIGURE 4
DESIGN OF INSTALLED PLANT




THE WATER STORE

**Table 2**
**Pilot Plant Design Description Conservation Co-op**

| Process | Design Details | Comments |
|---|---|---|
| Unit size | 680 L/day (150I.G.P.D.) | Toilet use 550 L/day. Solids wasting, backwashing and cleaning 25% of inflow-130 L/day<br>Total 680 L/day |
| Influent Flow Equalization | 2 - 340 litre tanks | Dual function of tanks: equalization and sedimentation System to operate in a batch mode |
| Screening | Hair/lint trap | Filter bag type |
| Sedimentation/Floatation | Hopper Bottomed tanks for solids collection and removal | To settle solids and waste to sewer. To flush out floating oils, foam, detergent products. |
| Filtration | Two filters;<br>• slow sand filter 0.125 m/h<br>• rapid sand filter 7.5 to 10 m/h | Two filters selected for flexibility and research component |
| Disinfection | Ultraviolet radiation using UV water sterilizer | Reduction of bacteria and viruses |
| Solids/Wastes Handling and Removal | Solids removal to deal with<br>• sedimentation tank solids<br>• sedimentation tank rinse water<br>• filter backwash wastewater<br>• overflows from all tanks | All discharges conveyed to sanitary sewer system |
| Treated Water Storage | 2 interconnected tanks 400 litres in size | To provide a source of treated water for pumping to toilets, cleaning of system and backwashing |

Criteria used in the design of the pilot plant is noted in **Table 2**. To keep the costs down and simplify the system a redesign was undertaken by The Water Store. Their system was installed and commissioned in July 1997 at a cost of approximately $22,800.

## 4.0 PROCESS CONFIGURATION AND ATTRIBUTIONS

The custom-designed unit by the Water Store for the treatment of the light greywater is shown in **Figure 4**. The pilot plant was sized to supply treatment water in excess of the toilet use requirements of the eight units with a 25% allowance for backwashing, solids wasting, and system cleaning. The unit is sized to provide a minimum of 680 L/day of reclaimed water.

The light greywater system in the Conservation Co-op is located in the bicycle storage room in the basement of the Co-op building. The main components of the light greywater treatment system are vortex suspended solids separation (EXCLUDER), a basket strainer, an equalization/sedimentation tank, a multi media filter, an ozone disinfection unit and a treated water storage tank. The Excluder was designed by Mr. Winston MacKelvie.

The wastewater reclamation system includes backwash and overflow features which assist in the treatment process. To control foaming and assist in the disinfection process, the sedimentation tank is ozonated with approximately 10% of the produced disinfectant. A sampling tap is located in the treatment process to monitor the reclaimed water to the eight units.

## 5.0 EQUIPMENT EVALUATION

### 5.1 Reclamation Treatment System

Water from the showers and baths of the eight units is collected in the equalization/sedimentation tank. Before the wastewater enters the tank, it passes through a separator to remove large solids and a basket strainer to trap hair and other medium-sized particles. The 0.76 metre diameter by 1.35 metre premier VU130 tank retains the wastewater to allow for the sedimentation of solids. The tank also serves as an equalization basin to handle the variable flow of the wastewater. The sedimentation/equalization tank is partially supplied with treated greywater which is cycled back from the treated water storage tank.

The water is pumped from the sedimentation/equalization tank through the multi-media filter using a Grundfos UP15-20 1/10 hp circulator pump. The sand filter is a MacClean CBW1001 filter filled with multi-media. The filter serves to remove residual solids that were not removed in the sedimentation process. The filter media is comprised of a top layer of anthracite, 350 mm thick, followed by a 150mm layer of sand, a 100mm layer of garnet and a 75mm layer of gravel at the bottom of the filter. The filter is backwashed every 24 hours.

After passing through the filter, the water is conveyed to the treated water storage tank which is of the same model and dimensions as the equalization/sedimentation tank. The storage tank is used to meet the fluctuating demand for the reclaimed wastewater. If the water level in the treated water storage tank is not high enough to meet demand additional volume is supplied with municipal water.

From the storage tank, the water is pumped through an Aqua Aire SW400 ozone generator with a Grundfos Jet Paq JP4 Pressure System and circulated back to the storage tank. Ozone is a strong oxidant that kills bacteria and viruses found in the wastewater. Ozone can effectively remove taste, odour an colour producing compounds. Ozone will leave no residual in the treated water but due to the short contact time with the wastewater, partially oxidized organic compounds may remain in the treated water. This ozone assists in the control of foam.

## 5.2 System Alterations

After two weeks of operation a 1 hp pump was installed by The Water Store to convey sufficient quantities of greywater through the filter. It was subsequently determined that the 1 hp pump was not suited for the filter media as clogging problems were encountered. The 1 hp motor was replaced with one 1/10 hp pump to reduce flow through the filter to conform with media design. It was also discovered that the filter media initially used was not appropriate for greywater systems. Multi-media was used to replace the original filter media.

A multi-media filter provided more effective use of the bed depth and increased the filter run time before backwash was required. The filter was backwashed daily after installation of the new filter media. Longer filter runs can occur if the solids removed in the sedimentation system is operating effectively.

It was discovered that there was problem with the inflow control valve not shutting properly. The inflow line had to be capped and secured. Later a manual valve was installed in the greywater line to permanently shut off the greywater influent during periods when the unit was not in use.

Problems have been encountered with the ozone unit. The unit was sent back to the manufacturer and subsequently repaired. It is currently operating properly. Other alterations included raising the outflow pipe on the equalization/sedimentation tanks. This reduced the carryover of solids from the equalization/sedimentation tanks to the filters.

# 6.0 TREATMENT PERFORMANCE

The proposed water quality criteria for light greywater reuse established for the purposes of this project are outlined in Table 3.

**Table 3**
**Water Reclamation Quality Objectives for the Conservation Co-op**

| Parameter | Concentration in Treated Greywater Effluent |
|---|---|
| Turbidity | 20 units |
| Colour | 30 units |
| Suspended Solids | 10 mg/l |
| Iron | 1 mg/l |
| Manganese | 0.5 mg/l |
| Bacteriological Content | Conform to Drinking Water Standards |

The monitoring program is still is in progress, however some preliminary treatment results are presented in Table 4.

**Table 4**
**Preliminary Water Reclamation Treatment Performance Results**

| Parameter | Concentration Observed |
|---|---|
| Turbidly | 6 N.T.U. |
| Colour | 2 T.C.U. |
| Suspended Solids | 13 mg/l |
| BOD | 19 mg/l |
| E. Coli | 17 counts/100 ml |
| Total Phosphors | 0.11 mg/l |
| Iron | 0.09 mg/l |
| Manganese | 0.01 mg/l |

Basically, the unit is meeting established water reclamation objectives except for the bacteriological quality.

## 7.0 FACILITY OPERATION AND MAINTENANCE

The Conservation Co-op wastewater treatment system was intended to function with minimum operation attendance. The system pumps operate continuously with tank levels controlled by floats.

The basket strainer needs to be checked regularly for buildup of solids. It is recommended it be cleaned weekly or as required.

The rapid sand filter at present must be backwashed daily. It is currently backwashed automatically on a timer control. Longer filter runs can be achieved by maximizing the removal of solids prior to the filter.

Sediment accumulates in the bottom of the sedimentation/equalization tank. Because the tank is flat bottomed, sediment removal is accomplished with a wet/dry vacuum. The sediment needs to be removed monthly. When the sedimentation/equalization tank is emptied for cleaning, the treated water storage tank also empties. At this time, the storage tank can be inspected to determined if cleaning is required.

The pumps are checked daily to confirm they are running properly.

The ozonator requires regular maintenance as it tends to build up dirt and residue on the basket contactors which needs to be cleaned. Oxidation potential metering probes need to be checked and cleaned. The probes should be replaced annually.

Modifications to the treatment facility are being explored to reduce the maintenance to a monthly program.

## 8.0 FACILITY COSTS

Table 5 provides a list of component costs for the waste water treatment system.

**Table 5**
**Principal Component Costs of Wastewater Treatment Components**

| Unit | Cost |
|---|---|
| 2 Premier VU130 Tanks | $ 1,070 |
| Basket Strainer | 105 |
| MacCLEAN CBW1001 Filter, Media & Alternative Backwash Valve | 1,510 |
| Grundfos Jet Paq JP4 Pressure System | 1,225 |
| Aqua Air SW410 Ozone Generator | 740 |
| 3 Pump Float Switches | 500 |
| Grundfos IPC Pumps | 310 |
| Grundfos KP200 1/3 HP | 650 |
| Electromni Activated Ball Valve | 420 |
| Electromni Motorized Ball Valve | 550 |
| Ozotech ORP Model 3000 | 1,890 |
| Ozotech ORP Probe # 32035 | 380 |
| Mazzi Injector #878 | 210 |
| Pipes, valves, switches, fittings, etc. | 1,740 |
| TOTAL | $ 11,300 |

The additional costs associated with the unit consists of the following:

| | | |
|---|---|---|
| Design, labour, commissioning | | $ 5,920 |
| Freight | | 350 |
| Plumbing | | 4030 |
| Electrical | | 1200 |
| | **Subtotal** | $11,500 |

Total cost to design and commission the unit was approximately $ 22,800

## 9.0 SAFETY

As with any wastewater treatment or electrical system, there are safety issues that must be addressed.

It is recommended that ozone disinfection system be located in a well ventilated area. The maximum naturally occurring level of ozone in air is 0.4 ppm. At 0.5 ppm ozone can cause irritation to eyes and nose. At higher levels, 1 to 10 ppm, ozone can cause headaches and nausea.

Before any maintenance is undertaken, pressure in pipes and filters need to be dissipated.

It is further recommended that wastewater storage tanks be located in a secure area that cannot be accessed by children. Signs can be posted in the area to warn of any possible dangers.

A fire extinguisher should be located in close vicinity to any electrical equipment.

## 10.0 CONCLUSIONS

The Conservation Co-op system is a small compact unit that is not technically complex. In case of failure, the units of the Co-op have their toilets hooked up to the municipal water supply.

The system is capable of meeting effluent criteria. Several factors related to the unit's treatment processes have affected treatment reliability. Performance and modifications are being explored. They include regular effective removal of solids and improved disinfection.

## A.4 SOOKE, B.C. OFFICE BUILDING (B.C. MINISTRY OF SOCIAL SERVICES)

- **Number of buildings**
  One

- **Type of use**
  Two-story office building (10000 $ft^2$), 24 full-time staff, two public washrooms.

- **Purpose of implementing reuse / recycling**
  No municipal sewer in area; insufficient space to install a conventional septic field due to large parking lot and small overall lot size.

- **Current status**
  Operational (system commissioned in April 1996).

- **What wastewater is reused**
  Blackwater and greywater.

- **Applications of reused water**
  Recycled wastewater is used for toilet flushing.

- **What wastewater treatment technology is used**
  A Zenon Cycle-Let® treatment system is used to treat the wastewater for recycling. The system incorporates a trash trap / sump tank, bio-oxidation, membrane filtration, carbon filter, and ultraviolet disinfection. The treatment capacity is 4550 L/day. *(See Cycle-Let technology summary).*

- **How excess wastewater is disposed of**
  Excess wastewater (82 L/day) is discharged to a subsurface disposal field.

- **Daily water balance**
  potable water consumption: 82 L/day
  non-potable renovated wastewater consumption: 1736 L/day
  excess wastewater discharged to leaching bed: 82 L/day

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  Annual savings of over 270,000 litres of potable water.

- **References**
  Corporate literature, Hill Murray & Associates Inc., Victoria, BC
  Corporate literature, Zenon Municipal Systems, Ann Arbor, MI

## A.5 SUSTAINABLE TECHNOLOGY CENTER, FRIDAY HARBOR, WA

- **Number of buildings**
  Two

- **Type of use**
  Low density commercial / office development (16000 $ft^2$ in two buildings)

- **Purpose of implementing reuse / recycling**
  Local interest in implementing sustainable technologies; limited subsurface wastewater drainage capacity due to island location.

- **Current status**
  Operational (construction completed in 1995).

- **What wastewater is reused**
  Blackwater and greywater.

- **Applications of reused water**
  Recycled wastewater is used for toilet flushing and landscape irrigation.

- **What wastewater treatment technology is used**
  Wastewater is treated by a Hydroxyl Systems™ plant (capacity 6000 L/day). The system includes a surge / settling tank, an aeration chamber with attached growth media, a porous foam biofilter, and disinfection by "electro-mechanical advanced oxidation," a proprietary ozonation process. *(See Hydroxyl Systems technology summary).*

- **How excess wastewater is disposed of**
  No information available.

- **Daily water balance**
  Unknown.

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  No information available.

- **References**

http://www.hydroxyl.com/mun_04.htm
Wastewater Treatment and Water Re-Use at an Office Complex: 1500 gpd (6000 Lpd)

## A.6 WASTEWATER RECLAMATION IN AN APARTMENT COMPLEX IN JAPAN

### 1. Introduction

Japan's freshwater availability on a per capita basis represents approximately one fifth that of the United States'. Some serious water shortages have occurred in Japan's major metropolitan areas. As a result of water shortages and a need to reduce pollutant loadings in receiving water bodies, water conservation measures and reuse initiatives have become an integral part of the solution to water management problems in Japan.

This case study examines water reuse in an apartment complex just outside Tokyo, Japan. The complex, constructed in 1978, was designed with both an on-site wastewater treatment system and water reuse treatment facility. The apartment complex, comprising 2,250 apartments, was initially fitted to accommodate water reuse in 888 units. The 888 units represent a resident population of 3,200.

The water reuse treatment system supplies water for toilet flushing, surface wash water and represents a supply source for an ornamental pond and stream.

### 2. Treatment Facility Description

The wastewater treatment facility for the apartment buildings, referred to as the "S" complex, provides tertiary treatment. This wastewater treatment system comprises several unit processes and operations which include: screening, aerated grit chamber, comminutor, equalization tanks, extended aeration activated sludge, sedimentation, alum coagulant, flocculation, clarification, filtration and disinfection.

The water reuse treatment system handles tertiary treated wastewater incorporating additional processes such as ozonation, adsorption tower, chlorination and activated carbon. The apartment complex has dual plumbing systems: water reuse and potable water plumbing.

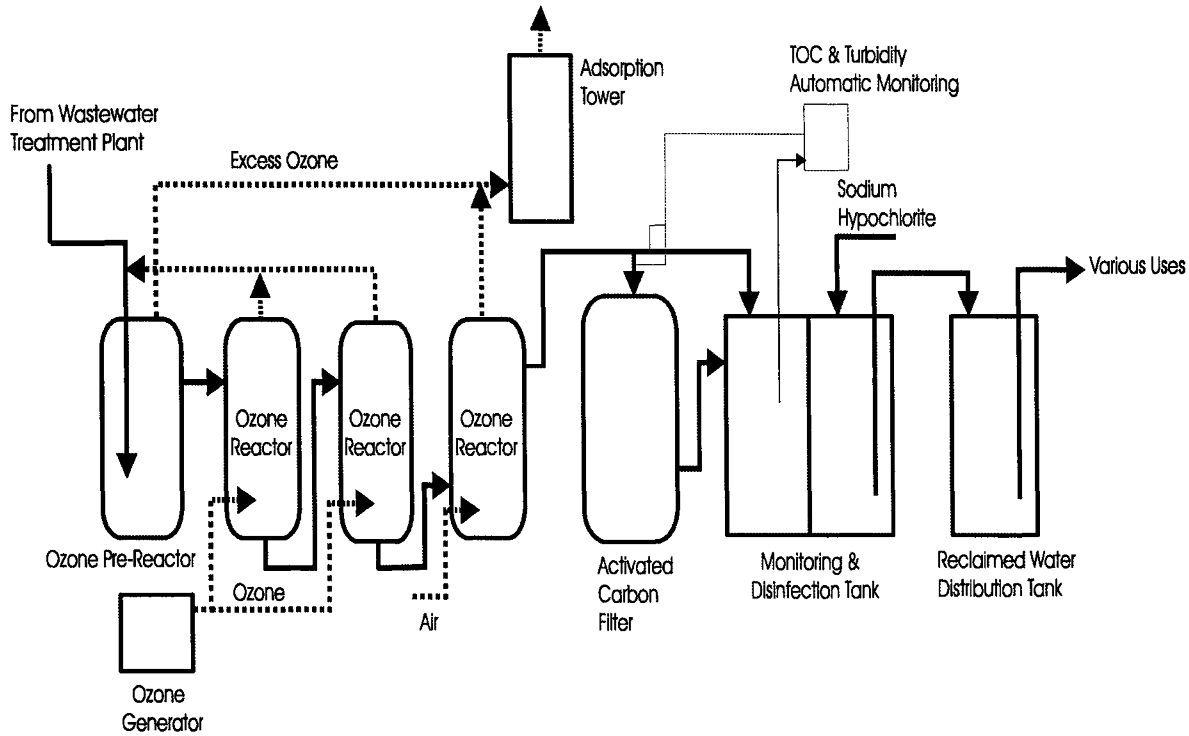
Average day wastewater generated from the apartment complex is 1,222 $m^3$ which represents 260 l/day/capita. Water reuse accounts for approximately 15% of total average water usage (160 $m^3$/day) in the complex.

### 3. Wastewater Treatment Configuration and Attributes

The wastewater treatment process reduces wastewater BOD from average influent levels of 200 mg/l to 10 mg/l. Suspended Solid levels are reduced from average levels of 250 mg/l to 10 mg/l. Approximately 75% to 80% of the treated wastewater is disinfected and discharged to a surface watercourse. The remaining 20% to 25 % of the treated wastewater is diverted to the reuse treatment facility.

Treated wastewater, prior to disinfection, can be diverted from the wastewater stream to the reuse treatment facility through a distribution splitter box. In the water reuse treatment process, tertiary treated effluent enters two ozone reactor vessels, connected in series. The ozone removes colour, odour and disinfects the water. Disinfected water is then pumped into an aeration chamber to provide retention time for ozone decay. The water then is pumped into a monitoring and disinfection tank where sodium hypochlorite is added. The water reuse treatment process is illustrated in Figure 1.

**Figure 1**
**Reclaimed Water Treatment Schematic Diagram**




Treated water is automatically tested for TOC and turbidity. When TOC and turbidity measurements are less than 15 mg/l and 5 NTU respectively, treated water is then pumped into a chlorine retention tank for final disinfection and distribution, otherwise it is pumped to an activated carbon filter.

Reuse water pipes were constructed of epoxy coated steel and marked with tape to further distinguished reuse plumbing from potable water lines. Flow metres were installed on a number of apartments to monitor water usage. A yellow shaded toilet was installed in the apartments to help mask any potential fixture discolouration.

## 4. Equipment Evaluation

### 4.1 Wastewater Treatment

The wastewater treatment equipment and process stream is described herein. Initially, wastewater is screened before entering an aerated grit chamber. The grit chamber removes particles 0.2 mm or larger and provides a 2 to 5 minute retention time at peak design flow.

Effluent from the grit chamber flows through a communitor to grind up coarse solids on the way to the aeration tank. The aeration tank is an activated sludge process which reduces organic loading. Aerobic bacteria are maintained in suspension then settled out in a sedimentation basin. From the sedimentation basin, wastewater flows to a flocculation tank where alum is added to form a floc. The flocs settles out in a clarification tank. Dual media filtration is used to further reduce suspended solids levels before disinfection.

## 4.2 Water Reuse Treatment

Tertiary treated wastewater is initially ozonated in the water reuse treatment facility. Two ozonation vessels are linked in series to provide colour and odour removal and disinfection. The ozone generators are automated to regulate ozone generation. A stand-by ozone generator is also provided for emergency conditions. Excess ozone is collected and released in an adsorption tower.

Following ozonation, the treated water quality is monitoring prior to final disinfection with sodium hypochlorite. The sodium hypochlorite solution is used to provide and maintain a disinfectant residual in the distribution system.

Monitoring controls in the water reuse treatment process ensure water quality meets a reuse standard of 15 mg/l (TOC) and 5 NTU (turbidity). A system operation is activated when measurements, taken every 15 minutes, indicate the treated water quality fails to meet this standard requirement. Upon failure the water is pumped through an activated carbon filter and then retested. Should the water still fail to comply with the standard a second time, the process is shut down.

## 5. Water Reuse Treatment Performance

Extensive monitoring of the facility has been performed. The wastewater reclamation criteria used in Japan is the Ministry of Construction's "Technical Guidelines for Wastewater Reclamation and Reuse". Water quality criteria and sampling results for reclaimed water use in the "S" apartment complex are presented in the following table.

## 6. Cost

Wastewater and reuse treatment facility capital costs are reported in Table 2. Costs are based on a Yen conversion to US dollars considering 1978 exchange rates.

The capital cost per apartment represents approximately $873 US for the reuse treatment facility. A monthly charge of $2.20 is levied against each apartment to cover reclaimed water treatment system operation and maintenance costs. In 1978, the chargeable potable water rate was $0.62/m$^3$.

## 7. Observations and Conclusions

An opinion survey was conducted to evaluate public acceptance of recycled water. At that time eighty-four (84) percent of the users reported that they had not noticed any difference (colour and odour) in toilet water from tap water. A large majority of the users indicated agreement with water reuse concepts considering it a viable and necessity measure to conserve water.

**Table 1**
**Water Reuse Treatment Performance**

| Parameter | Treatment Criteria | Treatment Performance (arithmetic mean) |
|---|---|---|
| Odour | no criteria | |
| Colour | < 10 | 0.9 |
| Turbidity | < 5 | 0.3 |
| Total Dissolved Solids (mg/L) | < 1000 | 445 |
| Suspended Solids (mg/L) | < 5 | 1.3 |
| pH | 5.8 - 8.6 | |
| Chemical Oxygen Demand (mg/L) | < 20 | 3.5 |
| Biochemical Oxygen Demand (mg/L) | < 10 | 2 |
| Phosphorus (mg/L) | < 1 | 0.5 |
| Coliform (organisms/ml) | no criteria | |
| General Bacteria (organisms/ml) | < 100 | |
| Residual Chlorine (mg/L) | < 0.2 | |
| Total Organic Carbon (mg/L) | < 15 | 4.1 |

**Table 2 - Costs of the Reclaimed Water Treatment System (1978)**

| Facility | Components | Cost ($US) |
|---|---|---|
| Wastewater Reclamation | Ozonation, Monitoring, Chlorination, activated carbon, electrical | 403,624 |
| Indoor piping and facilities | Dual system piping | 83,534 |
| Outdoor piping and facilities | Dual system piping | 174,038 |
| Reclaimed water tank and facilities | Tank, distribution systems, electrical | 114,162 |
| Total Cost (US 1978 dollars) | | 775,358 |

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## A.7 SIX HOMES IN CANBERRA AUSTRALIA

### 1. Highlights of Findings

Six homes in Canberra Australia were disconnected from the municipal sewage system and retrofitted with in-house wastewater treatment systems. Both blackwater and greywater are treated for reuse in irrigation and toilet flushing.

Two homes have been installed with conventional aerated septic systems and the remaining homes have activated sludge systems installed. The wastewater effluent in each of the six homes is disinfected by either ultraviolet irradiation or chlorine after primary treatment. The quality of effluent produced by the in-house treatment systems meets the parameters set by the Australian Capital Territory.

### 2. Treatment Objectives

Australian Capital Territory Electricity and Water (ACTEW) is investigating ways to reduce potable water demand and to address pollution concerns in receiving lakes and rivers. In 1995, ACTEW initiated a project where six urban houses in Canberra, Australia, were disconnected from the municipal sewage system. Each residence was equipped with an in-house wastewater treatment system. The treated wastewater is reused for toilet flushing and garden irrigation purposes.

The project was initiated to examine and minimize treated wastewater effluent volumes being discharged to the Murrimbidgee River and to provide information on the beneficial impacts of treating wastewater on-site and water reuse applications. The major advantages recognized for an in-house wastewater treatment and reuse system are associated with the cost of providing lot services, a centralized sewage treatment system and a reduction in water consumption. Additional objectives of the project were to determine changes in phosphorus levels, salinity and other soil properties in the residential gardens when irrigating with reclaimed water.

### 3. Process Configuration and Attributes

The six homes were equipped with one of two different wastewater treatment systems. Two homes were fitted with an aerated septic system and in the remaining four homes activated sludge treatment systems were installed.

Wastewater generated in each home is treated in the system then disinfected. Chlorine disinfection is used in five (5) of the residences and ultraviolet disinfection is used at the other. Treated effluent at each home is stored in a 13,000 L storage tank. The disinfected water is used for garden irrigation and toilet flushing.

### 4. Process Equipment

The wastewater treatment process in the aerated septic system comprises four stages. After wastewater screening a chamber represents an initial anaerobic stage where solids are allowed to settle. Overflow from the first chamber enters an aeration chamber where wastewater circulates through a submerged plastic media. Air is continuously pumped into the aeration chamber through a diffuser located in tank's bottom. Bacterial growing on the plastic media treats the wastewater. Occasional solids sloughs off the media where it is carried back into the settlement chamber. Settled solids and scum are also periodically air lifted back into the first chamber.

Treated effluent from the aeration chamber flows to a chlorine contact tank for disinfection. A thirty (30) minute contact time is maintained in the disinfection tank. After the disinfection process, the treated water is pumped to a 13,000 litre storage tank for circulation back into the distribution system.

The second wastewater treatment system comprises an intermittent cycle, extended aeration activated sludge process. Raw wastewater is screened before entering an aerobic chamber. Air is blown through a diffuser located in the tank's base which also is configured to keep organic material in suspension.

At regular intervals the air supply is switched off and the suspended material is allowed to settle. denitrification of the effluent is reported to occur during this stage of the process. The effluent from the aeration chamber is then disinfected with chlorine in a contact chamber. The water is retained in the chamber for a minimum of 30 minutes before being pumped to a 13,000 litre storage tank. One of the activated sludge systems uses ultraviolet radiation for disinfection.

## 5. Treatment Performance

Treated wastewater complies with Australian Capital Territory (ACT) Wastewater Reuse Guidelines. The ACT guidelines are presented in Table 1.

**Table 1**
**Treated Wastewater Reuse Guidelines**

| | |
|---|---|
| **Biochemical Oxygen Demand** | **20 mg/L** |
| **Suspended Solids** | **30 mg/L** |
| **Thermotolerant Fecal Coliform** | **30 cfu/100 ml** |
| **pH** | **6.5-8.5** |
| **Residual Chlorine** | **<0.5 mg/L** |

The Australian National Health and Medical Research Council guidelines require that the fecal coliform count have a median value not exceeding 1000 cfu/100 ml for five samples collected at not less than half-hour intervals. Wastewater sampling in the monitoring program was carried out on a monthly basis during the project's first year. In subsequent years, water parameter sampling frequency was reduced to every three months. Average monthly sample results obtained from effluent testing are presented in the Table 2.

**Table 2**
**Water Quality Sampling Results**

| | |
|---|---|
| **Biochemical Oxygen Demand** | **10 mg/L** |
| **Suspended Solids** | **8 mg/L** |
| **Thermotolerant Fecal Coliform** | **3 cfu/100 ml** |
| **pH** | **6.8** |

All of the above parameters met the water quality reuse criteria established by the Australian Capital Territory.

Approximately 90% of the individual test results were found to be in compliance with the ACT guidelines. Some individual houses achieved close to 100% compliance. It is reported that water sampling results at one house yielded results which did not comply. The concerned house with an activated sludge system had experienced problems with Nocardia bacteria growth forming a layer of scum at the top of the aeration chamber. This filamentous bacteria formed a poor settling biomass which carried over to the effluent. It was speculated this problem likely was associated with a household or medicinal product used in the home.

Soils in the irrigated area are sampled ten (10) times a year. Soil samples are analysed for inorganic nitrogen, total salinity and chloride concentrations. Sodium absorption ratios were measured to be approximately four, which is considered acceptable. To date no adverse soil effects have been reported.

## 6. Facility Operation and Maintenance

The monitoring program initiated in the homes is outlined in Table 3.

**Table 3**
**Monitoring Program**

| Test | Frequency |
|---|---|
| Fecal Coliform, Enterococci and Total Plate Count | Weekly for first 6 months<br>Monthly after 6 months |
| Cryptosporidium and Giardia | Every 6 months |
| Soil analysis for Fecal Coliform | Every 4 months during the first year<br>Every 6 months after the first year |
| Quality of effluent produced (Turbidity, Suspended Solids, Sp Conductance, pH, $BOD_5$, Ammonia, Nitrite, Nitrate, Phosphorus, Alkalinity, Dissolved Sodium, Calcium, Magnesium, Fecal Coliform, Enterocci, Total Plate Count, Total Chlorine Residual and Free Chlorine Residual) | Monthly during the first year<br>Every three months after the first year |
| Soil Profile and Ground water Quality | Before and after basis for comparison |

## 7. Safety

The irrigation water service lines for each residence were fitted with a reduced pressure zone backflow preventers and external taps were fitted with an anti-siphon device in accordance with the requirements of the plumbing code. Hose fittings for the reclaimed water taps were incompatible with normal hoses and all the reclaimed effluent lines were clearly marked.

Each individual treatment system was provided an alarm to notify users if the system was not functioning properly. The treatment systems had sufficient standby storage in the event of an emergency so water use would not have to be interrupted. The 13,000 litre tank was sized to accommodate sufficient reclaimed water storage for a three week period.

Householders were warned not to waste products containing bleaches, disinfectants and paint thinners as they could affect the system treatment performance and upset bacterial growth. Recommendations were provided for use of irrigation water including an advisory to minimize human or animal contact. Residents were also advised that reclaimed water should not be used to irrigate food crops which can be eaten raw or are not protected by a skin that would be removed prior to consumption.

## 8. Costing Results

The supply, installation and commission of the project cost approximately AUD$75,000. for all six sites. The treatment plants cost $5,000 and $4,400 respectively. The storage tanks and irrigation pumps etc. cost an additional $2,500 per site. The total installation cost at each residence was in the area of $12,000 Australian. These costs can be compared to the current cost of providing sewer and potable water services to a residence which is in the range of $16,000.

The cost of regular servicing of the plants was estimated to be $300/year. Monitoring and laboratory costs were expected to be approximately $80,000 for the duration of the study. Soil and Ground water studies added approximately $20,000 to the total cost of the project.

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Personal Communications

## A.8 CASA DEL AGUA, TUCSON ARIZONA

### 1. Highlights of Findings

Casa del Agua was developed in conjunction with the University of Arizona as a water-efficient, single-family research and demonstration facility. In 1985, an existing three bedroom, two bathroom, single family home, located in Tucson, Arizona, was designed and retrofitted for water and energy conservation. The home underwent plumbing modifications, architectural changes and was equipped with water-efficient appliances. This house became Casa del Agua, Spanish for "House of Water".

Casa del Agua stores rainwater and treats greywater for irrigation and toilet flushing reuse. Five water treatment systems were installed at Casa del Agua to assist in the selection and evaluation of a greywater treatment process. Each systems was readily adapted to the household pumping. Research was performed by the University of Arizona, with support of several local government agencies and private organizations.

The five treatment systems examined were:

1) Water hyacinths and sand filtration;
2) Water hyacinths, copper ion disinfection and sand filtration;
3) Aquacells, copper ion disinfection and sand filtration;
4) Aquacells, copper and silver ion disinfection and sand filtration; and
5) Cartridge filtration;

All systems treat greywater from the residence. Microbial and selected chemical parameters were studied for compliance with water reuse regulations in the State of Arizona. Samples were collected before and after greywater treatment on a bi-weekly basis.

### 2. Casa del Agua Description

During the course of the study, Casa del Agua was occupied by a typical family in order to provide realistic data for water and energy monitoring. The demonstration project provided an opportunity to research and test various domestic water treatment and conservation strategies.

Casa del Agua is equipped with water conserving shower heads, low-flush toilets, faucets with aerators and is landscaped with drought tolerant vegetation. Rainwater and treated greywater are collected and recycled for various reuse applications in order to reduce demand on municipal groundwater. It has been reported that the water conservation modifications and retrofits have reduced water use at the home by more than 50%. Approximately 31% of Casa Del Agua's total water budget is derived from recycled greywater.

The water used at Casa del Agua is supplied by the municipal groundwater system, a rainwater collection system and a greywater treatment system. Municipal groundwater is used to supply potable water to the sinks, showers and washing machine. Rainwater is stored for use primarily in lawn irrigation, evaporative coolers and some toilet flushing. Greywater is collected and treated for reuse in lawn irrigation and toilet flushing. Casa del Agua stores greywater produced in the winter months to meet landscape needs during the hot, dry summer months.

A study was conducted to install and examine five different treatment systems at Casa del Agua. The research allowed five (5) different treatment process to be compared for treatment performance, cost and reliability.

## 3. Process Configuration and Attributes

Rainwater draining off building, porch and greenhouse roofs is collected. Rain gutters were modified to add downspouts every twenty (20) feet as opposed to a more common forty (40) foot spacing. This ensured heavy rains would not overflow the gutter and could be collected. Rainwater supplies approximately 8% of the total dwelling water budget needs. This source is primarily used for landscape water with a limited quantity used for toilet flushing. Drought tolerant plants (xeriscaping) at Casa del Agua are irrigated through a sub-surface drip irrigation system.

The treated water distribution pipes at Casa del Agua are separate from the potable water system. Blackwater and kitchen sink water (with garbarator) are connected to a sewer for disposal. A washing machine, kitchen sink (sink without garbage disposal), wash basins, bath, and shower represent the greywater sources. Greywater is screened to remove lint, hair and other large particles then cycled to the in-house treatment system.

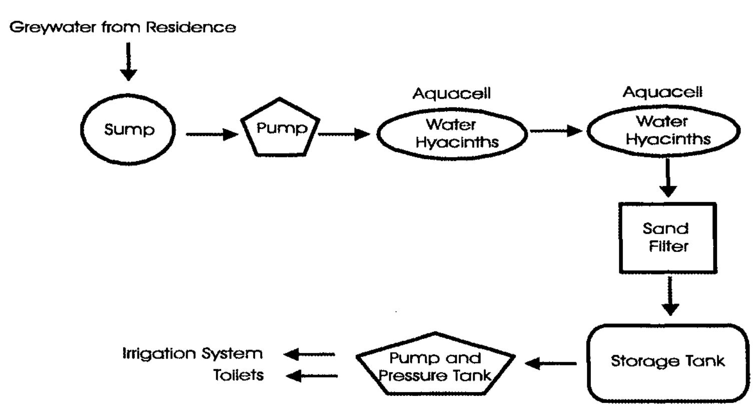
A description of the greywater treatment systems which were tested follows.

### Treatment System 1

The first greywater treatment system tested at Casa del Agua was a water hyacinth / sand filtration process. Greywater was pumped from a sump tank to a 1200 L galvanized tank, called an aquacell. Dual aquacells supporting water hyacinths were connected in series. Mean retention time in the aquacells was designed for approximately six days. Each tank was aerated using a small aquarium air pump.

Greywater from the second aquacell flowed into a sand filter for distribution through perforated PVC pipes buried just below the sand surface. The sand filter was 0.38 meters deep with a surface area of 3 square meters. Plants such as tomatoes and peppers were grown in the sand filter to help condition the soil. After passing through the sand filter, treated greywater drained into a 3,025 litre storage tank. The treated water was then available for irrigation reuse through a sub-surface drip irrigation system and/or re-routed back to the house for toilet flushing. A schematic of this treatment system is illustrated in Figure 1.

**Figure 1**
**Schematic of Treatment SystemOne**



**Treatment System 2**

Treatment system two represented a modification of System one. Changes in the process as illustrated in Figure 2 included recirculation of greywater from the treated water storage tank back to the first aquacell. Water was recirculated at a rate of 1,892 litres per hour. Before returning to the aquacell the treated water also passed through an electrostatic swimming pool purity unit for disinfection. The purity unit generated copper ions. An overflow pipe was introduced from the second aquacell to accommodate sand filter bypassing during hydraulic overload conditions.

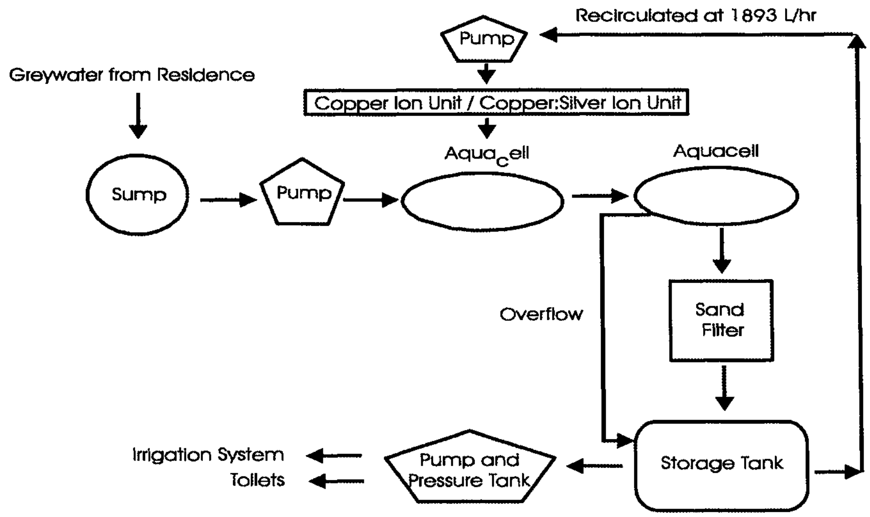



**Figure 2**
**Schematic of Treatment System Two**

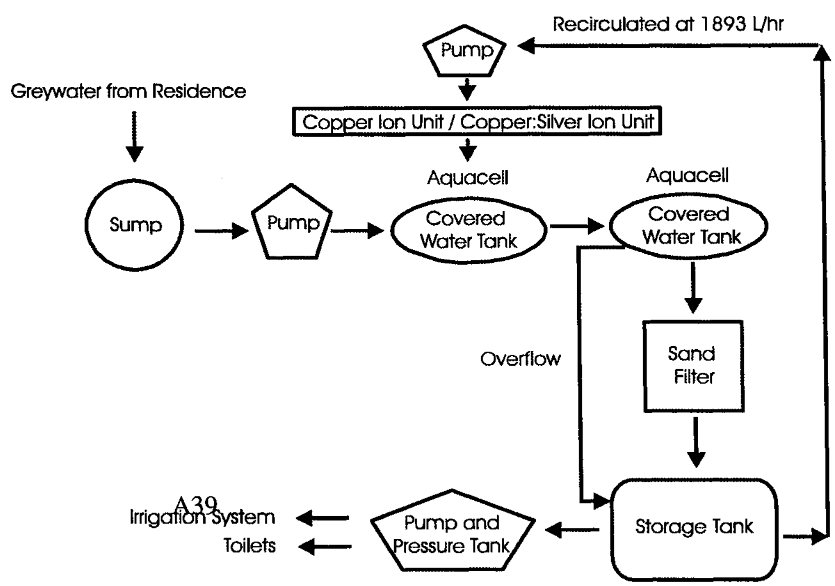
**Treatment System 3**

Treatment system three incorporated some additional modifications to system two. In this system the water hyacinths were removed and the aquacells covered with Styrofoam to minimize evaporation losses. Figure 3 illustrates a process schematic for treatment systems three and four.

**Treatment System 4**

Treatment System four was the same as Treatment System three with exception of the disinfection mode. A new electrostatic purity unity generating copper and silver ions was introduced for disinfection.

**Figure 3**
**Schematic of Treatment Systems Three and Four**



**Treatment System 5**

The final water treatment system (No. 5) represented a filtration process only. The aquacells and sand filter were removed and replaced with a 20 micron porosity cartridge filter. This process is illustrated schematically in Figure 4.

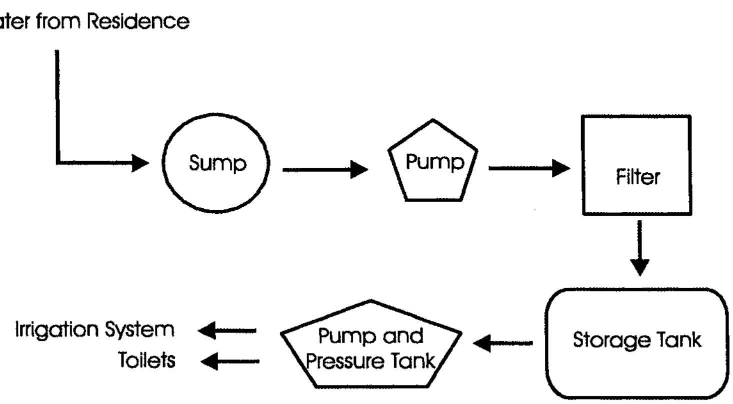



**Figure 4**
**Schematic of Treatment System Five**

## 4. Treatment Performance

The Arizona Department of Environmental Quality (DEQ) regulates the use of domestic greywater systems. Single and multi-family residences are permitted to use greywater for surface irrigation if they can meet applicable State requirements. The DEQ specifies that groundwater used for irrigation must incorporate a settling tank and a filtration device. When treated greywater water is to be used for surface irrigation, disinfection is required and the system must also compile with State water quality and monitoring specifications.

Treatment performance results for the five (5) systems tested in Casa del Agua, before and after treatment, are presented in Table 1.

**Table 1**
**Water Quality Test Results (Before and After Treatment)**

| Parameter | Treatment System 1 | | Treatment System 2 | | Treatment System 3 | | Treatment System 4 | | Treatment System 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | Before | After |
| Fecal Coliform ($Log_{10}$ CFU/100 mL) | 7.0 | 3.5 | 5.7 | 4.4 | 5.4 | 4.6 | 6.5 | 4.4 | 7.2 | 5.2 |
| Total Coliform ($Log_{10}$ CFU/100 mL) | 7.6 | 4.7 | 7.2 | 5.8 | 8.3 | 7.0 | 8.8 | 5.8 | 8.3 | 6.3 |
| pH | 6.7 | 6.7 | 7.7 | 7.7 | 7.6 | 7.8 | 7.6 | 7.8 | 7.5 | 7.8 |

| Parameter | Treatment System 1 | | Treatment System 2 | | Treatment System 3 | | Treatment System 4 | | Treatment System 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | Before | After |
| Nitrate (mg/L) | 1.8 | 1.5 | 2.3 | 1.4 | 2.8 | 2.3 | 2.0 | 2.0 | 3.0 | 2.6 |
| Suspended Solids (mg/L) | 40.3 | 16.8 | 35.8 | 4.7 | 48.0 | 9.3 | 19.3 | 7.0 | 19.1 | 7.7 |
| Turbidity (NTU) | 64.1 | 3.9 | 78.6 | 3.6 | 52.6 | 8.8 | 15.3 | 2.9 | 20.5 | 6.7 |
| Biochemical Oxygen Demand (mg/L) | 119.8 | 3.7 | NA | NA | NA | NA | NA | NA | NA | NA |

NA .. Data not available.

Treatment system performance results for key parameters are summarized in Table 2.

**Table 2**
**Reduction in Parameters with Treatment**

| Parameter | Treatment System 1 | Treatment System 2 | Treatment System 3 | Treatment System 4 | Treatment System 5 |
|---|---|---|---|---|---|
| Fecal Coliform Removal | 3.5 $Log_{10}$ | 1.3 $Log_{10}$ | 0.8 $Log_{10}$ | 2.1 $Log_{10}$ | 2.0 $Log_{10}$ |
| Total Coliform | 2.9 $Log_{10}$ | 1.4 $Log_{10}$ | 1.3 $Log_{10}$ | 3.0 $Log_{10}$ | 2.0 $Log_{10}$ |
| Suspended Solids | 58% | 87% | 81% | 64% | 60% |
| Turbidity | 94% | 95% | 83% | 81% | 67% |
| Biochemical Oxygen Demand | 97% | | | | |
| Nitrate | not significant | 39% | not significant | not significant | not significant |

Water hyacinths in treatment system one were found to reduce greywater BOD by approximately 86%. BOD levels were further reduced through sand filtration. System one was considered to be the most effective treatment process for reducing total and fecal coliform.

Treatment system two was not as effective in reducing coliform in the greywater as treatment system one. This was attributed to the fact that active recirculation through the aquacells reduced retention time and induced short circuit bypassing of the sand filter (due to hydraulic overloading) reducing the overall effectiveness of the system.

It was reported that treatment system three resulted in the lowest removal of coliform. This was attributed to the lack of water hyacinths influence in the process.

Treatment system four included an improved electrostatic purity unit over that of system three. This resulted in coliform reductions comparable to treatment system one. Treatment system five, which primarily comprised cartridge filtration, achieved similar albeit lower coliform reductions compared to treatment systems one and four.

The water reuse standard for turbidity in Arizona is 5 NTU. Systems one, two and four were able to meet the Arizona standard for turbidity. System two was found to the most effective process in lowering turbidity.

All five systems met State of Arizona regulations for nitrates, turbidity, and suspended solids concentrations. Nitrification / Denitrification was not considered necessary as a treatment requirement due to the initial low nitrate concentrations in the greywater (1.8 to 3 mg/l). Treatment system one was considered to provide the best overall treatment performance. It was reported that sand filtration was the most reliable of the various unit treatment processes evaluated.

None of the treatment systems were able to meet State of Arizona bacteriological standards for surface irrigation and urban re-use. The final system has incorporated an ultra violet irradiation unit in the process for disinfection.

## 5. Facility Operation and Maintenance

Some general operation and maintenance observations with the treatment systems are summarized as follows:

- The occupants of Casa del Agua are responsible for upkeep of the greywater treatment systems;
- Water Hyacinths are sensitive to air and water temperatures below 10 degrees Celsius. In an aerated system, the Hyacinths are typically harvested twice monthly to maintain good nutrient removal performance;
- Maintenance of the sand filter was minimal involving the occasional removal of plant roots;
- Electrostatic pool purity units are simple to use and easy to maintain. They can last several years without replacement; and
- It was reported that the 20-micron nominal porosity cartridge filters had to be changed frequently when used in treatment system five.

## 6. Cost

The construction of the treatment and distribution system in 1985 was reported to be approximately $1500. US. Treatment storage costs were estimated at $0.13 per litre.

## 7. Findings and Observations

Casa del Aqua is a demonstration and research house for water conservation and greywater reuse. Research conducted on the house has demonstrated that a combination of water conservation and greywater reuse can be an effective means to lower water demand.

Several different unit treatment processes were tested and evaluated by the University of Arizona. Water treatment based on monitored water quality indicated a low cost treatment solution could meet State of Arizona sub-surface irrigation requirements. The addition of an ultra violet irradiation unit allowed a water hyacinth / sand filtration treatment process to meet State bacteriological requirements for water reuse in surface irrigation and toilet flushing.

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Personal Communications

## A.9 DESERT HOUSE, PHOENIX, AZ

- **Number of buildings**
  One

- **Type of use**
  Prototype of a mass-produced single-family home constructed with separate greywater plumbing, rainwater harvesting and water-conserving fixtures. The home is an occupied domestic residence.

- **Purpose of implementing reuse / recycling**
  Ongoing research and demonstration project; need for water conservation in arid southwestern U.S.

- **Current status**
  Greywater system in operation for landscape irrigation; ongoing research program of Office of Arid Lands Studies, University of Arizona.

- **What wastewater is reused**
  The system recycles greywater from sinks, bathtub, shower, and washing machine. It is not known whether kitchen sink water is recycled or not.

- **Applications of reused water**
  All recycled greywater is used for landscape irrigation.

- **What wastewater treatment technology is used**
  Surge tank and filtration (unspecified).

- **How excess wastewater is disposed of**
  Excess wastewater (including all blackwater) is discharged to the city sewer.

- **Daily water balance**
  Unknown.

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  Unknown. at present.

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Personal communications, Dr. Martin Karpiscak, Office of Arid Lands Studies, University of Arizona

## A.10 MADISON, WISCONSIN RESEARCH HOMES

- **Number of buildings**
  Two

- **Type of use**
  Greywater recycling systems were installed in one new single-family home and one existing single-family home.

- **Purpose of implementing reuse / recycling**
  Research project.

- **Current status**
  No information available. It is unlikely that the systems described in the 1982 study are still operating. However, the Department of Civil and Environmental Engineering at the University of Wisconsin may still be conducting research on reuse / recycling in these or other locations.

- **What wastewater is reused**
  The system recycled "light greywater" from the bathtub / shower, bathroom sinks, and washing machine.

- **Applications of reused water**
  All recycled greywater was used for toilet flushing.

- **What wastewater treatment technology is used**
  The Aquasaver™ system (no longer available) included a sedimentation tank, pressure cartridge filter (20 μm), and chlorine tablet disinfection unit.

- **How excess wastewater is disposed of**
  Excess wastewater (including all blackwater) was discharged to a holding tank in one house and a septic tank / drainage field in the other.

- **Daily water balance**

| | House NE: | House VAR: |
|---|---|---|
| potable water consumption: | 127 L/day | 78 L/day |
| non-potable renovated wastewater consumption: | 33 L/day | 25 L/day |
| excess wastewater discharged to leaching bed: | N/A | N/A |

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  The installed cost of the Aquasaver treatment system was $3250 (1982 U.S. dollars). Operation and maintenance costs depend on electric power costs, as well as frequency of replacement of the system's cartridge filter and chlorine tablets.

- **References**

Boyle, W.C., R.L. Siegrist, D.L. Anderson, 1982. Alteration of In House Wastewater Flow with Low Flush Toilet Fixtures and Graywater Recycle. In Eikum and Seabloom, eds., 1982. 25-42.

Eikum, A.S. and R.W. Seabloom, eds., 1982. Alternative Wastewater Treatment. D. Reidel Publ. Co.

## A.11 CAMPUS CENTER FOR APPROPRIATE TECHNOLOGY (CCAT) HUMBOLDT STATE UNIVERSITY, ARCATA, CA

- **Number of buildings**
  One

- **Type of use**
  Modified single-family residence occupied by students. Toilet wastes are treated by a composting toilet; the plumbing system handles greywater only. A rainwater harvesting system is also in place.

- **Purpose of implementing reuse / recycling**
  Demonstration project; promotion of "green" lifestyle.

- **Current status**
  Unknown; assumed operational.

- **What wastewater is reused**
  "Dark" greywater, including kitchen sink, bathroom sinks, shower.

- **Applications of reused water**
  The treated greywater is used to irrigate the house's organic herb garden.

- **What wastewater treatment technology is used**
  Greywater is first screened to remove food particles and grease, then flows through a constructed wetland system for treatment. The wetland plants are harvested periodically for compost.

- **How excess wastewater is disposed of**
  No information available.

- **Daily water balance**
  Unknown.

- **Estimates or comparisons of the costs of residential recycling / reuse vs. conventional water supply, wastewater and plumbing systems**
  No information available. Based on descriptions, this reuse / treatment system is relatively "low-tech": construction and operating costs are expected to be low.

- **References**

CCAT Greywater
[project description and schematic provided by CCAT)

Gover, N., 1993. CCAT house demonstrates appropriate technology. *Small Flows* 7(2): p. 11. [Published by National Small Flows Clearinghouse, Morgantown, WV].

Campus Center for Appropriate Technology, Buck House
Humboldt State University
Arcata, CA 95521
(707) 826-3551
e-mail: CCAT@axe.humboldt.edu

## A.12 THE BLUE HOUSE, AALBORG, DENMARK

**Number of buildings**
Not clear.

- **Type of use**
  Restoration of forty 3-4 storey brick residential buildings, originally constructed between 1850 and 1910.

- **Purpose of implementing reuse/recycling**
  A development and demonstration project, showing the renewal of an old urban area with the saving of resources and using sustainability guidelines. Includes wastewater reuse, water conservation, and rainwater use.

- **Current status**
  Apparently planned or recently completed.

- **What wastewater is reused**
  Grey water from bathrooms, and rainwater.

- **Applications of reused water**
  Treated grey water and rainwater is used for washing and home cleaning. Toilets are supplied with treated grey water.

- **What wastewater treatment technology is used**
  Grey water will be treated by means of a "water wall" located in each dwelling, which includes "root zone cleaning" and reverse osmosis.

- **How excess wastewater is disposed of**
  Not stated.

- **Daily water balance**
  Not stated.

- **Estimates or comparisons of the costs of residential recycling/reuse vs. conventional water supply, wastewater, and plumbing systems**
  Not stated.

- **References**

Dietschchmann, H., 1998, "Ecological Urban Renewal in European Communities", European Directory of Sustainable & Energy Eficent Building, James & James, London, pp. 117-124.

## A.13 STUDENT RESIDENCE, LINACRE COLLEGE, OXFORD UNIVERSITY, UK

- **Number of buildings**
  One

  **Type of use**
  Accomodation hall for 23 students.

- **Purpose of implementing reuse/recycling**
  Demonstration system, replacing earlier grey water and storm water system.

- **Current status**
  Evaluation continuing.

- **What wastewater is reused**
  Grey water and stormwater.

- **Applications of reused water**
  Toilet flushing. Residents have not found slight foaming in the toilets to be a problem.

- **What wastewater treatment technology is used**
  Sand filters followed by hollow fibre ultra-filtration membranes.

- **How excess wastewater is disposed of**
  Sewer.

- **Daily water balance**
  Not stated.

- **Estimates or comparisons of the costs of residential recycling/reuse vs. conventional water supply, wastewater, and plumbing systems**
  Expected life span of the recycling system is 20 years. A positive cost-benefit is expected; pay-back is expected in 8-9 years. Cost-benefits of the Lineacre system are under review.

- **References**

Surendran, S., M.D. Smith, A.D. Wheatley, J. Murrer, M. Ward, L. Evans, 1998, "Development of In-House Water Reclamation Systems for Large Institutions", in Water Reuse Conference Proceedings, American Water Works Association and Water Environment Federation, Florida, pp. 731-743.

# Appendix B

## TREATMENT PROCESSES FOR RECYCLING AND REUSE

**B1. SEPTIC TANK**

**B2. CLIVUS MULTRUM GREYWATER FILTER™**

**B3. WATERLOO BIOFILTER™**

**B4. POLISHING FILTER**

**B5. ULTRAVIOLET DISINFECTION**

**B6. OZONE**

**B7. ALASCAN™ WASTEWATER SYSTEM**

**B8. BIOGREEN™ WASTEWATER TREATMENT SYSTEM**

**B9. BIOKREISEL™**

**B10. CLEAN FLUSH™ SYSTEM**

**B11. CYCLE-LET™**

**B12. HYDROXYL SYSTEMS™**

**B13. ROTORDISK™**

## B1. SEPTIC TANK

### 1. Description

A septic tank is defined by the Canadian Standards Association as an anaerobic digestion chamber in which domestic sewage is received and retained and from which the liquid effluent, which is comparatively free of settleable and floating solids, is then discharged.

The most common form of septic tank is a waterproof rectangular concrete box that includes the following elements:

- an inlet fitting that prevents blockage by surface scum and return of sewage gases into the plumbing system;
- an outlet fitting that retains surface scum within the tank;
- capacity above the liquid level to accommodate floating scum;
- one or more access openings that permit inspection and pumping of accumulated solids from the tank.

Additional features may include:

- tanks manufactured from fibreglass or plastic materials instead of concrete;
- a baffle that creates a two-compartment tank;
- an effluent filter that retains suspended solids within the tank;
- insulation to improve cold weather performance.

### 2. Principles of Operation

A septic tank removes settleable and floating solids by providing an average liquid retention period of 24 hours or more. Most materials that accumulate in the tank decompose under anaerobic conditions. Nevertheless, accumulated sediments must be pumped out periodically to prevent solids from clogging downstream treatment systems or pore spaces in the drainage field. Effluent filters, though not required, have become a recommended method of retaining solids in the septic tank.

### 3. Status of Technology

Septic tanks are an accepted element in any on-site sewage disposal system and are approved for use in every Canadian province and territory.

### 4. Operation and Maintenance

Routine inspection and pumping are suggested. The general recommendation is that the tank be pumped every three years; more or less frequent pumping may be required depending on the nature and amount of materials discharged to the system.

The effluent filter should be hosed down periodically as directed by the manufacturer to prevent solids contained in the effluent from damaging downstream disposal or treatment systems.

Intervals of one to three years have been suggested. Where the tank is overloaded, either hydraulically or by discharge of inappropriate materials, more frequent cleaning will be required.

### 5. Suitability to Small Flows

Septic tanks have traditionally been used to provide primary treatment to wastewater from single family dwellings. The minimum working capacity required by CSA specifications is 1800 L; minimum capacities required by Canadian provinces and territories for a 3 bedroom dwelling vary from 1800 to 3600 L. The septic tank in the Toronto Healthy House has a capacity of 3600 L and was designed for an average flow of 720 L/day. The insulated, prefabricated concrete tank is divided into two compartments and is equipped with an effluent filter.

### 6. Capital Costs

The cost of septic tanks varies depending on the manufacturer, excavation contractor, and transportation costs. Installed cost generally ranges from $600 to $1000 (Canadian dollars).

### 7. Effluent Quality

The literature contains information about the quality of effluent from a conventional septic tank intended to treat domestic sewage prior to subsurface disposal. The Toronto Healthy House appears to be the only potential source of information about a system that incorporates all of the following features:

- greatly reduced wastewater flows because of water conservation and recycling;
- influent quality influenced by results of wastewater recycling;
- tank capacity based on Ontario standards, which is larger than that required by other jurisdictions
- an insulated septic tank in a cold climate
- an effluent filter.

Unfortunately, information on the influent and effluent quality at the Toronto Healthy House is currently unavailable.

### 8. Utilization of Local Resources

Prefabricated concrete tanks for single family dwellings are commonly produced by a local manufacturer and delivered to the installation site in two pieces. On-site assembly includes watertight joining of the two pieces and addition of a riser to the surface if required. Concrete tanks for larger systems may be constructed on site. Fibreglass or plastic tanks may be imported from other provinces or regions.

### 9. References

Canadian Standards Association, 1990. Prefabricated Septic Tanks and Sewage Holding Tanks. CAN/CSA-B66-M90.

Bedinger, M.S., Johnson, A.I., and Flemming, J.S., eds. Site Characterization and Design of On-Site Septic Systems. ASTM STP 1324, American Society for Testing and Materials.

Paloheimo, R., 1996. Reusing Treated Wastewater in Domestic Housing: the Toronto Healthy House Project. Disposal Trenches, Pre-Treatment and Re-Use of Wastewater Conference, University of Waterloo, May 13 1996. 61-78.
http://mha-net.org/msb/html/papers-n/palo01/wastewa.htm

Townshend, A.R., 1996. Commissioning Guide for the Toronto Healthy Houses Water Systems. CMHC CR File No. 6740-5.

Townshend, A.R., Jowett, E.C., Le Craw, R.A., Waller, D.H., Paloheimo, R., Ives, C., Russell, P., and Liefhebber, M., 1997. Potable Water Treatment and Reuse in the CMHC Toronto Healthy House. In Bedinger et al., eds.

## 10. Suppliers, Contractors, Consultants

Septic Tanks: consult local telephone directory

Septic Tank Effluent Filters (product used in Healthy House):
Orenco Systems Inc.
814 Airway Ave.
Sutherlin, OR 97479
Tel: (541) 459-4449 Fax: (541) 459-2884

Toronto Healthy House
Creative Communities Inc.
26 Garnock Ave.
Toronto, ON M4K 1G8
Tel: (416) 466-5172 Fax: (416) 466-5173

## 11. Conditions for Success

Septic tanks provide primary treatment for domestic wastewater that includes blackwater. They are not normally used for greywater because solids must be particulate (settleable or floatable) in order for septic tank treatment to be effective.

Septic tank performance is highly dependent on total and peak hydraulic loading, as well as types of material that can be discharged to the system. Education is essential to ensure that system users fully understand these limitations.

## B2. CLIVUS MULTRUM GREYWATER FILTER™

### 1. Description

The Clivus Multrum Greywater Filter (model LPF20) consists of a pair of nylon filters and a discharge pump enclosed in a polyethylene storage tank (62 cm long × 47 cm wide × 61 cm high). The system is designed to filter particles and fibers from greywater prior to discharge into a soil bed filtration system or other treatment unit.

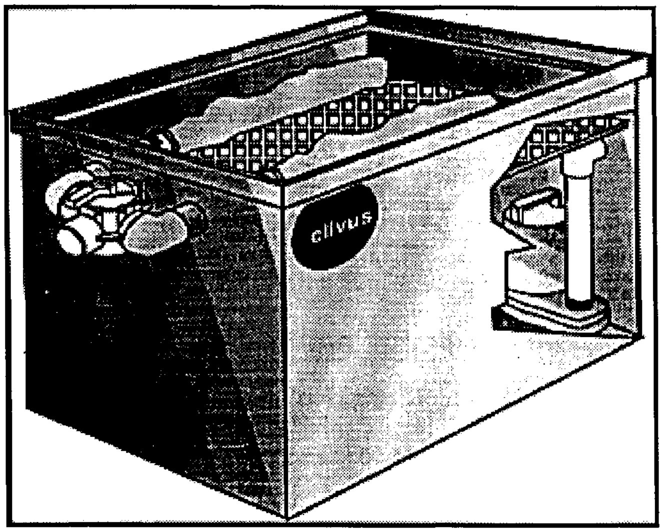


Figure 2.1: Clivus Multrum Greywater Filter

### 2. Principles of Operation

Greywater enters the system through a valve-controlled PVC inlet pipe that directs the flow to one of two nylon filters. The filters retain large particles of hair, lint, soap, food, and other sediment found in normal greywater. The 1/3 HP electric pump discharges the filtered greywater that accumulates in the tank through a garden hose coupling.

### 3. Status of Technology

The technology has been commercially available for many years as a ready-to-install, self-contained unit.

### 4. Operation and Maintenance

Frequency of maintenance depends on rate of use. In a typical household, the nylon filters may need to be replaced every two months. The operator sets the inlet control valve to direct flow to the inactive filter prior to removing the previously-active filter for maintenance. The injection pipes also need to be cleaned periodically, though much less frequently than the filters need changing.

The system does not require backwashing. The polyethylene storage tank itself is corrosion-resistant and seamless to prevent leakage.

**5. Suitability to Small Flows**

The system is designed to accommodate flow rates generated by an average household. The pump capacity ranges from 30 to 77 L/min, depending on the head. Optional pumps are available if higher volumes are expected.

**6. Capital Costs**

The cost of the unit, including pump, is approximately $500 (U.S. dollars). Large retail plumbing suppliers carry these systems.

**7. Effluent Quality**

The LPF20 Greywater Filter is designed to be used in conjunction with other treatment technologies; it does not reduce BOD or organic nutrient content. Post-filtration turbidity and TSS data are unavailable.

**8. Utilization of Local Resources**

The system is delivered ready-to-install. A licensed plumber and electrician may perform the installation. The unit does not require excavation and cannot be buried.

**9. References**


Clivus Multrum Inc. product sheets

Clivus Multrum Inc. website (http://clivusmultrum.com/greywater.html)

Lindstrom, C.R., 1992. Using Greywater: A Basic Planning Manual for the Processing of Greywater. Cambridge, MA: Clivus Multrum Inc. 30pp.

Scott, L., Clivus Multrum representative, personal communications.


**10. Suppliers, Contractors, Consultants**

Clivus Multrum Inc.
1 Eliot Square
Cambridge, MA 02138
Tel: (800) 425-4887 Fax: (978) 557-9658

Lawrence Scott, Clivus Multrum representative
Ann Arbor, MI
Tel: (734) 995-4767

## 11. Conditions for Success

The Clivus Multrum Greywater Filter provides pre-treatment of greywater for use in conjunction with the Clivus Multrum soil bed filtration system, and is potentially useful for pre-treatment in advance of other treatment units. The system is designed to treat greywater only, and is not suitable for filtration of combined wastewater that contains blackwater. In order to prevent septic conditions, the filtered greywater must not be stored in the polyethylene tank for long periods.

## B3. WATERLOO BIOFILTER™

### 1. Description

The Waterloo Biofilter was developed at the Waterloo Centre for Groundwater Research to provide secondary treatment of municipal wastewater, domestic wastewater, and landfill leachate in conjunction with other treatment processes. It is an aerobic treatment device that removes organic matter by biological oxidation and oxidizes ammonia to nitrate under aerobic conditions. Limited removal of bacteria and viruses is also expected.

In the Toronto Healthy House, the Waterloo Biofilter treats 3600 L/day of septic tank effluent plus recycled wastewater. Approximately 2880 L/day of biofilter effluent is returned to a 2000 L recirculation tank located between the septic tank and the biofilter. Water may cycle through the recirculation tank and biofilter three to five times. Of the remaining biofilter effluent, 600 L/day is treated by a polishing filter and ozonation unit prior to recycling. The remaining 120 L/day is disposed of in a subsurface gravel pack.

### 2. Principles of Operation

The internal components of the Waterloo Biofilter include:

- a sewage pump (when the sewage source is not gravity drained);
- a sprinkler system that evenly distributes the liquid sewage over the foam;
- synthetic foam blocks used as a filter medium;
- geodrain grid baskets to contain the filter media;
- discharge piping;
- ventilation system (either natural convection or a small fan);
- waterproof, air-tight stainless steel cabinet to enclose the entire system.

Auxiliary components include:

- a septic tank to remove solids, grease, grit and oil from sewage before it enters the Waterloo Biofilter;
- a flow equalization or surge tank;
- a disposal trench or recirculation system;
- plumbing.

The biofilter receives effluent from a recirculation tank, which provides improved treatment and load levelling. Denitrification (conversion of nitrate to nitrogen gas, which is vented through the plumbing system) takes place in the anaerobic environment of the recirculation tank.

The filter is housed in an air-tight stainless steel cabinet with a removable front access panel. The overall dimensions are about 3.25 $m^2$ by 1.2 m deep. A sprinkler system evenly distributes wastewater at a temperature of 150°C on top of the filter medium, which consists of synthetic foam blocks randomly placed in five geodrain grid baskets. The random packing increases surface area, porosity and retention time, while also providing flow channels for the passage of wastewater and air. The foam filter medium has the flow characteristics of gravel and the surface area and absorptive capacity of silt. Typical loading rates are often 10 times greater than loading rates of solid particle media such as sand. Most importantly, the blocks provide an excellent substrate for growth of aerobic bacteria, both on the surface and within the voids of the foam. The microbes remove suspended and dissolved organic solids from the wastewater under aerobic conditions.

Air flow is maintained by natural convection or by a small fan that distributes forced air from the building's ventilation system to the top of the filter media. Forced ventilation can reduce BOD and solids by 5% and can greatly enhance the nitrification process. Air flowing around the baskets and filter media is vented through a plumbing vent near the bottom of the filter cabinet. After percolating through the biofilter, treated effluent collects in the bottom tray of the cabinet and exits through a central drain that leads to subsequent treatment systems.

### 3. Status of Technology

The Toronto Healthy House is the only reported application of the Waterloo Biofilter for wastewater recycling. Other applications include experimental systems for treatment of domestic wastewater, light greywater, secondary clarifier effluent, and landfill leachate. The Waterloo Biofilter is slated for installation in a number of homes owned by the Northwest Territories Housing Corporation.

### 4. Suitability to Small Flows

Design loading rates are 50 to 80 cm/day based on a filter volume of 3 to 5 cubic metres. This size is suitable for a flow rate of 1700 L/day. Surge loading rates up to 204 cm/day over several days are reported to have little effect on efficiency of the biofilter. The biofilter system may be housed above ground for gravity return or in-ground with a pressure disposal trench.

### 5. Operation and Maintenance

The sprinkler nozzles are self draining to minimize plugging. However, they should be checked periodically to ensure that they do not become blocked. They can be removed by uncoupling the pipes and removing the whole nozzle and distribution assembly.

The foam filter medium will compact over time due to the steady weight of the water. The upper portion of the filter medium is contained in mesh fabric bags to facilitate removal if cleaning is required. Replacement will likely be required every five years depending on water volumes and loading rates.

The pump should be switched off manually before any maintenance is performed. Even though the filter is vented, there is the possibility of carbon dioxide buildup as a by-product of aerobic oxidation. The gas should be allowed to dissipate before approaching the biofilter.

## 6. Capital Costs

The installed cost of the Waterloo Biofilter, excluding the required pretreatment system (septic tank) is $6220. Operation and maintenance costs include electric power, sludge and residue pumping, pump and fan maintenance, and replacement of the filter medium as required. Operating costs for a Waterloo Biofilter installed as a component of a residential wastewater treatment system are approximately $800 per year.

## 7. Effluent Quality

Preliminary results from the Toronto Healthy House are representative of a biofilter fed at a rate of 3600 L/day from a recirculation tank. The biofilter / recirculation tank subsystem is fed from a septic tank that receives grey and black water from both potable and recycled water sources. Composition of the septic tank effluent, which averages 720 L/day, has not been measured.

Biofilter effluent characteristics, based on preliminary sampling, are as follows:

| | | | |
|---|---|---|---|
| BOD | 6 mg/L | $NO_2 + NO_3$ | 36 mg/L |
| TSS | 4 mg/L | total P | 22 mg/L. |
| total N | 42 mg/L | | |

Reported removal rates are:

| | | | |
|---|---|---|---|
| TSS | 95% | total N | 20-50% |
| BOD | 90-95% | coliforms | 90-99% |

The microbes and bacteria need some time (about 100 days) to become effective in removing organic nitrogen molecules. After four months of operation at the Toronto Healthy House with influent BOD and TSS values of 266 and 39 mg/L, the BOD and TSS values of the biofilter effluent were 16 and 10 mg/l, respectively.

## 8. Utilization of Local Resources

The Waterloo Biofilter is a patented system that has been adapted to a variety of applications that required site-specific design and construction. It may also be appropriate for inclusion in "packaged" systems that are designed for specific applications such as a residential wastewater recycling.

## 9. References

Bedinger, M.S., Johnson, A.I., and Flemming, J.S., eds. Site Characterization and Design of On-Site Septic Systems. ASTM STP 1324, American Society for Testing and Materials.

Jowett, E.C., 1995. Replacing the Tile Bed with the Waterloo Effluent Filter. Conference proceedings, Univ. of Waterloo, pp 43-64.

Paloheimo, R., 1996. Reusing Treated Wastewater in Domestic Housing: the Toronto Healthy House Project. Disposal Trenches, Pre-Treatment and Re-Use of Wastewater Conference, University of Waterloo, May 13 1996. 61-78.
http://mha-net.org/msb/html/papers-n/palo01/wastewa.htm

Townshend, A.R., 1996. Commissioning Guide for the Toronto Healthy Houses Water Systems. CMHC CR File No. 6740-5.

Townshend, A.R., Jowett, E.C., Le Craw, R.A., Waller, D.H., Paloheimo, R., Ives, C., Russell, P., and Liefhebber, M., 1997. Potable Water Treatment and Reuse in the CMHC Toronto Healthy House. In Bedinger et al., eds.

Wastewater Technology Centre and Davis Engineering and Associates Limited, 1995. Assessment of Appropriate Technologies for Wastewater Treatment and Disposal for Rural Communities in Newfoundland, volume II.

## 10. Suppliers, Contractors, Consultants

Waterloo Biofilter Systems Inc.
2 Taggart Court, Unit 4
Guelph, ON N1H 6H8
Tel: (519) 836-3380 Fax: (519) 836-3381

Creative Communities Inc.
26 Garnock Ave.
Toronto, ON M4K 1G8
Tel: (416) 466-5172 Fax: (416) 466-5173

## 11. Conditions for Success

The Toronto Healthy House is currently the only example where the Waterloo Biofilter is used to treat septic tank effluent (including both black and greywater) for recycling. A Waterloo Biofilter has been successfully treating light greywater (shower and bath water) from a YMCA camp for a number of years; no sampling results are available. The supplier notes that it would be preferable to include kitchen sink wastewater along with shower and bath water in this installation. The supplier also notes that the biofilter is not clogged by soap gels, as might be expected for a sand filter.

It is reported that the Waterloo Biofilter can operate at temperatures ranging from -40°C to 30°C. The rate of biological growth is affected by operating temperatures, with higher removal and growth rates expected at the higher range of operating temperatures.

Toxic shock loadings of detergents, bleach, cleaning agents and other chemicals can kill or upset the biomass. Homemade cleaners are generally less harmful to the treatment system and should be used in place of commercial cleaners. Household hazardous wastes should never be dumped down the drain or flushed down the toilet, as they can disable the biological system.

# B4. POLISHING FILTER

## 1. Description

Following treatment by a septic tank and Waterloo Biofilter™, reclaimed wastewater in the Toronto Healthy House passes through a polishing filter for tertiary treatment prior to disinfection and re-use. The unique aspect of this technology is that it combines anthracite and activated carbon filtration in a single unit.

## 2. Principles of Operation

The unit was originally designed for upward flow, but has been converted to downward flow with different filter media with improved results. The first stage filter is a roughing filter with a coarse anthracite medium. The second stage contains fine activated carbon supported on a sand layer. Activated carbon is preferred as a filter medium both for its light weight and for its filtration capability during the start-up phase of operation before the biological treatment system has fully matured.

The filter is 1.2 m deep and .3 m in diameter, corresponding to a loading rate of .36 m/hr. A flow meter with a needle valve on the discharge line controls the flow rate of the incoming reclaimed water.

## 3. Status of Technology

The polishing filter described here is a prototype designed by RAL Engineering Limited specifically for use in the Toronto Healthy House. The unit was developed as a component of a complete system that treats combined (grey and black) wastewater from a single family residence for reuse. The system will be incorporated in residential applications in the Northwest Territories, and will be adapted and enlarged to treat greywater in a Vancouver apartment building.

## 4. Operation and Maintenance

The filter described here is a relatively passive technology that consumes little energy. It does not require monitoring or control equipment other than dosing and backwash pumps.
However, routine maintenance is essential. In the Toronto Healthy House, monthly inspection of the complete system by trained personnel is proposed.

The filter is backwashed automatically, based on a timer. Current backwash intervals are approximately weekly. The filter is backwashed with pre-filtered renovated water drawn from storage; waste backwash water is discharged to the septic tank. A double check valve is installed in the backwash line to prevent backflow in case the system pressure drops below the gravity head on the filter.

The activated carbon needs to be replaced every 1 to 3 years depending on the raw water quality. If the carbon is not replaced, only the aesthetic qualities of the water will be affected. A change in appearance of the reclaimed water will remind users that the carbon should be replaced.

## 5. Suitability to Small Flows

This design was developed for use in a single-family residence: flow in the Toronto Healthy House units averages 620 L/day. Units with a capacity eight times larger are being designed to treat greywater in the Vancouver apartment building demonstration project.

## 6. Capital Costs

When used as a component of a complete wastewater treatment system, the cost of the filters is less than $2000 (Canadian dollars). The price would likely decrease if the filters were available as regular production models rather than custom-built prototypes.

## 7. Effluent Quality

Preliminary results from the Toronto Healthy House:

| | Influent | Effluent |
|---|---|---|
| BOD | 6 mg/L | 2 mg/L |
| Suspended Solids | 4 mg/L | 2 mg/L |
| TOC | 12 mg/L | 3 mg/L |

## 8. Utilization of Local Resources

The filters described here are components of a complete system that is produced by the supplier for installation by a local plumbing contractor.

## 9. References

This technology is evolving, and there is currently no specific reference. The following references describe the Toronto Healthy House system, including the original version of the filter.

Bedinger, M.S., Johnson, A.I., and Flemming, J.S., eds. Site Characterization and Design of On-Site Septic Systems. ASTM STP 1324, American Society for Testing and Materials.

Paloheimo, R., 1996. Reusing Treated Wastewater in Domestic Housing: the Toronto Healthy House Project. Disposal Trenches, Pre-Treatment and Re-Use of Wastewater Conference, University of Waterloo, May 13 1996. 61-78.
http://mha-net.org/msb/html/papers-n/palo01/wastewa.htm

Townshend, A.R., 1996. Commissioning Guide for the Toronto Healthy Houses Water Systems. CMHC CR File No. 6740-5.

Townshend, A.R., Jowett, E.C., Le Craw, R.A., Waller, D.H., Paloheimo, R., Ives, C., Russell, P., and Liefhebber, M., 1997. Potable Water Treatment and Reuse in the CMHC Toronto Healthy House. In Bedinger et al., eds.

## 10. Suppliers, Contractors, Consultants

RAL Engineering Ltd.
482 Queen Street, East
Newmarket, ON L3Y 2H4
Tel: (905) 853-0626 Fax: (905) 853-8807

Creative Communities Inc.
26 Garnock Ave.
Toronto, ON M4K 1G8
Tel: (416) 466-5172 Fax: (416) 466-5173

## 11. Conditions for Success

Reclaimed wastewater must be adequately treated by other means prior to filtration. The filtered effluent must be disinfected before it is stored or re-used.

## B5. ULTRAVIOLET DISINFECTION

### 1. Description

Ultraviolet light is shortwave electromagnetic radiation with a wavelength of 5 to 400 nm. It disinfects wastewater that has already received secondary treatment (or greater) by destroying bacteria, viruses and protozoa.

### 2. Principles of Operation

An open-channel configuration is most common for UV wastewater disinfection. The basic components of the system are tubular low-pressure mercury arc lamps .75 to 1.5 m in length and 15 to 20 mm in diameter. The lamps are either suspended above the wastewater or submerged directly in the flow. Submerged lamps are encased in quartz tubes to prevent cooling. As the wastewater flows past the lamps, concentrated UV energy penetrates the reproductive mechanism of the microorganism. This alters the genetic material, including DNA and RNA, thereby killing the organism or preventing it from replicating.

### 3. Status of Technology

UV systems have been used in both large and small scale systems for treatment of water and wastewater. Trojan Technologies indicate that more than 1400 of their municipal UV disinfection systems are in operation. A number of these units are used for reuse / recycling applications, including irrigation of golf courses and renovation of treated wastewater for potable use.

### 4. Operation and Maintenance

UV treatment requires no supervision or operator attention. Lamps are placed in the channels in modules so that they can easily be removed for maintenance and replacement. In some cases, scale may build up on the quartz tubes which tends to reduce the effectiveness of the system. Mechanical wiper and sonic cleaning systems can be installed, but they are not as effective as desired.

### 5. Suitability to Small Flows

Ultraviolet disinfection has been used extensively in small-scale applications. The Trojan AquaUV Advantage 5 units used to treat potable and renovated water in the Toronto Healthy house have a capacity of 19 L/minute. Although one of these units is used to disinfect renovated wastewater in this demonstration project, the manufacturer indicates that the units are designed to disinfect potable tap water only. The smallest UV treatment system available from Trojan which is designed specifically for wastewater treatment is the UV3000, which has a capacity of 25000 L/day (suitable for approximately 20-25 residences).

### 6. Capital Costs

The retail price (Canadian dollars) of the Trojan AquaUV units in the Toronto Healthy House ranges from $500 (Advantage 5 model) to $685 (Advantage 5 Plus model).

## 7. Effluent Quality

Wastewater in the Toronto Healthy House passes through a septic tank, biofilter and polishing filter prior to UV disinfection. No information is currently available about the quality of the renovated water following UV disinfection.

## 8. Utilization of Local Resources

UV systems are manufactured units. The small-scale system described here requires only plumbing connections and a 110V power supply.

## 9. References

Bedinger, M.S., Johnson, A.I., and Flemming, J.S., eds. Site Characterization and Design of On-Site Septic Systems. ASTM STP 1324, American Society for Testing and Materials.

Townshend, A.R., Jowett, E.C., Le Craw, R.A., Waller, D.H., Paloheimo, R., Ives, C., Russell, P., and Liefhebber, M., 1997. Potable Water Treatment and Reuse in the CMHC Toronto Healthy House. In Bedinger et al., eds.

Metcalf & Eddy, Inc., 1991. Wastewater Engineering Treatment, Disposal, and Reuse, 3rd ed. New York: McGraw-Hill.

Paloheimo, R., 1996. Reusing Treated Wastewater in Domestic Housing: the Toronto Healthy House Project. Disposal Trenches, Pre-Treatment and Re-Use of Wastewater Conference, University of Waterloo, May 13 1996. 61-78.
http://mha-net.org/msb/html/papers-n/palo01/wastewa.htm

Townshend, A.R., 1996. Commissioning Guide for the Toronto Healthy Houses Water Systems. CMHC CR File No. 6740-5.

Trojan Technologies Inc. product literature

Wastewater Technology Centre and Davis Engineering and Associates Limited, 1995. Assessment of Appropriate Technologies for Wastewater Treatment and Disposal for Rural Communities in Newfoundland, vol. II.

## 10. Suppliers, Contractors, Consultants

Trojan Technologies Inc.
3020 Gore Road
London, ON N5V 4T7
Tel: (519) 457-3400 Fax: (519) 457-3030

Creative Communities Inc.
26 Garnock Ave.
Toronto, ON  M4K 1G8
Tel: (416) 466-5172   Fax: (416) 466-5173

**11. Conditions for Success**

The effectiveness of the UV treatment also depends on the intensity of the light and the duration of exposure.

Turbidity in the wastewater can absorb UV energy and shield the microorganisms from exposure. For this reason, pre-treatment is required to reduce the concentration of suspended solids and to increase transmissivity. The Trojan UV3000 system, which is specifically designed for wastewater treatment, requires influent with a total suspended solids content less than or equal to 30 mg/L and at least 50% transmissivity to UV light.

Soap, iron, oils and other contaminants have the potential to coat the UV lamps and reduce the degree of disinfection. Nevertheless, filtered greywater is likely to be sufficiently low in turbidity to allow for efficient UV disinfection.

UV disinfection does not require the addition of chemicals to the wastewater, nor does it contribute to the formation of toxic compounds. However, unlike chlorination and other chemical treatment methods, there is no residual concentration of chemical disinfectant to prevent re-contamination of the treated wastewater.

The units require some "warm up" time before they are ready to receive wastewater. The units are suited to constant flow and do not function well with variable flows.

## B6. OZONE

### 1. Description

Ozone is an extremely reactive gaseous oxidizing agent that rapidly kills microorganisms, leaving no residuals or by-products in the treated water except oxygen and carbon dioxide. It is used in the Toronto Healthy House to disinfect, to remove taste, odour and colour, and to break down soap and oils in reclaimed wastewater.

### 2. Principles of Operation

Ozone gas is generated from air or pure oxygen when a high voltage arc passes between a pair of narrowly spaced electrodes. Cooling water is used to remove heat generated by the process. Oxygen can also be converted to ozone by ultraviolet light or radiation of shorter wavelength. The gas is chemically unstable and decomposes to oxygen very quickly after generation; as a result, it must be generated on-site and cannot be stored. Treatment must take place in ozone-resistant containers.

Ozone is highly soluble in water; an injector dissolves the gas in the water stream. Ozone kills bacteria by disintegrating the cell wall in a process known as cell lysis. It is also thought to be a more effective virucide than chlorine. The degree of microorganism inactivation increases markedly at higher temperatures, but decreases with mixing.

The effectiveness of ozone in oxidizing organic and inorganic compounds depends on the temperature and pH of the water. Highly reactive hydroxyl radicals form under alkaline pH conditions that cause molecular ozone ($O_3$) to decompose, or in treatment units that combine ozonation with ultraviolet irradiation. Hydroxyl radicals accelerate the reaction rate and are able to remove more compounds than either UV or ozone alone.

### 3. Status of Technology

Ozonation has been used to treat drinking water since the early 1900s, particularly in Europe. There are currently over 90 municipal installations in Canada and the U.S. Other applications include cooling towers and water bottling plants. Small-scale ozone generators for household use are available from several manufacturers. As mentioned previously, ozonation is part of the wastewater recycling process at the Toronto Healthy House.

### 4. Operation and Maintenance

Household ozone generators operate automatically; no regular maintenance is required. The units require an ordinary domestic electric power source (110 V / 15 A). Proper ventilation must be provided if the system is located in an enclosed area. Air-fed ozone generators also require an intake filter to remove moisture and dust, unlike oxygen-fed systems.

## 5. Suitability to Small Flows

Ozonation has been used for water and wastewater treatment in household applications and in larger scale treatment facilities. Ozonation systems are being used to treat water from domestic, municipal and commercial sewer systems; fish hatcheries and farms; liquid food processing waste; and industrial toxic waste.

The ozonation unit in the Toronto Healthy House is intended for household uses, including treatment of drinking water and water used in swimming pools and hot tubs. The unit generates 400 mg of ozone per hour from air. Dimensions of these units are 33 mm × 33 mm × 11 mm.

## 6. Capital Costs

The ozonation unit in the Toronto Healthy House (A.H. Simpson Model SW400) cost approximately $500 (Canadian dollars). The cost of the system installed at the Conservation Co-Op in Ottawa is as follows (U.S. dollars):

| | |
|---|---|
| OZ2PCS Ozone Generator | $ 529.00 |
| OZOTECH ORP Model 3000 | $ 1,349.00 |
| OZOTECH ORP Probe #32035 | $ 270.00 |
| Mazzi Injector | $ 149.00 |

## 7. Effluent Quality

Recycled wastewater at the Toronto Healthy House is treated by a septic tank, biofilter, and polishing filter prior to ozone disinfection. In preliminary test results, *E. coli* and total coliform counts were zero following ozonation. Ozone was selected for use in this system because, in addition to disinfection, it could remove colour from the recycled wastewater. No laboratory results are available, but visual comparison of recycled wastewater before and after ozonation indicates satisfactory colour removal.

Baron et al. (1998) cite the following results for sand filter effluent treated with ozone at a concentration of 12 mg/L for reuse in horticulture. Reported values improved with increased ozone dosage:

Removal efficiency: turbidity: up to 50%
COD: up to 35%
colour and nitrites: up to 90%

Effluent bacterial concentrations:
total coliforms: 1 to 50 / 100 mL
fecal coliforms: < 1 to 10 / 100 mL

Ozone residuals can be acutely toxic to aquatic life. However, ozone dissipates so rapidly that residuals are not normally present by the time the effluent is discharged. Ozonation can also produce some toxic mutagenic and/or carcinogenic compounds. These compounds are usually unstable and are only present for a matter of minutes in ozonated water. It should be noted that if the ozonation process is stopped too soon or if an insufficient amount of ozone is used, some compounds may remain in the stream. However, the presence of an ozone residual after treatment indicates that there was sufficient ozone supplied to carry all reactions to completion.

**8. Utilization of Local Resources**

Household ozone generators are manufactured units. Most require only plumbing connections and a 110V power supply. Larger units may require local contractors for construction and installation. The unit used in the Toronto Healthy House is a Canadian-made product.

**9. References**

Baron, J.; Langlais, B.; Perez-Parra, J.; Del Castillo, E.; Vallverdru, A., 1998. The use of ozone as tertiary treatment before reuse: practical application in Almeria, Spain. Water Reuse 98 Conference Proceedings, American Water Works Association, February 1998. 33-40.

Droste, R.L., 1997. Theory and Practice of Water and Wastewater Treatment. New York: John Wiley & Sons.

Metcalf & Eddy, Incorporated. Wastewater Engineering Treatment, Disposal, and Reuse, 3rd ed. New York: McGraw-Hill, 1991.

Rakness, K.L., Demers L.D., and Blank, B.D., 1996. An Oxidant Waiting to Happen, Ozone System Fundamentals for Drinking Water Treatment. Opflow 22(7), July 1996. American Water Works Association.

Towles, J. The Technology of Ozone in the Oxidation of Organic Compounds -- The Production and Decomposition of Ozone. Pyramid Environmental Technologies, Inc.

**10. Suppliers, Contractors, Consultants**

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Richmond Hill, ON L4C 5E5
Tel: (905) 770-9110 Fax: (905) 770-9884

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Surrey, BC V3W 8J9

Creative Communities Inc.
26 Garnock Ave.
Toronto, ON, M4K 1G8
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## 11. Conditions for Success

The household ozonation unit described here (A.H. Simpson Model SW400) is marketed for treatment of mildly polluted water in household applications, including hot tub and swimming pool water. It is used successfully in the Toronto Healthy House to disinfect and to remove colour from recycled wastewater.

## B7. ALASCAN™ WASTEWATER SYSTEM

### 1. Description

The AlasCan Wastewater System is a self-contained tank designed to treat household greywater by extended aeration. The greywater tank is normally installed in conjunction with the AlasCan composting tank, which handles toilet and garbage disposal waste, to make a complete residential or commercial wastewater plant. In this configuration, the greywater tank also handles a small percentage of water from the blackwater compost tanks.

### 2. Principles of Operation

The greywater tank is divided into three chambers: a surge chamber, an extended aeration chamber, and a clarification chamber. The surge chamber serves as a primary clarifier to remove solids. Suspended aerobic bacteria remove organic nutrients from the greywater in the reaction chamber. An air compressor provides additional aeration. Finally, the water passes through a clarification chamber prior to discharge. The minimum hydraulic retention time is 18 hours.

### 3. Status of Technology

The AlasCan system has been commercially available for approximately 6 years and is currently undergoing the NSF accreditation process. Approximately 100 complete composting and greywater treatment systems have been installed in Alaska. Units have also been installed in Minnesota, Ohio, and California. Although the manufacturer is considering setting up a demonstration project, the AlasCan has not been used for water reuse / recycling to date.

### 4. Operation and Maintenance

The system operates independently and can be monitored by AlasCan's remote computer hook-up. Under normal operating conditions, little owner maintenance is required. A hand-operated sludge pump is used to remove accumulated solids from the bottom of the three treatment chambers every six months (or as required).

### 5. Suitability to Small Flows

The AlasCan is currently operating in private homes and in a municipal park. The system is designed to treat 950 L/day of residential greywater; the surge capacity is 190 L/day. The product representative claims that the system is able to treat the greywater generated daily by 8-12 adults. Accordingly, the manufacturer is considering producing a smaller unit capable of meeting the treatment needs of a four-person household.

### 6. Capital Costs

The retail cost of the AlasCan Wastewater Treatment Tank is $2495 (U.S. dollars).

## 7. Effluent Quality

The system (without additional filtration) removes 60%-70% of organic matter and 45%-50% of suspended solids. The average $BOD_5$ of the effluent (based on 5 samples) is 23 mg/L; average TSS is 18 mg/L. Post-treatment disinfection may be required for domestic non-potable reuse.

## 8. Utilization of Local Resources

The unit is shipped pre-assembled from the factory in Minnesota. Local plumbing and electrical contractors may be required for installation. The unit is normally installed in the basement of a house; no additional construction or excavation is required.

## 9. References

AlasCan Internet website: http://www.alascan.com/

Mr. David Kern, AlasCan Product Representative, personal communication.

Totten Sims Hubicki Associates, 1997. Conservation Co-Op Residential Water Reclamation Interim Report. (Report prepared for CMHC).

## 10. Suppliers, Contractors, Consultants

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e-mail: drewid@star21.com

## 11. Conditions for Success

The AlasCan Wastewater Treatment Tank appears to be capable of providing renovated water for toilet flushing and other non-potable domestic reuse; however, its ability to do so has not yet been tested in a demonstration study. Post-treatment disinfection may be necessary if the effluent is to be used for this purpose.

The system has been successful in treating 100% greywater: no pre-treatment is required. However, the surge chamber is not large enough to equalize the influent greywater flow.

The extended aeration process may produce odours and the blower required for aeration may be noisy.

Bulking and filamentous bacteria can create ongoing operational problems and poor effluent quality. A trained operator may need to be called to identify and correct problems. Restoring the process may require altering the loading patterns, or removing the activated sludge and re-seeding the extended aeration chamber. In addition, the microorganisms are sensitive to household detergents and cleaners. These products should be used with caution.

# B8. BIOGREEN™ WASTEWATER TREATMENT SYSTEM

## 1. Description

The BioGreen Wastewater Treatment System is a Japanese technology that is now being marketed in Canada. The BioGreen is designed to provide domestic wastewater treatment for individual homes and small communities, but has also been used in small commercial applications. The system is composed of two settling tanks, a fermentation tank, two aeration tanks, and an effluent holding tank. Total retention time in the system is three to five days, which kills most *E. coli* bacteria. The treated effluent can be reused or discharged to a surface water body in accordance with local regulations; further disinfection is generally not required.

In Japan, approximately 30 BioGreen systems are being used for reuse / recycling applications. Treated wastewater from private homes and apartments, dormitories, offices buildings, schools, a hospital, a senior care facility, two resorts, and a temple is being reused for toilet flushing, landscape irrigation, and ornamental ponds. The system is also being used to provide recycled bath and laundry water at a site in Okinawa.

## 2. Principles of Operation

Raw wastewater enters two settling tanks that remove sediment, debris and floating material. The first tank is larger than a conventional settling tank and acts as a flow equalization or surge tank. The water flows from the settling tanks to the fermentation tank where sludge and half of the available carbohydrates are removed by filtration.

The next stage of the treatment process is aeration. The two aeration tanks contain a number of filters. Critical flow rates are maintained by a control valve. Air is injected through draft tubes to create a dissolved oxygen gradient. The gradient supports microorganisms with varying oxygen requirements, thereby expanding the food chain for nutrient digestion and minimizing sludge production. From the second aeration tank, the treated wastewater flows to the effluent holding tank, which further reduces suspended solids prior to discharge or reuse.

## 3. Status of Technology

The BioGreen system has been used to treat wastewater in Japan for over 15 years. Although the North American distributor has elected not to undergo the NSF certification process, the system has been approved for use by the B.C. Ministry of Health, the Newfoundland and Labrador Department of Environment, and the Nova Scotia Department of the Environment.

There are presently four demonstration units installed in Newfoundland, where research is ongoing to optimize the technology for the Canadian climate and environment. Units at the University of British Columbia and in the Fraser Valley are in routine operation. These units were installed under the B.C. Ministry of Health Innovative Designs and Technology Policy and guidelines for non-conforming lots. The distributor is continuing to sell household units throughout the Lower Mainland of British Columbia, and is investigating installing small community units in British Columbia and Alberta.

Treated effluent from the Canadian installations is not currently being reused.

### 4. Operation and Maintenance

A minimum level of knowledge is required to operate and maintain the system. Yearly maintenance and backwashing of the aeration chambers is recommended. The settling chambers should be pumped out every 5 to 10 years.

### 5. Suitability to Small Flows

The typical household unit has a design treatment capacity of 1600 L/day, although household units capable of handling flows of up to 3000 L/day are available. The typical unit used in domestic applications is 2.9 m long, 2.0 m wide and 2.0 m in height.

### 6. Capital Costs

The purchase price of a typical household unit is less than $10,000 Canadian dollars. Operating costs are low as the only moving part that requires power is the compressor. The distributor suggests an allowance of $8 per month based on 24-hour-a-day operation.

### 7. Effluent Quality

The system is designed to meet discharge criteria of 5 mg/L for both biochemical oxygen demand (BOD) and suspended solids (TSS). The *E. coli* concentration in the treated effluent is below 1000 organisms per 100 mL, due in part to the long retention time in the system. For this reason, the distributor claims that effluent can generally be discharged or reused without further disinfection, as has been practiced in Japan. However, if further reduction in fecal coliform bacteria is desired, a disinfection process can be added to the system.

### 8. Utilization of Local Resources

The units for sale in Canada are manufactured in British Columbia and Newfoundland. The units are sold with all internal components installed. The homeowner or local contractors install the unit and establish plumbing and electrical connections.

### 9. References

Internet website: http://www.enviroaccess.ca/fiches_3/FA3-01-96a.html
Enviro-Access Technological Fact Sheet: BioGreen (Nfld.) Ltd. Secondary Wastewater Treatment.

Internet website: http://www.suimon.com/
Suimon Engineering of Canada Ltd.

Phillips, J., 1998. Suimon Engineering Canada Ltd., personal communications.

### 10. Suppliers, Contractors, Consultants

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BioGreen (Nfld.) Ltd.
P.O. Box 1240
Deer Lake, NF A0K 2E0
Tel: (709) 635-5170 Fax: (709) 635-5334/5000
e-mail: perrybg@atcon.com

**11. Conditions for Success**

Although the manufacturer claims that the treated effluent approaches drinking water quality, post-treatment disinfection may be necessary if the effluent is to be reused / recycled.

The system is sensitive to elevated loads of household cleaning products.

# B9. BIOKRELSEL™

## 1. Description

The Biokreisel is an on-site, in-ground treatment plant that uses a rotating biological contactor to treat septic tank effluent. Aerobic bacteria and other microorganisms that inhabit the treatment plant feed on nutrients contained in the wastewater.

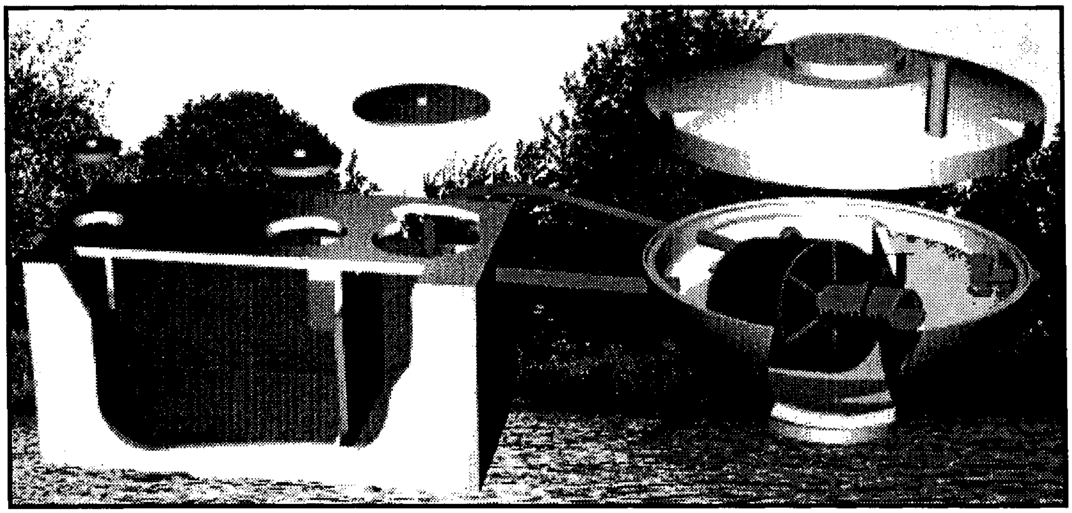

Figure 9.1 Biokreisel

## 2. Principles of Operation

The Biokreisel treatment system is enclosed in a two-piece hemispherical concrete tank. An interior wall divides the tank into two areas, the operating chamber and settling chamber. Wastewater discharged from the septic tank collects in the basin of the operating chamber. Bacteria and other microorganisms attached to the drum-shaped fixed growth medium are alternately exposed to air and wastewater as the drum rotates. One innovative feature of the Biokreisel is that the fixed growth drum is mounted on a diagonally-inclined hollow PVC axle rather than a horizontal solid shaft. Two intertwined hoses within the axle act as a screw pump as the assembly rotates, drawing the clarified water up the inclined axle and depositing it in the settling chamber. After settling, the effluent is discharged from the unit via a standard gravity outflow tee.

## 3. Status of Technology

The Biokreisel has been in commercial production in Europe for five years and is expected to receive NSF accreditation as a Class I aerobic treatment unit in the near future. A number of units are currently operating in the U.S. and in Rexton, New Brunswick.

## 4. Operation and Maintenance

A user-friendly control panel operates the system, monitors critical functions, and alerts the owner if service is required. The innovative hemispherical shape of the unit eliminates corners that might otherwise become clogged with settled solids. A submersed pump automatically removes accumulated solids from the bottom of the settling chamber. A circular access cover / vent at the top of the unit provides access to the interior of the tank for service if necessary. All metal parts are corrosion-resistant (hot-dipped galvanized steel or stainless steel).

## 5. Suitability to Small Flows

The unit is designed for on-site treatment of wastewater (combined black and greywater) from single-family homes. The treatment capacity is 2271 L/day.

## 6. Capital Costs

The estimated retail cost of the Biokreisel is $4500 - $5500 U.S. dollars. Additional expenses include excavation and installation costs, as well as the cost of the conventional septic tank that must be used in conjunction with the Biokreisel. The 2271 L/day treatment capacity may allow the unit to be "shared" between two residences to reduce capital and operating costs.

## 7. Effluent Quality

Most RBC systems are designed to treat water in successive stages; effluent from an RBC system is comparable to that from an activated sludge process if enough stages are used. In contrast, the Biokreisel uses only a single stage. The manufacturer claims that the unit is capable of reducing $BOD_5$ and TSS by over 90%, to 25 mg/L and 30 mg/L, respectively. The effluent is claimed to be clear and odorless.

## 8. Utilization of Local Resources

There are significant opportunities for use of local resources in fabrication and installation. The concrete tank would be cast and the remaining components assembled locally under license. Installation requires contractors for excavation, plumbing and electrical work.

## 9. References

Carroll, L.W., Nordbeton North America, personal communications.

Metcalf & Eddy, Inc., 1991. Wastewater Engineering Treatment, Disposal, and Reuse, 3rd ed. New York: McGraw-Hill.

Nordbeton GmbH promotional brochure and technical summary.

Tchobanoglous, G. & E.D. Schroeder, 1987. Water Quality. Addison-Wesley.

## 10. Suppliers, Contractors, Consultants

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Lake Monroe, FL 32747
Tel: (407) 322-8122 Fax: (407) 322-8159

## 11. Conditions for Success

The Biokreisel appears to be capable of providing renovated water for toilet flushing and other non-potable domestic reuse; however, its ability to do so has not yet been tested in a demonstration study. Post-treatment disinfection may be necessary if the effluent is to be used for this purpose.

The compact tank profile minimizes the "footprint" of the unit, allowing it to be installed on lots which would otherwise be too small for a conventional on-site treatment system. The manufacturer also claims that the unit is suitable for installation in areas with a high groundwater table.

Organic removal rates of RBCs may decrease below 13°C. The surface area of the RBC may be increased to compensate for cooler temperatures if necessary.

## B10. CLEAN FLUSH™ SYSTEM

### 1. Description

The Clean Flush System is a residential greywater recycling system that uses greywater from the bathtub or shower for toilet flushing. Greywater is drained to a 340 L holding tank, from which it is pumped to the toilet tank The system is expected to reduce residential water use by up to 30%.

### 2. Principles of Operation

Greywater entering the holding tank passes though a 50 mesh stainless steel mesh filter that removes lint, hair, and other large debris. The filtered greywater is automatically delivered to the toilet tank when the toilet is flushed. The tank is fitted with connections to the potable water supply (with a backflow preventer) and a high level overflow to the sewer. If the greywater level in the tank drops too low, a float valve allows potable water to enter the tank. If the tank level rises too high, excess greywater discharges by gravity through the trapped sewer connection.

### 3. Status of Technology

A patent for the Clean Flush System is pending. A prototype unit has been successfully installed and operated in a private residence. Further testing, evaluation, and development is planned before the system is introduced to the market. Regulatory issues related to greywater quality, and the possibility of process improvements including disinfection, are under consideration.

### 4. Operation and Maintenance

Experience to date indicates that the filter screen must be removed and washed every two months.

### 5. Suitability to Small Flows

The system is designed for single family residential use.

### 6. Capital Costs

In its present form, the Clean Flush System is expected to cost less than $500 (Canadian dollars), which may increase if design improvements are incorporated.

### 7. Effluent Quality

Performance monitoring, including assessment of recycled water quality, is proposed before the system is marketed. In the prototype system, odours are not apparent unless the house is unoccupied, and the greywater is not exchanged, for an extended period.

### 8. Utilization of Local Resources

The Clean Flush system will be a manufactured unit; installation will require plumbing connections and a 110V power supply only.

## 9. References

Milley, Graham, Clean Flush Systems Inc., personal communications, Feb./March, 1998.

## 10. Suppliers, Contractors, Consultants

Clean Flush Systems Inc.
18 Gardner Street
Grand Falls-Windsor, NF A2A 2T3
Tel: (709) 489-0800 Fax: (709) 489-0801

## 11. Conditions for Success

The Clean Flush system is designed to recycle light greywater from showers or baths for toilet flushing in a single family residence. Because light greywater contains sufficient nutrients and bacteria to create septic conditions if the greywater remains in the holding tank for extended periods, incorporation of a disinfection unit in the treatment process may be desirable.

## B11. CYCLE-LET™

### 1. Description

The Cycle-Let process consists of three steps: biological treatment, filtration, and final polishing / disinfection. The technology is based on the combination of bio-oxidation and membrane separation. The treated effluent is used for toilet flushing and landscape irrigation.

The Cycle-Let is designed primarily to treat wastewater at commercial and institutional facilities. For example, it has been installed in shopping malls, office buildings, and schools Canadian applications include an office building, trailer park, ski resort, and radar sites in the high arctic. It is suitable for sites with limited sewer capacity or limited capacity for conventional subsurface wastewater discharge.

### 2. Principles of Operation

The wastewater is initially collected in a buried pre-treatment trash tank that removes grit and gross solids. The trash tank also provides flow equalization and emergency storage capacity. The effluent is then pumped to the biological treatment system, which incorporates both aerobic and anaerobic processes. Aerobic treatment oxidizes organic solids and converts organic nitrogen to nitrates; the anaerobic stage converts nitrates to nitrogen gas. Self-cleaning, tubular ultrafiltration membranes remove suspended solids and microorganisms; solids are returned to the biological treatment tank for further digestion. Effluent then passes through activated carbon adsorbers which remove any remaining colour and odour. Finally, UV disinfection and ozonation destroy any remaining microorganisms. The reclaimed wastewater is stored in a reservoir until it is needed for toilet flushing.

### 3. Status of Technology

Over 100 Cycle-Let systems are currently operating in the U.S. and Canada. The technology has been tested by the National Sanitation Foundation and is certified for process performance and reliability under NSF standard No. 41. It also meets California Title 22 Standards for Water Reuse, and is consistent with health and safety standards in the British Columbia Plumbing Code.

### 4. Suitability to Small Flows

The Cycle-Let is typically used in office buildings, shopping centres and schools where toilet flushing is the largest source of water consumption. In applications where demand for toilet flushing may not be as large, the system can be used for landscape irrigation or to reduce the drainage field area required for subsurface discharge.

Designs are customized based on the application, required treatment capacity, and site conditions. The capacities of Canadian systems range from 4500 L/day for an office building to 2.3 million L/day for a ski resort. The systems can be designed to serve flows in the range of 4500 L/day to 3.18 million L /day.

## 5. Operation and Maintenance

Because the system is completely automated, operation and maintenance demands on the owner are minimal. The manufacturer provides comprehensive operation and maintenance services under contract. System operations are monitored and controlled remotely by computer and telephone connections. Alarms are incorporated in the system to alert the operations centre of problems or malfunctions.

The equipment requires trained specialists for maintenance. Trained personnel may also be called upon to solve operational difficulties associated with the biological process. Stored solids need to be removed by hauling once a year.

## 6. Capital Costs

A small system with a treatment capacity of about 4500 L/day can cost in the range of $80,000 to $100,000, depending on requirements.

## 7. Effluent Quality

The manufacturer claims that the treated effluent is "crystal clear, odourless, colourless, and coliform and bacteria free." Reported effluent quality, based on treatment of combined (grey and black) wastewater for use in toilet flushing is:

| | | |
|---|---|---|
| BOD < 5 mg/L | Suspended Solids < 5 mg/L | Turbidity < 2 NTU |
| Nitrogen Removal 85-90% | Total Coliforms < 2.2/100 mL | |

## 8. Utilization of Local Resources

This patented treatment technology has been adapted and applied by consultants in Canada and the United States. Prefabricated systems are delivered to the installation site. Concrete flow equalization and sludge holding tanks may be constructed on site, depending on system size. Because the system requires experienced operation and maintenance personnel, opportunities may exist for qualified local companies to provide this service.

## 9. References

Totten Sims Hubicki Associates, 1997. Conservation Co-Op Residential Water Reclamation Interim Report. Prepared for Canada Mortgage and Housing Corporation.

Zenon Municipal Systems Inc. and Hill, Murray & Associates promotional literature.

## 10. Suppliers, Contractors, Consultants

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845 Harrington Court
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Zenon Municipal Systems, Inc.
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Tel: (800) 443-3006 Fax: (734) 761-7842

Hill Murray & Associates Inc.
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Victoria, BC V8X 3W4
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e-mail: <hma@islandnet.com>

## 11. Conditions for Success

The Cycle-Let has been used to reclaim combined (grey and black) wastewater for use in toilet flushing. The manufacturer's representative has expressed reservations about the ability of this system to treat 100% greywater because of low nutrient and carbon content.

The Cycle-Let is a sophisticated technology that depends on experienced operation and maintenance. It is suitable for applications where the capital and operating costs are justified by site limitations, high drinking water costs or wastewater disposal costs.

# B12. HYDROXYL SYSTEMS™

## 1. Description

The Hydroxyl Systems™ process uses a number of technologies to treat domestic or municipal wastewater. Domestic-scale systems commonly include an equalization / settling tank, screened effluent pump, attached growth aeration chamber, porous foam biofilter, and advanced oxidation / ozonation. Although the system is most often used to treat potable water and wastewater, it has also been used for reuse / recycling applications, including irrigation and toilet flushing.

## 2. Principles of Operation

The Hydroxyl Systems™ treatment unit used for residential applications functions as a sequencing batch reactor. The wastewater first enters a flow equalization tank, where materials that float or settle are removed. The tank is sufficiently large to accommodate daily peak flows. Further removal of total suspended solids is achieved by Hydroxyl's Positive Flotation Mechanism (PFM)*, which introduces electrostatically-charged micro-bubbles of air into the wastewater. The bubbles adhere to suspended solids and float particulate matter to the surface where it is removed mechanically. The wastewater is screened and pumped into a high-efficiency aeration chamber. Blowers maintain high oxygen levels and promote mixing. Microorganisms attached to suspended plastic media feed on nutrients in the wastewater, thereby reducing biochemical oxygen demand. The attached biological growth is self-regulating and resistant to shock loading. The treated wastewater is then circulated through an aerated, porous foam biofilter that further reduces BOD, converts ammonia to nitrate and traps fine solids. Finally, the water is disinfected by "Electro-Mechanical Advanced Oxidation," a proprietary process that combines ozonation and mechanical agitation to form highly-reactive hydroxyl radicals. These hydroxyl radicals destroy bacteria, viruses and other pathogenic organisms.

## 3. Status of Technology

The technology is in full commercial production. Although the manufacturer customizes the design for each proposed installation, the treatment system consists of a series of skid-mounted modular sub-components to simplify fabrication.

## 4. Operation and Maintenance

The treatment system is installed in a self-contained, weatherproof shelter. System processes are controlled by a programmable logic controller and monitored from the company's offices; minimal operator attention is required. The system must be inspected twice a year for preventive maintenance. Sludge must be removed from the equalization tank and aeration basin every two years. The biofilter is constructed in sections for easy inspection and servicing. The Electro-Mechanical Advanced Oxidation unit requires little maintenance.

* The Positive Flotation Mechanism is not normally included in domestic-scale systems.

## 5. Suitability to Small Flows

The system recommended for domestic installations has a treatment capacity of 3000 L/day; as such, it should be capable of treating waste from several single-family homes or townhouses. There are over 30 of these units currently in operation; in Canada, two are being used to treat wastewater for reuse. A 6000 L/day system supplies renovated wastewater for toilet flushing and irrigation at the Sustainable Technology Center, a retail / office complex in Washington State.

## 6. Capital Costs

The installed price of a 3000 L/day system capable of supplying renovated wastewater for non-potable reuse is approximately $20,000 - $30,000, depending on engineering services required, site access, geographic location, permitting, and other variable costs. The company suggests that larger cluster systems may reduce the cost to well below $10,000 per home, including plumbing, power and installation costs.

## 7. Effluent Quality

Water-soluble organic compounds, bacteria, viruses, and other pathogenic organisms are ultimately oxidized into carbon dioxide, salts and water. $BOD_5$ and TSS are consistently below 10 mg/L. The clear, odourless, disinfected effluent can be safely reused for irrigation, toilet flushing and other purposes.

## 8. Utilization of Local Resources

The complete turnkey system is manufactured in British Columbia, shipped to the installation site and installed by company personnel. Local contractors may be used for larger installations.

## 9. References

Hydroxyl Systems Inc. Internet website (http://www.hydroxyl.com)

Jürgen Pütter, Hydroxyl Systems Inc., personal communications

## 10. Suppliers, Contractors, Consultants

Hydroxyl Systems Inc.
P.O. Box 2278, 9800 McDonald Park Road
Sidney, BC V8L 3S8
Tel: (250) 655-3348 Fax: (250) 655-3349

## 11. Conditions for Success

The Hydroxyl Systems$^{TM}$ process has been used to treat raw wastewater for reuse / recycling. Modular design allows additional components to be used in conjunction with or in lieu of the standard components to achieve the desired level of treatment. The system is temperature sensitive but good for fluctuating flows.

# B13. ROTORDISK™

## 1. Description

The Rotordisk is a rotating biological contactor designed to treat domestic wastewater (combined greywater and blackwater). The system consists of a primary clarifier or settling tank that contains the rotating biological contactor (RBC) and a final settling tank for biosolids removal. The unit recommended for household wastewater treatment, model S-12, is a self-contained system enclosed in a fiberglass tank. Alternatively, the rotating biological contactor mechanism itself is available for installation in a conventional concrete settling tank.

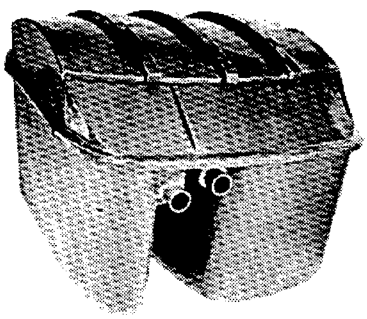
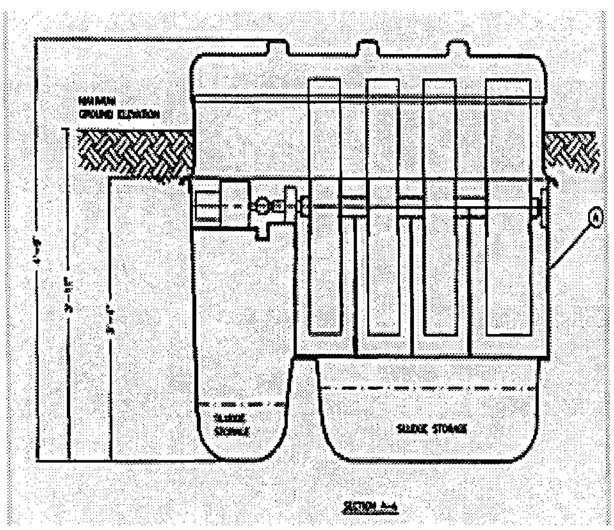
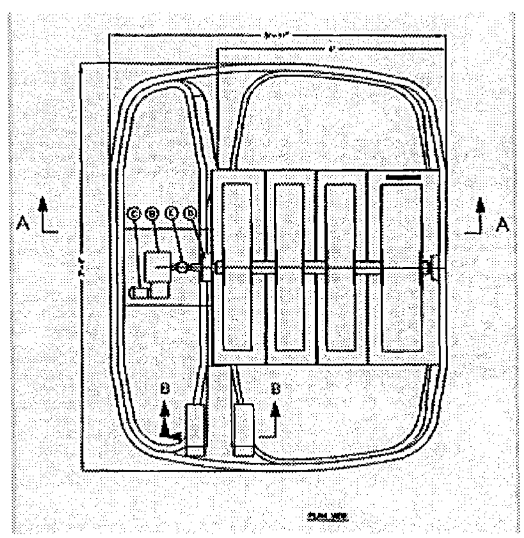


Figure 13.1 Rotordisk




## 2. Principles of Operation

Like all RBCs, the Rotordisk is designed to support attached microbial cultures that are naturally present in wastewater. A number of honeycombed or corrugated disks, normally polystyrene or polyvinyl chloride, provide a large surface area for aerobic bacteria and other microorganisms to cling to. The disks are mounted above a trough on a rotating horizontal shaft. Wastewater flows past successive disks under gravity in a serpentine pattern. As the disk assembly rotates, the microorganisms are alternately exposed to air and to wastewater, allowing them to feed on nutrients contained in the wastewater. Excess biomass that sloughs off the disks remains in suspension due to the mixing action of the disks, then settles out in the final settling tank.

## 3. Status of Technology

The Rotordisk has been in commercial production for over 15 years and has received NSF Class I accreditation for wastewater treatment. The technology has been approved by the Ontario Ministry of Environment and Energy for both surface and subsurface discharge. Effluent from a number of Rotordisk installations in Indonesia is reused for cooling water and irrigation. Post-treatment disinfection may be required for domestic non-potable reuse.

## 4. Operation and Maintenance

The Rotordisk does not require a skilled operator or continuous monitoring. Routine maintenance includes greasing the shaft bearings, periodic drive chain adjustment and lubrication. Sludge must be pumped out every nine months (or as required) by a vacuum truck / septic hauler, in the same fashion as a septic tank. The manufacturer claims that operating costs are lower than other mechanical treatment systems or bubble aeration systems.

## 5. Suitability to Small Flows

Rotordisk model S-12 is specifically designed for on-site treatment of wastewater from single-family homes. The treatment capacity is approximately 3270 L/day. The unit is self-contained and does not require pre-treatment by a septic tank or other means; however, S-12 units have been installed downstream of septic tanks. The unit can be installed above or below grade, as required.

## 6. Capital Costs

The cost of a standard fiberglass Rotordisk S-12 unit is $7500 (Canadian dollars), plus excavation and installation costs.

## 7. Effluent Quality

The unit is capable of reducing influent $BOD_5$ and TSS by over 90%, to 12 mg/L and 6 mg/L, respectively.

## 8. Utilization of Local Resources

The unit is shipped pre-assembled from the factory in Ontario to minimize site construction. Installation requires contractors for excavation (if unit is to be installed below grade), plumbing and electrical work.

## 9. References

CMS Group Inc. Internet website: http://www.rotordisk.com

Delevante, David, CMS Group Inc., personal communications, February / March 1998.

Rotordisk: The Simple Sewage Treatment System. (promotional brochure)

Rotordisk: Testing of a Rotordisk™ S-12 at the National Sanitation Foundation to Standard No. 30 Testing Protocol, as Performed in 1981/82. (promotional / technical brochure)

Totten Sims Hubicki Associates, 1997. Conservation Co-op Residential Water Reclamation Interim Report. CMHC, January 1997.

**10. Suppliers, Contractors, Consultants**

CMS Group Inc.
185 Snow Boulevard, Suite 200
Concord, ON L4K 4N9
Tel: (905) 660-7580 Fax: (905) 660-0243

**11. Conditions for Success**

The Rotordisk appears to be capable of providing renovated water for toilet flushing and other non-potable domestic reuse; however, its ability to do so has not yet been tested in a demonstration study. Post-treatment disinfection may be necessary if the effluent is to be used for this purpose.

The Rotordisk system is designed to treat a combination of blackwater and greywater flow. If the greywater contribution exceeds 50% of the total flow, the system will not function properly. The manufacturer recommends that the Rotordisk not be used to treat wastewater that contains greater than 30% greywater.

# Appendix C

# AREAS AND SITUATIONS IN CANADA THAT COULD BENEFIT FROM THE APPLICATION OF WASTE WATER RECYCLING AND RE-USE WITH EXAMPLES

Prepared for

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# AREAS AND SITUATIONS IN CANADA THAT COULD BENEFIT FROM THE APPLICATION OF WASTEWATER RECYCLING AND REUSE, WITH EXAMPLES

## 1.0 INTRODUCTION (1)(4)

In the past, societies around the world have tried to meet their insatiable water demands by expanding supply systems. As the new millennium approaches, there is the realization that both ecological and economic limits have been reached. There is a need to replace supply management with a new approach that harmonizes economic goals with environmental criteria.

The key to meeting water shortages and water pollution problems is to embrace a new social ethic of conservation, efficiency, recycling, and reuse. The purpose of this discussion paper is to identify areas or situations in Canada that could benefit from the application of wastewater renovation, recycling and reuse primarily in residential systems, with consideration to rainwater cistern systems and water conservation. Where specific technologies are identified by proponent as examples they are described in some detail so the reader may appreciate their basic differences..

The background addresses water resource; water and wastewater infrastructure; and wastewater renovation, recycling and reuse issues as they affect the adoption of this new approach. The body of the discussion paper considers potential Canadian applications on a regional water resource/geographic basis, and on a more general site-specific basis. A number of the specific completed and ongoing technology recycling installation examples have resulted from various CMHC initiatives.

## 2.0 BACKGROUND

### 2.1 Water Resource Issues (1)(2)(3)(4)(5)

Although water is a renewable resource, it is also a finite one. The water cycle makes available only so much each year in a given location. One of the clearest signs of water scarcity is the increasing number of countries in which population has surpassed the level than can be sustained comfortably by the water available. Water scarcity problems may also stem directly from human activities - deforestation, over grazing, over farming, or urban development. Degraded land increases flash runoff decreasing seepage, and thus aquifer recharge.

As a result of global warming the earth's temperature is expected to rise somewhat altering the hydrological cycle. Sea levels will rise, rainfall patterns will shift, and drought areas will develop in the Prairies such as already have been experienced in California.

Increased precipitation is projected for the Arctic and south eastern Canada. Summers will be drier with more frequent droughts except in the Arctic and in the St. Lawrence Atlantic region. Demands on water for irrigation in the West will increase and intensify.

Whether local rainfall decreases or not, warmer weather will increase evapotranspiration boosting water demands for crop irrigation, lawns and gardens. More winter precipitation will fall as rain and the snow will melt earlier reducing river flows during the summer when they are needed most. With diminished surface water supplies even more reliance will be placed on ground water.

Canada uses more water per capita than any other country except the United States. Despite an apparent abundant supply, clean water may be in short supply or inaccessible at specific locations at certain times of the year. Water problems across Canada involving both surface and ground water threaten the quality of life of many Canadians in various regions of the Country.

Pollution is more often the cause of water problems for Canadians than any absolute scarcity of supply. Wastewaters from municipalities on the Great Lakes and St. Lawrence River contain toxic chemicals that are not removed by treatment. Pollution from various sources including agriculture leads to contamination of the groundwater on which more than one-quarter of all Canadians rely for their water supply.

There is an ongoing population shift on a national basis from water rich areas (East) to water poor areas (West). People choosing to leave metropolitan areas for small town and rural living are putting new demands on small water and wastewater systems.

Increasing pressures on available supplies, conflicting demands, and new threats to water quality from climate change are converging to make Canadians aware that they can no longer take plentiful supplies of clean water for granted. Many fear that our present water policies are inadequate to cope with the emerging pressures on our water resources. Such anxieties have produced a mood for change.

## 2.2 Water and Wastewater Infrastructure Issues (1)(3)(6)

Much of Canada's existing water and wastewater infrastructure needs major upgrading or replacement to meet existing and expanding demands. Inadequate and poorly maintained wastewater infrastructure reduces water quality in surface water bodies and in groundwater.

Costs of operation and maintenance of existing services are excessive. Servicing of new areas is expensive where permitted and often prevented when conventional, piped community services are not available.

Conservation, once viewed as just an emergency response to drought, has become a sophisticated cost effective and environmentally sound package of measures for balancing water budgets. A number of Canadian municipalities have embraced municipal water conservation programs including Edmonton, Winnipeg, Waterloo and Ottawa-Carleton.

Many water shortages around the world stem from the widespread failure to value water at anything close to its true worth. Under pricing water perpetuates the illusion that it is plentiful. In Canada, unmet water and wastewater infrastructure capital requirements; population growth with location shifts; and government fiscal constraints are driving the move towards full cost, user pay direct consumer charges. Future new user pay pricing policies will increase demand for cost-competitive and more efficient environmental technologies including wastewater renovation, recycling and reuse systems.

A full cost, user pay system will also encourage private financing and investment in innovative recycling technologies and practices that reduce water consumption and wastewater discharges. Further, higher prices will provide revenues to properly service and maintain wastewater renovation and recycling systems.

### 2.3 Wastewater Renovation, Recycling and Reuse Issues (1)(7)

Potable water used once can be recycled in the same home, commercial establishment or factory; or collected from one or more sites, treated and redistributed to a new location for reuse. Reuse or recycling of wastewater streams could be employed whereever it is necessary or appropriate to do so. These circumstances are most likely to arise in places where there is an apparent water problem.

Examples of such renovated water applications include:

- domestic, municipal, public lands, golf courses and farm land irrigation services,
- residential and institutional laundry and toilet services, and
- fire protection services and potentially, potable water services.

Two cities in the world, Windhoek, Namibia, and Denver, Colorado, USA, are pioneering the reclamation of municipal wastewater for drinking. It is expensive (70 US cents per 1000 litres). At the present time in Canada turning municipal wastewater into potable water while technically achievable is not being considered for both psychological and economic reasons.

Current regulations governing water reuse and recycling systems present a local barrier to their adoption. To obtain a change in the regulations requires following complex procedures and time consuming processes often involving multiple agencies. There is a reluctance by regulators to assume any part of the risk and liability for the performance of innovative technologies. Reformed regulations should emphasize public health and environmental performance rather than technological process.

Liability for the ongoing maintenance of any device installed, and the quality of water flowing from the device after installation must be assumed by a responsible public or private body. The ultimate success of reclamation, recycling, and reuse systems will depend upon acceptance by owners and users for their economic cost, performance, reliability, ease of quality monitoring and required maintenance.

## 3.0 POTENTIAL APPLICATIONS BY REGION (1)(2)(3)(4)(6)(8)(9)

Wastewater renovation, recycle and reuse systems may be used in the regions of Canada where surface and groundwater supplies are in short supply, inaccessible or contaminated. This section of the paper identifies some of these areas on a regional basis across Canada.

Even in a water wealthy country like Canada physical signs of water stress already exist. As a rule of thumb, hydrogeologists designate water stressed countries as those with annual supplies of 1000 - 2000 cubic meters per person or 2740 - 5480 litres per person per day. The major area in Canada approaching this limit of supply is in the southern Prairies especially the basins of the South Saskatchewan, Red and Assiniboine rivers due to agricultural based activities. On a seasonal basis, these basins have less than 2500 litres per capita per day. There is not always enough water for crop irrigation and residential use.

More than half of Canada's irrigated land is in Alberta. Alberta and to a lesser extent Manitoba and Saskatchewan account for 95 percent of all agricultural irrigation demand in Canada. In rural areas there is lack of surface water with dugouts drying up or being loaded with toxic algae blooms by July. Ground water which serves more than 50 percent of the Saskatchewan population tends to be expensive and of poor quality being deep and saline.

The economy of the Prairie region is based on other large and growing water-use activities - energy and mineral developments. New demands are expected for deep-well injection to maintain pumping pressure in depleting oil fields and for tar sand development.

British Columbia has the greatest flow of water among the provinces with half of it coming from the coast and inland mountain ranges. The rainy coastal areas would support rainwater cistern systems where suitable surface or groundwater supplies are unavailable. The Province does have local water short areas in the southern interior (Okanagan Valley) and in urban growth areas (Surrey). In British Columbia water reuse is practised mainly in the Okagagan Basin (eg. Vernon, Osoyoos, Oliver, Armstrong, Penticton), Cranbrook and Kamloops areas.

Shortages are also emerging in the urban growth regions of Waterloo and Halton in Southern Ontario. The Regional Municipality of Waterloo with a population of 350,000 is Canada's largest metropolitan area dependent on ground water for its supply. Faced with water problems and the high cost of obtaining surface water from the nearby Grand River or Lake Hurron, some 120 kilometres to the west, the Region has conducted a vigorous conservation program to cut water demand.

Although all provinces have some cause for a alarm, serious damage to surface waters is found in Ontario, Quebec, and parts of Atlantic Canada. The Great Lakes supply one-third of all Canadians with drinking water.

All of the population of Prince Edward Island rely on wells for household water. Ground water problems here, and across Canada, involve both depletion and contamination of aquifers from agricultural operations and from waste disposal site plumes. Some 18 percent of the wells on Prince Edward Island are contaminated with pesticides.

A seasonal shortage of water can affect almost any part of the country with serious results. In the summer of 1987, for example, residents in parts of Newfoundland had to boil water for drinking, and others had to travel long distances to obtain water. In Newfoundland there are relatively few good surface waters. Many surface waters rising in conifer/peat areas are dark in colour contaminated by natural organic compounds including tannins. In these cases there is a reliance on rainwater for domestic water requirements.

In Nova Scotia rainwater cistern systems endorsed by the Provincial Department of Health have been used successfully for some time. The Centre for Water Resources Studies (CWRS) has provided the technical support for this development.

The North is an Arctic desert with low precipitation. Reliable seasonal flows are relatively low in northern basins where freezing reduces flows significantly in winter. Many communities have difficulty getting dependable supplies of safe drinking water - drawing water from lakes, rivers and constructed reservoirs below freezing depth.

These physical problems along and geographic isolation, small community size, high capital and operating costs, and lack of technical back-up, make water efficiency a key requirement in northern communities. An innovative solution to the high cost of traditional piped systems has been trucked services. However, the cost of trucked services has risen significantly in the last few years resulting in initiatives to demonstrate the efficacy of wastewater renovation and recycling in both Arctic and Sub Arctic communities.

## 4.0 POTENTIAL SITE SPECIFIC APPLICATIONS

Wastewater renovation, recycling and reuse applications, with or without water conservation and rainwater cistern components, may be beneficial at specific sites within regions for three main reasons related to public health, environmental and/or economic constraints:
to supplement limited available potable water sources whether surface water or groundwater,
to enhance water pollution abatement, and
to be more cost effective over conventional water supply, wastewater treatment and disposal methods in areas otherwise unsuitable for new or re-development.

Site specific conditions such as soil, geology, topography size, access and closeness to water bodies which were not considered previously on a regional basis are all contributing factors to the adoption of water reclamation, recycling and reuse systems. Another significant economic factor is remoteness from conventional municipal servicing.

### 4.1 Supplementation of Available Potable Water Supplies

It may be necessary to supplement available local surface water supplies on a seasonal basis or on an annual basis where the demand exceeds the watershed yield. Deteriorating water quality during particular seasonal periods may also be a reason for supplementing the production of stressed water treatment plants.

Local hydrogeological conditions may not produce adequately yielding wells of suitable water quality. This is particularly true of many areas within the Precambrian Shield and in the sub-Arctic regions of Quebec and Labrador. Salt water intrusion may limit the useful yield of wells in coastal areas as previously mentioned.

## 4.2 Protecting the Receiving Environment

Local sites may be limited or be prevented from development because resulting wastewater discharge would cause contamination of the receiving environment. Such sites may have poor soils; provide no area to locate disposal fields because of steep topography; be in rock or have high water tables - any or all of the reasons why conventional septic tank disposal bed systems are not permitted.

For these sites wastewater reclamation with recycling and water conservation systems would significantly reduce the volume of wastewater for disposal. They would produce a high-quality effluent not requiring further treatment in natural soils. Both factors lessen the risk of polluting the receiving environment.

In British Columbia, residences and commercial facilities built on mountain sides, on rock in the Fraser Canyon, and on poorly draining loam soils in the interior valleys are difficult to service by conventional pollution abatement technologies. Malfunctioning septic systems serving year-round residences, cottages, resort properties, and marinas threaten recreational lakes in Ontario and elsewhere.

### 4.2.1 Retrofitting Existing Wastewater Disposal Systems (11)

Many residences have old sewage disposal facilities which are not acceptable by to-day's standards. These systems may now be deemed over-loaded as a result of improvements to the dwelling, changes in family occupancy, or the installation of modern water consuming devices. In these cases, the introduction of water conservation devices, and wastewater renovation and recycling could permit continued use of the existing property without taxing its ability to safely carry away highly treated wastewater by ground disposal.

### 4.2.2 Replacing Wastewater Holding Tanks (11)

In many small communities there are commercial buildings and homes that do not have municipal services and cannot be served by conventional on-site disposal systems. They rely on wastewater holding tanks that must be pumped out on a regular basis by a contracted septage hauler.

Holding tanks also serve isolated houses high-up on steep, rocky hills, or on small islands with little soil or high water table. Marinas and recreational resorts under similar local conditions also rely on holding tanks and septage haulage to remain in business.

In all these cases the high cost of hauling septage provides an economic incentive to upgrade using a wastewater renovation and recycling system. There is no geographical limit in Canada to this application of recycling technology to enhance water use without degrading the environment.

## 4.3 Servicing Remote Development More Cost Effectively (12)

Residential water reclamation and recycling systems are most attractive in remote situations away from community services in areas where power must be generated onsite, water supplies are scarce;

and/or conventional septic tank based systems are not suitable or affordable. These include island developments and other isolated sites where road access is difficult.

As in the Northwest Territories, First Nation communities across the Prairies and in Northwestern Ontario are served by truck haul systems. Truck service is provided to houses with plumbing based on the criteria of 90 litres per capita per day (one-half of the design amount for piped systems).

Trucked water and wastewater service has been preferred in the less densely populated areas of communities served by a central core piped system because of distance from the source of water supply, unfavourable ground conditions, and strip development. Truck service is also employed where adequate ground or surface water supply is not available to individual remote residences.

With increasing water use, infilling as communities grow, and rising operational costs, there has been considered a point based on life-cycle costing that truck haul would be replaced by central servicing. The point in time when the major capital outlay for conventional piped services would be required could be further delayed or avoided by the introduction of individual residence wastewater renovation and recycling systems. In this case economics would again drive the adoption of recycling.

## 5.0 EARLY DEVELOPERS AND ADOPTERS OF WASTEWATER RENOVATION AND RECYCLE SYSTEMS IN CANADA

The Thedford Corporation of Ann Arbor Michigan with its proprietary Cycle-Let$^{R}$ system successfully pioneered in the USA the reclaiming of wastewater from office complexes, and commercial enterprises including laundries, schools, and sports related facilities for toilet and urinal flushing and onsite landscaping at locations with no sewer capacity or poor ground disposal potential. The Cycle-Let$^{R}$ technology is now owned by Zenon Environmental Inc., Burlington, Ontario and is marketed by Zenon Municipal Systems Inc., Ann Arbor, Michigan. To-date, the company has not entered into the residential market in the USA or Canada, sales being driven by cost effectiveness and regulatory approvals.

Since the early 1990's Canadian companies mainly based in the West have developed wastewater renovation systems producing high quality effluents suitable for accepted recycle and reuse applications. Their applications to-date with brief technology descriptions are presented herein.

With the Toronto Healthy House and subsequent initiatives, CMHC has been very active in supporting the development of renovation technologies in Canada and their application. Completed and ongoing projects being undertaken by CMHC and its various partners are also described in some detail.

### 5.1 Commercial, Proprietary Systems

Five proprietary systems are described. Three of the companies are Western based. All of the installations cited are in the West and the North.

### 5.1.1 Zenon Municipal Systems Inc.

The first Cycle-Let[R] installations in Canada have arisen from the activities of Hill, Murray & Associates, Victoria, B.C., a design build and operate, consulting firm representing Zenon Municipal Systems Inc. To-date, three Cycle-Let[R] systems have been approved under the Province of British Columbia Ministry of Health's Innovative Technologies Policy. The first fully recycling building is the Sooke Office Building of the British Columbia Buildings Corporation for the Ministry of Social Services in Sooke, B.C. built in 1996.

There were no sewers in the area and the site was too small for the needed standard septic disposal field. The 10,000 ft building has a full-time staff of 24 and two separate, public washrooms. By installing the 1000 GPD fully recycling, tertiary-quality Cycle-Let[R] wastewater treatment facility the discharge was reduced to an average of 18 GPD from 400 GPD requiring a disposal field of only 17 feet of pipe. This results in an annual savings of 60,000 gallons of potable water.

The treatment system is housed in a 400 $ft^2$ maintenance room in the basement of the building. The process incorporates biological treatment, membrane filtration, activated carbon, and ultraviolet disinfection. Sludge is accumulated within the biological reactor and requires only once-a-year hauling. The system was installed according to a build - operate - management service agreement. The technology has been certified by National Sanitation Foundation International.

Hill, Murray and Associates Inc. has also customed designed two, 2500 GPD fully recycling, pre-assembled, Arctic-ready wastewater treatment systems for the Department of National Defence Long Range Radar sites at Cambridge Bay and Hall Beach in the Eastern Arctic soon to become Nunavut.

Commissioned in December 1995, each facility serves from 25 to 60 full-time staff. Total water consumption at the sites has been reduced from 1500 to 2500 gallons a day. The treated water is discharged to the tundra with minimal effect through an Arctic compatible disposal system.

Water collected from showers, urinals, toilets cafeteria and cleaning facilities is treated for recycling in toilets and urinals. Each plant is monitored 24 hours a day, seven days a week by a Programmable Logic Controller linked by modem to Hill, Murray's offices in Victoria. The Sooke Office Building is also provided with the same monitoring and remote control system.

### 5.1.2 Hydroxyl Canada

Hydroxyl Canada, Sidney, B.C. incorporated in 1992 has developed potable water treatment and residential wastewater treatment systems with research grants from the National Research Council of Canada. The Company has combined its own proprietary processes with optimized conventional treatment processes. Each Hydroxyl system is equipped with a fully automated Programmable Logic Controller (PLC) system, auto dialer, and non-dedicated telephone line connection for remote monitoring and/or control by qualified service personnel.

The original development by which the Company is named was the generation of hydroxyl free radials which have a higher relative oxidation power than ozone and twice that of chlorine. The hydroxyl free radicals can be produced by electro-mechanical or electro-chemical methods. In each case, ozone is first produced from which the hydroxyl free radicals are derived. This advanced oxidation technology is incorporated into a number of unit processes. These include attached growth extended aeration, air flotation solids separation, and tertiary bio-filter unit processes.

The Company's HS-R residential treatment system which is preceded by a septic tank consists of a three-chamber tank providing attached growth extended aeration secondary treatment, biofiltration tertiary treatment, and disinfection by hydroxyl free radicals. Based on batch operation the effluent is circulated several times to optimize free radical oxidation.

The high quality effluent is suitable for recycling for toilet flushing and for landscape irrigation. The HS-R Hydroxyl System is approved for installation under the British Columbia Ministry of Health's "Innovative Designs and Technologies Policy." The Company also offers a "design - build - maintain" service.

The Company's first water reuse application is a 6000 LPD (1500 gpd) unit serving the Sustainable Technology Centre, Friday Harbour, San Juan Island, Washington, across the Haro Strait, north-east of Victoria. The Centre is a privately-funded development utilizing a combination of innovative systems and construction techniques. It is largely self-sufficient for its, water, sewage, power and heating requirements.

One hundred percent of the Centre's non-potable water use as toilet flush water and landscape irrigation water is renovated water supplied by the Hydroxyl treatment system. Since start-up in the spring of 1995, water requirements have been reduced by 90 percent.

### 5.1.3 Aquatex Corporation

The Aquatex Corporation of Edmonton, Alberta sells water and wastewater treatment systems based on proprietary ozonation techniques for aeration, oxidation and disinfection. The Company offers a residential immobilized bioreactor wastewater treatment system. The treated effluent described as clear, pathogen free with low $BOD_5$ low nutrient levels, and high dissolved oxygen is suitable for recycling applications such as toilet flushing and irrigation.

The system is preceded by an equalization tank. The first component, an immobilized media anaerobic bioreactor, is followed by an immobilized anoxic bioreactor. Effluent from the third component, an immobilized aerobic bioreactor is recycled back to the anoxic reactor for nitrogen removal. In the fourth and final stage ozone is applied for disinfection. The system is fully automated with digital and analog sensors feeding data to a programmable logic controller.

Aquatex's first installation with recycling is the Hobbema Institution of Corrections Canada located on First Nations land about one and one-half hour's drive from Edmonton, Alberta. The wellness centre and half-way house facility built in 1997 and still being commissioned is designed for 70 residents and 35 staff.

Up to 4500 GPD of black water is directed to the Aquatex plant for secondary treatment before discharge into a constructed wetland. The effluent from the wetland is retained in a storage pond. Water from the storage pond is pumped into the facility's utility water system for all uses except potable water and fire protection.

### 5.1.4 Proteus Environmental Systems Inc.

Proteus Environmental Systems Inc. of Calgary, Alberta, has developed a proprietary primary solids separation technology called Closed Chemically Enhanced Treatment System (C-CETS) based on alum precipitation. Secondary and tertiary treatment processed can be added by Proteus to offer entire Modular Effluent Treatment Systems (METS).

At Prince Albert, Saskatchewan, a 105 $m^3/d$ METS was installed in early 1995 at the Hazeldell wastewater treatment plant serving a 115 home subdivision and also receiving some commercial - industrial wastewater. The basic C-CETS system is followed by sand filters and Waterloo Biofilters™ with UV disinfection to produce a high-quality effluent before discharge. The sludge is thickened and trucked off-site to the City of Prince Albert incinerator for disposal.

The installation was used to demonstrate and further develop the METS technology as well as provide technology verification with slow sand filtration prior to disinfection as demonstrated at Hazeldell. Its performance was verified by the Canadian Environmental Technology Advancement Corporation-West in 1997. Proteus feels the treated effluent can be used for flushing toilets, laundry and bathing and is therefore interested in pursuing wastewater treatment opportunities involving renovation, recycling and reuse.

### 5.1.5 Clean Flush Systems Inc.

Clean Flush Systems Inc. of Grand Falls, Newfoundland, is developing an individual home grey water recovery toilet flush water system. The system consists of a primary cartridge filter, holding tank, secondary cartridge filter and recycle pump. There is no disinfection of the treated water. For houses served from a piped water distribution system provision is being made through an approved cross connection to supply potable water as a system back up.

## 5.2 CMHC Supported Initiatives

The Healthy House Water System now being marketed by Creative Communities Research Inc. came about as a result of Canada Mortgage and Housing Corporation's Housing Design Competition in the Urban Infill Category won by Martin Liefhebber Architect Inc. Subsequently, other applications for the Healthy House Water System have been pursued with continuing support from CMHC. CMHC has also supported two other independent water renovation and recycling projects involving multiple and single housing units.

### 5.2.1 Healthy House Water Systems (13)(14)

The following Healthy House Systems have been and are being developed by Creative Communities Research Inc. with support from CMHC and other partners.

### 5.2.1.1 Toronto Healthy House

The Toronto Healthy House is a four-story duplex dwelling built on an area not much larger than would be occupied by a two-care garage. Each lot measures 22.5 feet by 80 feet deep. It is based on principles of environmental responsibility contributing to the fundamental needs of the inhabitants with a minimum demand for energy consuming resources.

Each unit provides its own wastewater treatment and disposal as well as fresh water from a rain water cistern system. Equipped with water conservation devices each reclaims wastewater and recycles it to toilets, laundry, exterior hose bibs, and optionally to showers and baths.

The lane on which the houses are located has no piped water or sanitary sewer services. A written estimate from the City of Toronto of $205,000 to provide these services encouraged off-grid servicing. The site, however, provided a constraint for onsite wastewater disposal because it is on the side of a steep hill of fine sandy silt soil of low permeability.

Treated rainwater supplies potable water for drinking, food preparation, and dishwashing. Wastewater is treated by a septic tank with effluent filter below the car port, a recirculating tank below the basement, and a Waterloo Biofilter™ housed in a sealed stainless steel enclosure in the basement. The Waterloo Biofilter™ is ventilated by a forced air fan. A 120 L/day portion of the Waterloo Biofilter™ effluent is disposed of onsite in a leaching bed, and the design 600 L/day remainder is further treated for reuse.

Polishing consists of two-stage roughing sand and slow sand filters with ozone post disinfection. Ozone is also applied for trace organic oxidation and colour removal.

The system is working well at the single-house scale meeting the non-potable needs of toilets, laundry, gardening, shower and bath. The Healthy House Water System marketed by Creative Communities Research Inc., Toronto, Ontario, has application where water supply is expensive or scarce; and where tight soils and small lots make disposal of effluents difficult.

### 5.2.1.2 Northwest Territories Housing Corporation (15)

Water is one of the most plentiful commodities in the Northwest Territories. Yet water/sewage service is the most costly of the utilities provided by the NWT Housing Corporation to public housing tenants accounting for 39 percent of the utility bill. In 1992 the average cost to deliver water to public housing in the NWT was $49.80 per 1000 litres. The Canadian average was $0.40. From FY 1995/96 to FY 1991/92 the total cost of water and sewer services rose from 17 million to 20 million an increase of over 18 percent.

Public Housing tenants are using an average of 63 litres of water per person per day which is at the recommended Health Canada minimum of 65 litres per day. Expecting tenants to reduce water use by installing conservation devices is not an option to reduce costs.

The challenge is to reduce costs while at the same time to provide tenants with more water to promote better health and hygiene. This could be achieved with wastewater renovation and recycling as consumption becomes independent of supply. Further, the cost of truck hauling away excess wastewater would be reduced.

The NWT Housing Corporation has contracted with Creative Communities Research Inc. to supply initially five Healthy House Water Systems for demonstration purposes in 1998 at houses on truck haul services. The project is also being supported by the Health Protection Unit, Health & Social Services Ministry, Government of the Northwest Territories, and CMHC Yellowknife.

Three houses of the Yellowknife Dene Band at N'Dilo on Latham Island on the east side of Yellowknife and two at Dettah, 15 km east of Yellowknife, on Great Slave Lake have been built to accommodate the Healthy House wastewater treatment and renovation equipment. The houses have been built with conventional truck haul wastewater storage tanks so they can be occupied before the Healthy House equipment is installed. Four additional houses at Holman on Victoria Island are to follow in a second stage.

The equipment to be placed in the foundation crawl space will include a newly developed low-head "fermentation" tank with sedimentation and anaerobic filter chambers. The existing wastewater storage tanks will continue to serve as a back-up to the Healthy House System.

The NWT Housing Corporation operates approximately three thousand seven hundred dwellings across the North which depend on truck haulage for water supply and sewage removal service. Should the Healthy House Water System prove to be suitable for remote northern communities, the potential is there to cut delivered water costs 50 percent in 37 communities with public housing. Adoption by others in the North would mean even greater utility cost savings.

#### 5.2.1.3 Quayside Village Co-Housing Building

The 20-unit Quayside Village Co-Housing building, located north of Vancouver within the jurisdiction of the North Shore Health Unit, which is presently under construction, is being double plumbed to recycle renovated grey water. The building site has municipal servicing making it a good location to demonstrate greywater recycling in a multiple family setting. CMHC, National Office, Policy and Research Division is providing financial assistance for this demonstration project.

The total design water requirement is 20,000 L/day - 12,000 L/day fresh water, and 8,000 L/day recycle. The renovated grey water will be used for flushing toilets. The water savings in the building are expected to be about 40 percent. All blackwater, and treatment system waste flows will be discharged to the municipal sewer. Approved cross-connection devices will permit potable water to replace renovated greywater should malfunction of the Healthy House Water System occur.

The first unit in the renovation system will be a trash tank under the building floor slab to collect scum and provide some settleable solids removal. The effluent will overflow to a second chamber which will also receive recirculated Waterloo Biofilter™ effluent for denitrification. The combined flows will be pumped to the Waterloo Biofilter™. The forward flowing Waterloo Biofilter™ effluent will be pumped to a head tank/setting tube for gravity flow through the RAL Engineering roughing and slow sand filters. The renovated water storage tank will also be located beneath the building floor slab. A supply pump with pressure tank will distribute the treated renovated water throughout the building. A recirculating pre and post ozonation system will be used to oxidize trace organics, control colour build up, and disinfect the effluent before use.

In-line sensors will provide a comprehensive picture of system status to a Programmable Logic Controller (PLC). Should the PLC record an alarm condition, power to the pumps will cut off flow to the distribution systems. Supply of water will revert to the city main through the cross connection. An inline turbidimeter with preset alarm points will measure water quality prior to disinfection at all times. Ozone production and flow will be sensed by the PLC which will increase the dose and/or shut off the feed pump as required.

#### 5.2.1.4 Mohawks of the Bay of Quinte

The Mohawks of the Bay of Quinte together with the Ontario First Nations Technical Services Corporation, Toronto, Indian and Northern Affairs Canada, and CMHC Technical Policy and Research, Ottawa, as partners are planning to build in 1998 a demonstration healthy house to R2000 standard with radiant heating and a water renovation system using the Healthy House Water System technology.

The house will be located on Highway No. 2 backing onto the Salmon River just east of Shannonville. It will be at the west end of a parcel of land suited for subdivision development (up to twenty houses). The water supply for the house will be from an existing, nearby well of sufficient capacity to serve additional lots. Unused treated renovated water will be disposed of on-site by means of an infiltration trench.

Initially, the Healthy House water system will serve only the demonstration house. The opportunity is presented for future cluster development using a communal water system based on wastewater renovation and recycling concepts.

The Mohawks of the Bay of Quinte are most suited to build demonstrate, and transfer the Healthy House Water System technology to other First Nation Communities. They are already skilled in R2000 construction, have an experienced Works Department familiar with the Waterloo Biofilter™ installation serving their School and Health Unit, and have their own airstrip for receiving visitors travelling by First Nations Air and other chartered aircraft.

### 5.2.2 Other CMHC Supported Initiatives

Two other CMHC supported initiatives involve greywater alone and combined greywater/blackwater renovation for recycling purposes.

#### 5.2.2.1 Conservation Coop Residential Water Reclamation Project

CMHC has collaborated with the Conservation COOP in Sandy Hill, Ottawa, to develop and demonstrate a greywater treatment system to produce renovated water for toilet flushing. The 1985, four-storey building has in total 82 residential units. Two plumbing stacks were double plumbed so eight units are involved in the demonstration project.

A total of 1300 L/d of greywater is available. The treated water requirement for 6 L toilet flushing is 550 L/d with an additional 70 L/d for filter backwashing. Greywater is derived from showers, baths and kitchen sinks. The basement communal laundry is not included. All black water from the toilets and dishwashers together with the unused grey water is discharged to the municipal sewer.

The custom-built greywater system made up mostly from commercially available components consists of a vortex separator, settling tank, sand filter, and treated water storage tank. Ozone treatment is also provided for oxidation of organics and disinfection. All of the equipment is located together on the floor in an area of the building basement.

#### 5.2.2.2 CMHC Northern Healthy House

CMHC Ontario Region in collaboration with First Nation tribal councils in northwestern Ontario is presently developing an unplugged, off-grid northern healthy house. Up to five units are being planned initially with construction to start in southern locations (Thunder Bay and Eagle Lake) in the summer of 1998. The motivation is to build better, self-reliant housing at less cost than present houses which rely on the power grid and community water and wastewater services.

The primary power source will be active solar or wind energy depending on the location. Hot water radiant heating will be employed. The water supply will be surface water or rainfall. Wastewater will be renovated for toilet flushing and irrigation with bathing/showering optional. Unused renovated wastewater will be disposed of on-site mainly by ground infiltration. Back-up systems will also be provided.

All mechanical components are planned to be supplied pre-installed in a shipping container for on-site integration into the housing structure with minimum of connections to the house electrical, heating and plumbing systems. The preselected equipment will be assembled at a central, urban facility and trucked to any road accessible remote site. This approach, besides assuring quality control, reduces on-site construction costs and delays.

## 6.0 SUMMARY

This paper has discussed a new approach by which to address water shortage and water pollution problems as they increasingly impact adversely on human activity and the environment. Regional and local problem areas across Canada have been identified which show that wastewater renovation, recycling and reuse with front end rainfall utilization and building water conservation practices could provide an ethical and economic solution to these life threatening concerns.

The benefits of wastewater renovation, recycle and have already been recognized by commercial equipment suppliers, government housing agencies, and other early adopters involved with commercial and residential buildings. Wastewater renovation systems will become even more reliable, efficient and user friendly as more is learned from the demonstration programs described in this paper.

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