

MEMBRANE SCIENCE AND TECHNOLOGY FOR WASTEWATER RECLAMATION

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Contents

1. Introduction
2. Wastewater reclamation: An overview
 - 2.1. The Fundamentals of Wastewater Reclamation
 - 2.1.1. Evolution of Wastewater Reclamation
 - 2.1.2. Current Status
 - 2.1.3. Wastewater Reclamation and Its Future
 - 2.1.4. Wastewater Regulations
 - 2.1.5. Health and Environmental Concerns in Wastewater Management
 - 2.2. Wastewater Characteristics
 - 2.3. Wastewater Reclamation Process
 - 2.3.1. Primary Treatment
 - 2.3.2. Secondary Treatment
 - 2.3.3. Tertiary or Advanced Treatment
3. Fundamental of Membrane Technology in Wastewater Reclamation
 - 3.1. Membrane Definition and Process Terminology
 - 3.2. Membrane process classification
 - 3.3. Membrane Configurations
 - 3.3.1. Module Configuration and Pressure Development
 - 3.4. Membrane Operation
 - 3.4.1. Microfiltration and Ultrafiltration
 - 3.4.2. Nanofiltration
 - 3.4.3. Reverse Osmosis
 - 3.5. Membrane Fouling
 - 3.5.1. Type of Fouling
 - 3.5.2. Effect of Cross-Flow Velocity
 - 3.5.3. Effect of Membrane Surface Treatment
 - 3.5.4. Membrane Fouling Control
4. Membrane life
5. Membranes market size
 - 5.1. Investment Cost Analysis
6. Membrane Bioreactor (MBR)
 - 6.1. MBR Configurations and Commercial Technologies
 - 6.2. MBR Characteristics
 - 6.2.1. Physical Parameters
 - 6.2.2. Chemical Parameters
 - 6.3. Fouling Control in MBR

6.4. MBR Design and Operation

6.4.1. MBR System Operational Parameters

6.4.2. Design Calculation

6.5. Case Studies

6.5.1. Solbegra Plant

6.5.2. Eden Project, St Austeel, Cornwall, UK

7. Reverse Osmosis (RO)

7.1. Types of Membrane used in RO

7.2. Application of Reverse Osmosis

7.3. Design and Operational Considerations for RO Systems

7.4. Process Operating Parameters

7.5. Pilot-Scale Studies for RO

8. Conclusions

Appendices

Glossary

Bibliography and Suggestions for further study

Biographical Sketches

Summary

Wastewater is widely recognized as one of significant, growing and reliable water sources. Wastewater production is the only potential water source which will increase as the population grows and the demand on fresh water increases. The management of wastewater reclamation has basic scope of balancing water availability and water demand, at reasonable cost and with acceptable environmental impacts. Wastewater reclamation technology needs to be appropriate and sustainable, operated and maintained easily, and very efficient in removing organic matter and pathogens present in wastewaters.

This chapter extensively discusses the potential of implementing membrane technology in wastewater reclamation. By taking into consideration for the need of wastewater reclamation process that should be known the wastewater characteristic, type of membrane processes and commercial application of membrane technology. Although membrane technologies became commercially available more than 30 years ago, it is experiencing rapid development and improvements. A wide variety of membrane processes can be categorized according to driving force, membrane material, membrane type and configuration, removal capabilities and mechanism, and membrane fouling and cleaning. For example pressure driven, membrane processes include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). Among these membrane processes, membrane bioreactor (MBR) and reverse osmosis (RO) processes are well suited for application of wastewater reclamation process due to their effective energy requirement, compact configuration and high quality product.

Consider the energy requirement, the existing conventional wastewater reclamation system effluent after secondary and tertiary treatment need high energy requirement and step processes due to supply water for removal of biodegradable organic matter (in solution or suspension) and suspended solids. It is costly and has a large footprint in installation of reclaimed water distribution system. Having seen disadvantages given by

conventional wastewater reclamation process, it is necessary to propose the use of membrane technology that can be implemented efficiency from the technological and economical perspectives.

1. Introduction

The feasibility and reliability of providing adequate quantities and quality of water to meet societal needs is constrained by geographic, hydrologic, economic, and social factors. Projections of unprecedented global population growth, particularly in urban areas, have fueled concerns about water availability in increasingly complex environmental, economic, and social settings. To address the environmental, social, and economic impacts of water resources development and avert the ominous prospects of water scarcity, there is a critical need to reexamine the water resources systems. The local water resourcing problems can provide sufficient motivation for recycling in their own right. Water scarcity can be assessed simply through the ratio of total freshwater abstraction of total resources, and can be used to indicate the availability of water and the pressure on water resources. Water stress occurs when the demand for water exceeds the availability amount when poor quality restricts its use. It provides an indication of how the total water demand puts pressure on the water resource.

Moreover, the emerging paradigm of sustainability water resources management emphasizes whole system solution to reliably and equitably meet the water needs of present and future generations. Understanding the concepts of sustainable water resources management as a foundation of water reclamation is of fundamental importance. The principle of sustainability is defined as ‘Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of the future generations to meet their own needs’ (Sikdar 2005). Therefore, the goal of sustainable water resources development and management is to meet water needs reliably and equitably for current and future generations by designing integrated and adaptable systems, optimizing water-use efficiency, and making continuous efforts toward preservation and restoration of natural ecosystems. The transition to a sustainable society poses a number of technological and social challenges. Technological innovations can help to improve the considerations for sustainability that must include energy and resource use and environmental pollution (Hermanowicz 2005).

Water reclamation is a process by which wastewater from homes and businesses is cleaned using biological and chemical treatment so that the water can be returned to the environment safely to augment the natural systems. The factors that should be included in decisions on wastewater reclamation process include contaminant removal, source water quality, reliability, existing conditions, process flexibility, utility capabilities, costs, environmental compatibility, distribution system wastewater quality, and issues of process scale. Based on these factors, the progress of technological development on wastewater reclamation is viewed by membrane technology that has tremendous potential resulting from universal capabilities and competitive costs.

Membranes have gained also an important place in wastewater reclamation process and are used in a broad range of applications. As a relatively new technology, membranes

have often been disregarded in the past in favor of conventional biotreatment plants. However, a number of indicators suggest that membranes are now being accepted increasingly as the technology of choice. Membrane technology offered as an alternative non-conventional wastewater treatment due to dynamic development of secondary and advanced wastewater treatment process. The usage of the reclaimed water decreases the pollution sent to sensitive environments. Membrane technology helps decrease diverging water from sensitive eco-systems which depend greatly on the flow to improve the quality of the water. Energy requirement of the treatment process is low compared to other alternatives of augmentation of water supply. Advances in membrane technology for wastewater reclamation contributed to its increasing recognition as reliable technology for cost effective production of high quality effluents.

Total population living in water-stressed area is expected to increase more than 20% by 2025 (IWMI 2000). The capacity of effluent wastewater becomes also increase due to retrofit and upgrade, normally relating to a requirement for improved effluent water quality without incurring a larger footprint. It is expected that opportunities for application of membrane technology will be accepted. To consider the energy requirement, the existing conventional wastewater reclamation system effluent after secondary treatment need very high energy requirement. Moreover, the treatment of wastewater reclamation beyond secondary treatment can be costly and energy intensive due to removal of biodegradable organic matter (in solution or suspension) and suspended solids. The tertiary or advanced treatment of wastewater reclamation also needs many steps to remove the bacteria, reduce suspended solid after secondary treatment, and disinfect water to produce useable water. It is also costly and needs a large footprint in installation of reclaimed water distribution systems. Having seen disadvantages given by conventional wastewater reclamation processes due to their low cost-effectiveness and reliability, it is necessary to offer an overview on advanced treatment technology, including membrane technology.

2. Wastewater Reclamation: An Overview

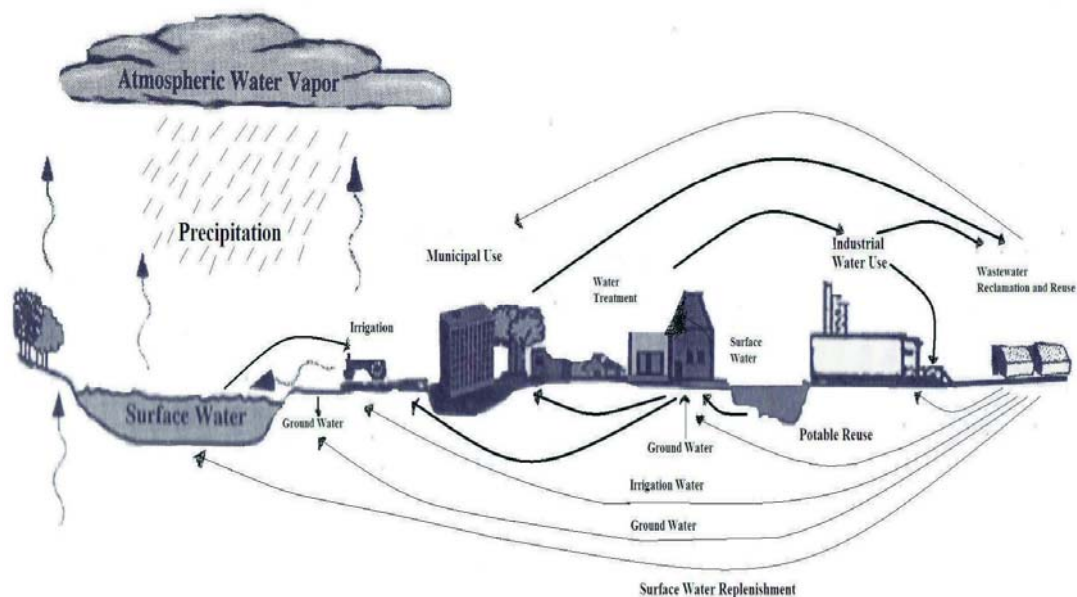


Figure 1. Role engineered treatment, reclamation, and reuse facilities in the cycling of

water

Wastewater is essentially the water supply of the community after it has been used in a variety of applications such as combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments. They may be present as groundwater, surface water, and storm water. Wastewater contains numerous pathogenic microorganisms and also nutrients, which can stimulate the growth of aquatic plants. Wastewater may contain toxic compounds or compounds that potentially may be mutagenic and carcinogenic. For these reasons, the removal of wastewater from its source of generation, followed by treatment, reuse or dispersal into the environment is important to protect public health and the environment.

2.1. The Fundamentals of Wastewater Reclamation

Wastewater reclamation is the treatment or processing of wastewater to make it reusable with definable treatment reliability and meeting water quality criteria. The benefits of wastewater reclamation and factors driving its future are summarized in Table 1.

Rationale for wastewater reclamation
<ul style="list-style-type: none"> • Wastewater is a limited resource. Increasingly, society no longer has the luxury of using water only once. • Acknowledge that water recycling is already happening and do it more and better. • The quality of reclaimed wastewater is appropriate for many non-potable applications such as irrigation and industrial cooling and cleaning water, thus providing a supplemental water source that can result in more effective and efficient use of water. • To meet the goal of water resource sustainability it is necessary to ensure that water is used efficiently. • Water reclamation and reuse allow more efficient use of energy and resources by tailoring treatment requirements to serve the end-users of the water. • Water reuse allows the protection of environment by reducing the volume of treated effluent discharged to receiving waters.
Potential benefits of wastewater reclamation
<ul style="list-style-type: none"> • Conservation of fresh water supplies. • Management of nutrients that may lead to environmental degradation. • Improved protection of sensitive aquatic environments by reducing effluent discharges. • Economic advantages by reducing the need for supplemental water sources and associated infrastructure. Reclaimed water is available near urban development where water supply reliability is most crucial and water is priced highest. • Nutrients in reclaimed water may offset the need for supplemental fertilizers, thereby conserving resources. Reclaimed water originating from treated effluent contains nutrients; if this water is used to irrigate agricultural land, less fertilizer is required for crop growth. By reducing nutrient (and resulting pollution) flows into waterways, tourism, and fishing industries are also helped.
Factors driving further implementation of wastewater reclamation
<ul style="list-style-type: none"> • Proximity: Reclaimed water is readily available in the vicinity of the urban environment, where water resources are most needed and are highly priced. • Dependability: Reclaimed water provides a reliable water source, even in drought years, as production of urban wastewater remains nearly constant. • Versality: The wastewater treatment process is available to provide water of nonpotable applications and can produce water of quality that meets drinking water requirements. • Safety: Nonpotable water reuse systems have been in operation for over four decades with no documented adverse public health impacts in many countries. • Increasing pressure on existing water resources due to population growth and increased

<p>agricultural demand.</p> <ul style="list-style-type: none"> • Public interest: Increasing awareness of the environmental impacts associated with overuse of water supplies, and community enthusiasm for the concept of water reclamation. • Environmental and economic impacts of traditional water resources approaches: Greater recognition of the environmental and economic costs of water storage facilities such as dams and reservoirs. • More stringent water quality standards: Increased costs associated with upgrading wastewater treatment facilities to meet higher water quality requirements for effluent disposal. • Necessity and opportunity: Motivating factors for development of water reclamation projects such as droughts, water shortages, prevention of seawater intrusion and restrictions on wastewater effluent discharges, plus economic, political, and technical conditions favorable to water reclamation.
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Table 1. The benefits of wastewater reclamation and driving factors (Asano 1998, Asano et al 2007)

Methods of reclamation in which removal of contaminants is brought about by chemical or biological reactions are known as unit processes. At the present time, unit operations and processes are grouped together to provide various levels of treatment known as preliminary, primary, advanced primary, secondary (without or with nutrient removal), and advanced (or tertiary) treatment as shown in Table 2.

Treatment level	Description
Preliminary	Removal of wastewater constituents such as rags, sticks, floatables, grit, and grease that many cause maintenance or operational problems with the treatment operations, processes, and ancillary systems.
Primary	Removal of a portion of the suspended solids and organic matter from the wastewater.
Advanced primary	Enhanced removal of suspended solids and organic matter from the wastewater. Typically accomplished by chemical addition or filtration.
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is also typically included in the definition of conventional secondary treatment.
Secondary with nutrient removal	Removal of biodegradable organics, suspended solids, and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus).
Tertiary and advanced	Removal of residual suspended solids (after secondary treatment), remaining after normal biological treatment when required for various water reuse applications. Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this definition.

Table 2. Levels of the wastewater reclamation

In preliminary treatment, gross solids such as large objects, rags, and grit that may damage equipment are removed. In primary treatment, a physical operation, usually sedimentation is used to remove the floating and settle the materials found in

wastewater as shown in Figure 2.



Figure 2. Sedimentation tanks (Wikipedia 2010)

For advanced primary treatment, chemicals are added to enhance the removal of suspended solids and, to a lesser extent, dissolved solids. In secondary treatment, biological and chemical processes are used to remove most of the organic matter. In advanced treatment, additional combinations of unit operations and processes are used to remove residual suspended solids and other constituents that are not reduced significantly by conventional secondary treatment.

2.1.1. Evolution of Wastewater Reclamation

Indication of the use of wastewater for agricultural irrigation extends back approximately 3000 years to the Minoan Civilization in Crete, Greece (Angelakis 2003). In modern times, the beginnings of water reclamation can be traced to the mid-nineteenth century with the introduction of wastewater systems for conducting household wastes. Some of the significant worldwide activities in wastewater reclamation that have occurred since 1960 are summarized in Table 3.

Period	Location	Event
1962	La Soukra	Irrigation with reclaimed water for citrus plants and ground water recharge to reduce saltwater.
1965	Israel	Use of secondary effluent for crop irrigation.
1968	Windhoek, Namibia	Research on direct potable reuse and subsequent implementation.
1969	Wagga Wagga, Australia	Landscape irrigation of sporting fields, lawns, and cemeteries.
1977	Tel-Aviv, Israel	Dan region project- Groundwater recharge via basins. Pumped groundwater is transferred via a 100

		km long conveyance system to southern Israel for unrestricted crop irrigation.
1984	Tokyo, Japan	Toilet flushing water for commercial buildings in the Shinjuku District using reclaimed water from the Ochiai wastewater treatment plant operated by the Tokyo Metropolitan Sewerage Bureau.
1988	Brighton, UK	Inauguration of the Specialist Group on Wastewater reclamation, Recycling and reuse at the 14th Biennial Conference of the International Association on Water Pollution Research and Control (currently, the International Water Association, headquartered in London ,UK).
1989	Girona, Spain	Golf course irrigation using reclaimed water from the Consorci de la Costa Brava wastewater treatment facility.
1999	Adelaide, South Australia	The Virginia Pipeline Project, the largest water reclamation. project in Australia- irrigating vegetable crops using reclaimed water from the Bolivar Wastewater Treatment Plant (120,000 m ³ /d).
2002	Singapore	NEWater-reclaimed water that has undergone significant purification using microfiltration, reverse osmosis, and ultrafiltration disinfection. NEWater is used as a raw water source to supplement Singapore's water supply.
2010	Singapore	The largest wastewater treatment will be built in Jurong Singapore in June 2010

Table 3. The evolution of wastewater reclamation and reuse in the world (Lane 1990, Baird and Smith 2002).

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