DIRECT POTABLE REUSE

A Path Forward

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A PATH FORWARD

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ACRONYMS

ac-ft/yr	Acre-feet per year
ft	Feet
AWT	Advanced water treatment
CDPH	California Department of Public Health
CEC	Constituents of emerging concern
CRMWD	Colorado River Municipal Water District
DPR	Direct potable reuse
ECLSS	Environmental control and life support systems
gal/d	Gallons per day
GWRS	Groundwater Replenishment System
HACCP	Hazard analysis and critical control points
IPR	Indirect potable reuse
ISS	International Space Station
kWh	Kilowatt-hour
MCL	Maximum contaminant levels
Mgal/d	Million gallons per day
mo	Month
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NWRI	National Water Research Institute
OCWD	Orange County Water District
OCSD	Orange County Sanitation District
RFP	Request for proposals
QRRA	Quantitative relative risk assessment
RWC	Recycled water contribution
SWRCB	State Water Resources Control Board
TECQ	Texas Commission for Environmental Quality
TDS	Total dissolved solids
TOC	Total organic carbon
UPA	Urine processor assembly
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
WHO	World Health Organization
UVA	Ultraviolet absorbance
WRRF	WateReuse Research Foundation
WRS	Water recovery system
yr	year

PREFACE

Terms used throughout this report are summarized in the following table for ease of reference.

Term	Definition[a]
Advanced treatment	Removal of residual trace constituents following treatment by micro- and ultrafiltration, with or without demineralization, as required for specific water reuse applications.
Barrier	A measure used to limit the presence of specific constituents, such as pathogens. Barriers could include consumer education, source control, wastewater treatment processes, dilution and natural attenuation in the water body, storage in reservoirs, effective drinking water treatment, and extensive raw and treated water monitoring to ensure high quality drinking water.
De facto indirect potable reuse	The withdrawal of drinking water from rivers or surface water reservoirs that contain varying amount of treated wastewater discharged from upstream cities, industries, and agricultural areas.
Direct potable reuse	The introduction of purified water from an engineered storage buffer either directly into a potable water supply distribution system downstream of a water treatment plant, or into the raw water supply immediately upstream of a water treatment plant. In direct potable reuse, purified water is not placed into an environmental buffer.
Engineered storage buffer	Water storage containment facility of sufficient volumetric capacity to retain purified water for a sufficient period of time to allow for the measurement and reporting of specific constituents to be assured that the quality of water provided meets all applicable public health standards prior to discharge to the potable water system.
Environmental buffer	A groundwater aquifer or surface water storage reservoir into which purified water is placed and where it must remain for a specified period of time, before bring withdrawn for potable purposes.
Indirect potable reuse	The planned incorporation of purified water into an environmental buffer for a specified period of time before bring withdrawn for potable purposes.
Multiple barriers	An engineered system in which a number of independent barriers are combined in series to achieve a high degree of reliability.
Product water	Water discharged from a specified treatment train.
Purified water	Advanced treated water whose quality has been deemed safe for human consumption, regardless of the source of the water.
Recycled water contribution (RWC)	The volume of recycled water divided by the total volume of water (recycled plus dilution water from other sources).
Secondary treatment	Removal of biodegradable organic matter (in solution or suspension) and suspended solids, with or without nutrient removal. Disinfection is also typically included in the definition of conventional secondary treatment.
Tertiary treatment	Removal of residual suspended and colloidal solids (after secondary treatment), usually by granular medium filtration, microscreens, cloth filters, or membranes (e.g., micro- and ultrafiltration).

[a] The definitions presented in this table are consistent with, but not direct statements from, Senate Bill 918 and/or California Department of Public Health (CDPH) draft groundwater recharge regulations.

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1
INTRODUCTION

Due to increasing water scarcity, the limits of current conventional water supplies, and the need for water agencies to maximize beneficial use of all available water resources, water agencies and others are interested in defining the guidelines and criteria needed for *direct potable reuse* (DPR) in which purified water is introduced directly into a potable water supply distribution system or into the raw water supply immediately upstream of a water treatment plant. Reflecting the increased interest in DPR, the Governor of the State of California signed into law Senate Bill 918 in September 2010. This bill mandates that the California Department of Public Health (CDPH) adopt uniform water recycling criteria for indirect potable reuse (IPR) for groundwater recharge by the end of 2013. If an expert panel convened pursuant to the bill finds that the criteria for surface water augmentation would adequately protect public health, the development of criteria for surface water augmentation by the end of 2016 is also mandated in the bill. Further, the bill requires CDPH to investigate the feasibility of developing regulatory criteria for DPR and to provide a final report on that investigation to the Legislature by the end of 2016. The full text of Senate Bill 918 may be found in Appendix A. The California Water Code (SWRCB, 2011) has been amended to include the provisions of Senate Bill 918.

In light of the interest in DPR, the purpose of this report is to provide a general overview current knowledge related to DPR and to identify the information that must develop through targeted studies to inform the public, public and private water agencies, and regulatory agencies regarding the feasibility of implementing DPR as a viable water supply management option. Although the background information on DPR and the needed research identified in this report are applicable across the country and throughout the world, the primary focus is on providing information so that the feasibility of DPR can be evaluated in California.

1-1 BACKGROUND

Primary uses of recycled water in California are for irrigation of agricultural crops, landscape irrigation, and groundwater recharge. Although irrigation with treated wastewater has been occurring for decades, it is reaching logistical and economic constraints. The augmentation of drinking water sources with purified water through groundwater recharge or surface water additions is known as *indirect potable reuse* (IPR). Groundwater recharge is becoming of greater interest in areas needing to augment or diversify their water supply. Compliance with CDPH draft regulations (CDPH, 2008) for groundwater recharge requires (1) a minimum residence time in an aquifer, called an environmental buffer; and (2) tertiary or advanced wastewater treatment depending on the type of recharge application (surface spreading versus injection) in combination with the allowable recycled water contribution (RWC) and other sources of recharge water not of wastewater origin, which serve to dilute the recycled water. The draft recharge regulations do not specify the water source used for dilution, but would allow dilution with groundwater. Compliance with drinking water and other water quality standards is determined in the product water, with the exception of disinfection byproducts for surface spreading projects, where compliance is determined after passage through the vadose zone.

The CDPH is also in the process of developing draft regulations for surface water augmentation that are likely to include similar types of requirements regarding retention time, treatment, and blending with the surface water. The primary benefit of an environmental buffer is to provide time to react should treatment be inadequate due to process failure or other factors. In the past, it was thought that the extended residence time afforded by the environmental buffer would also provide for additional treatment. While an environmental buffer is relevant for tertiary treated water, any water quality benefits afforded by the retention of water that has been purified with reverse osmosis and advanced oxidation, or other types of advanced treatment, in an environmental buffer are minor, if any.

Amount of Water Recycled

In 2009, the California State Water Resources Control Board (SWRCB) approved a Recycled Water Policy which includes a goal to increase the use of recycled water over 2002 levels by at least 1 million ac-ft/yr (acre-feet per year) by 2020 and by at least 2 million ac-ft/yr by 2030 (SWRCB, 2009). As of 2010, actual recycling is estimated to be 650,000 ac-ft (Bryck et al., 2008). While this volume of water represents a major achievement, it falls far short of the State's goal, and only represents only about 19% of the approximately 3.5 million ac-ft of treated wastewater discharged to the ocean each year.

Barriers to Achieving Recycling Goal

A number of barriers make it difficult to achieve the State's water recycling goal, including:

- Expansion of agricultural irrigation, in general, is not feasible due to the long distance between the large sources of recycled water (cities) and the major agricultural demand (rural areas).
- Cost and disruption to construct pipe systems to convey recycled water and the need to provide winter water storage facilities further limit agricultural reuse.
- Landscape irrigation may not be economically feasible due to the dispersed nature of the demand.
- The cost of providing parallel distribution of tertiary treated supply is high due to the fact that the distance between large users in most communities is large and most water is consumed by small users that are not served efficiently and seasonality issues.
- Historically, the value of water from surface and groundwater supply sources has not reflected the true costs of providing the supply, resulting in a distinct economic disadvantage for the production of purified water.

1-2 RATIONALE FOR DIRECT POTABLE REUSE

In the future, a decision to implement DPR, which would occur on a case-by-case basis, will be based on a combination of environmental and economic factors.

Communities deciding to implement DPR would be influenced by the same factors that have driven some communities to implement IPR plus some additional factors. The typical factors driving communities to IPR include the following:

- The need for construction and operation of a parallel recycled water distribution system required to supply tertiary water to irrigation sites is avoided. Regardless of cost, installation of parallel distribution systems may not be feasible in some urban environments due to space and disruption constraints.
- Alternative sources of water are either of poor quality or prohibitively expensive.
- Traditional sources of surface water supply are being reduced because of diversions to meet environmental protection regulations, reductions in allocations, and reductions in flow brought about by climate change.
- Groundwater has been overdrafted and only poor quality groundwater is now available in some areas.
- With advanced treatment technology it is now possible to remove contaminants effectively and reliably to extremely low levels that have no known health concerns.
- Recycled water is a reliable source of supply which exists in close proximity to the demand.

Additional factors that would drive some communities to DPR include the following:

- Communities that lack suitable hydrogeology for groundwater recharge cannot implement IPR projects based on the current CDPH draft regulations. While no regulations have been established for surface water augmentation, when drafted they are likely to include blending and residence time requirements that may limit this type of reuse application to large reservoirs (which are not available to many communities).
- Direct potable reuse is potentially less costly than the use of tertiary recycled water for irrigation. The typical cost for parallel distribution of

tertiary treated supply is $400 - $2100/ac-ft whereas the typical cost for advanced membrane treatment including advanced oxidation is $700 - $1,200/ac-ft (Atwater, 2008; Lichty, 2008; and Richardson, 2011).

- Direct potable reuse, in which purified water is introduced into the water supply without the need for an extended residence time in an environmental buffer, may represent a feasible alternative approach for some communities to augment and diversify their water supply portfolio.
- Direct potable reuse may require less energy than is required for other water supply sources. For example, the energy required to provide 1 ac-ft to an Orange County water system (Deshmukh, 2010; Taffler et al., 2008) is:
    - Ocean desalination = 3,700 kWh (kilowatt-hour)
    - State Project water = 3,500 kWh
    - Colorado River water = 2,500 kWh
    - Purified water = 800 - 1,500 kWh
- Direct potable reuse avoids potential water quality issues associated with groundwater and surface water sources (e.g., contamination plumes or illicit surface water discharges).
- Current technology is sufficient to replace the environmental buffer with an engineered storage buffer through a combination of monitoring, storage, and treatment reliability measures. Future monitoring technology may obviate the need for an engineered storage buffer.

1-3 SCOPE OF THIS REPORT

The scope of this report is to identify information and the types of research studies that are necessary to provide a starting rationale for the discussion of the feasibility of DPR, including; engineering, economic, regulatory, and public acceptance considerations. The focus of the recommended research studies is on the following two potential barriers to DPR implementation:

- Science and Engineering. Studies needed to identify information on the methods and means of implementing DPR with and without an engineered storage buffer as a substitute for the environmental buffer now required.
- Public Acceptance. Studies and activities needed to gain a sufficient level acceptance of DPR by the public such that it is not a barrier to implementation are described.

Specifically, the results of the studies described in this report are intended to provide information and background material for consideration by the CDPH expert panel that will be convened pursuant to Senate Bill 918 to provide recommendations to CDPH regarding the feasibility of developing uniform water recycling criteria for DPR. Nothing in this report should be regarded as an implicit or explicit statement that the outcome of the DPR feasibility discussion is foregone in favor of, or against DPR.

1-4 REPORT ORGANIZATION

This report is organized into the following six chapters:

1. Introduction
2. Workshops on Potable Reuse
3. Review of Direct Potable Reuse Projects
4. Technical Issues in Direct Potable Reuse
5. Public Acceptance Issues in Direct Potable Reuse
6. Research Needs in Direct Potable Reuse

A review of the important workshops on potable reuse, held over the past 35 years, is presented in Chapter 2. The purpose, organization, findings, and recommendations or conclusions are presented for each workshop. DPR projects that have been implemented in the past and/or are currently in operation or planned are reviewed in Chapter 3. The review of these DPR projects is intended to provide perspective on the different process configurations that have been used to achieve DPR. Based on the material presented in Chapters 2 and 3, the technical issues that must be addressed if DPR is to become a viable option are identified and discussed in Chapter 4. Public acceptance issues that must be addressed if DPR is to be a viable option are presented and discussed in Chapter 5. From the delineation of the issues in Chapters 4 and 5, research projects designed to resolve the issues associated with DPR are presented in Chapter 6. References cited in the report are presented following Chapter 6.

2
WORKSHOPS ON POTABLE REUSE

The purpose of this chapter is to review past and current thinking with respect to issues on potable reuse. The literature contains thousands of articles, reports, presentations, and analyses that deal with some aspect of DPR. From this vast amount of available material, three reports stand out as being seminal with respect to DPR. They are:

1. Research Needs for the Potable Reuse of Municipal Wastewater (U.S. EPA, 1975)
2. Protocol Development: Criteria and Standards for Potable Reuse and Feasible Alternatives (U.S. EPA, 1980)
3. Direct Potable Reuse Workshop (CUWA et al., 2010)

Each of these reports reflects the best thinking at the time from academics, consultants, practitioners, the public, and regulators. Not surprisingly, many of the issues identified in the 1975 workshop are still timely. In what follows, each of these reports is reviewed with respect to (1) the purpose of the workshop; (2) the organization of the workshop; (3) workshop findings; and (4) workshop conclusions or summary or recommendations, depending on the format used. In most cases, material from the workshop summaries has been quoted directly rather than paraphrasing, so that the flavor of the report is not lost.

2-1 RESEARCH NEEDS FOR THE POTABLE REUSE OF MUNICIPAL WASTEWATER, 1975

Just three years after the passage of the Clean Water Act and the formation of the U.S. Environmental Protection Agency (U.S. EPA), a workshop was held in Boulder, CO, on March 17-20, 1975, on *Research Needs for the Potable Reuse of Municipal Wastewater* (U.S. EPA, 1975).

Purpose of Workshop

The stated objective of the workshop was to: "define and establish the priorities for research needed to develop confidence in the reuse of wastewater for potable purposes" (U.S. EPA, 1975).

Organization of Workshop

"The first day of the workshop was devoted to the presentation and discussion of current research and demonstration activities related to treatment technology and health effects associated with current and proposed water reuse applications." The second and third days of the workshop were devoted to small group discussions. The discussion groups were as follows:

1. Treatment reliability and effluent quality control for potable reuse,
2. Wastewater treatment for potable reuse,
3. Health effects of potable reuse associated with inorganic pollutants,
4. Health effects of potable reuse associated with viruses and other biological pollutants,
5. Health effects of potable reuse associated with organic pollutants, and
6. Socio-economic aspects of potable reuse" (U.S. EPA, 1975).

Workshop Findings

The principal findings from the small group discussions were as follows.

1. *Treatment reliability and effluent quality control for potable reuse*. The following research areas were identified: (1) establish water quality standards for potable reuse, (2) define requirements for fail/safe reliability, and (3) define allowable limits of product quality variability.
2. *Wastewater treatment for potable reuse*. A large-scale demonstration effort to "characterize the long-term effectiveness and reliability of various alternative treatment systems for producing a potable quality product" (U.S. EPA, 1975) was identified as the principal need.
3. *Health effects of potable reuse associated with inorganic pollutants*. This group identified the balanced use of epidemiological and toxicological methods as being extremely important. An epidemiological program was recommended that included an ". . . assessment of the relationship

between current water quality and the incidence and prevalence of chronic diseases, as well as a determination of the body burdens of inorganic substances. Recommended toxicological studies included *in vitro* screening of concentrated toxicants, *in vivo* animal toxicity testing, and population dose estimation." (U.S. EPA, 1975)

4. *Health effects of potable reuse associated with viruses and other biological pollutants.* This group ". . . highlighted the development and evaluation of rapid and relatively simple methods for detection of viruses having major public health significance as being among the areas warranting extensive research." (U.S. EPA, 1975) Another high priority research recommendation was "Determining the degree and mechanisms of removal and inactivation of viruses in reclaimed waters." (U.S. EPA, 1975)
5. *Health effects of potable reuse associated with organic pollutants*. The principal recommendation from this group was ". . . that EPA should develop a viable and visible program to assess the potability of reused water." (U.S. EPA, 1975)
6. *Socio-economic aspects of potable reuse*. The two principal recommendations from this group were to: (1) ". . . identify the extent to which the U.S. population is presently being supplied former wastewater as a part of the raw water supply and (2) that a public education program be undertaken to indicate the true picture concerning the current practice of indirect water recycling." (U.S. EPA, 1975)

Workshop Conclusion

The conclusion from the workshop was that it was ". . . apparent that there are many specific research needs related to treatment technology and reliability, health effects, and socio-economic considerations for potable water reuse. The importance of proceeding with the accomplishment of this research is related not only to the recognized need for future direct reuse, but also because of the insight these investigations will provide concerning our current supply sources, many of which are currently influenced by upstream discharges of municipal and industrial wastewaters.” (U.S. EPA, 1975)

2-2 PROTOCOL DEVELOPMENT: CRITERIA AND STANDARDS FOR POTABLE REUSE AND FEASIBLE ALTERNATIVES, 1980

In 1980, the U.S. EPA sponsored a workshop on *Protocol Development: Criteria and Standards for Potable Reuse and Feasible Alternatives.* The workshop was held at Airlie House in Warrenton, VA on July 29-31, 1980 (U.S. EPA, 1980).

Purpose of Workshop

“The purpose of this workshop was not to develop specific criteria and standards but to provide guidance with respect to approaches, problems, solutions and needed research or investigations for establishing a pathway to protocol development for potable reuse criteria and standards and for consideration of non-potable options” (U.S. EPA, 1980).

Organization of Workshop

The workshop was organized into two major sections. The first section included introductory papers that outlined the broad issues. The second section included six work groups that presented their reports and revised issue papers with conclusions and recommendations regarding protocol development for potable reuse criteria and standards, and non-potable options (U.S. EPA, 1980). The six groups were:

1. Chemistry,
2. Toxicology,
3. Microbiology,
4. Engineering,
5. Ground-Water Recharge, and
6. Non-Potable Options.

Workshop Findings

The principal findings from the small group discussions were as follows.

1. *Chemistry* . "Specific analytical methods exist for 114 specific organic priority pollutants and for other designated organic contaminants in

drinking water. Analytical quality control has been established for these contaminant analyses and is being tested. However, many more specific organic contaminants remain without systematic methodology or quality control procedures. Broad spectrum analysis to determine the presence of many organic chemicals simultaneously is needed on a routine basis to help define the presence and variability of these components." (U.S. EPA, 1980)

2. *Toxicology.* "Prevention of excessive exposure to inorganic, radiologic and particulate substances can generally be handled by setting maximum contaminant levels (MCLs) and by application of appropriate treatment technology. However the management of risks from organic substances presents more complex problems. Where adequate information is available on specific organics of concern, additional MCLs should be set. With respect to the non-MCL and unknown organic fractions an innovative approach was recommended." (U.S. EPA, 1980)
3. *Microbiology.* "Proposals for direct potable reuse require a complete reevaluation of the means for biological control. There should be no detectable pathogenic agents in potable reuse water. Potable reuse requires stricter microbiological standards, including quality control monitoring than the current national coliform MCLs for drinking water." (U.S. EPA, 1980)
4. *Engineering.* "In considering the various available treatment systems and approaches, it was felt that treatment technology does not appear to be a limiting factor and that maximum-flexibility should be allowed in treatment designs so that the most cost effective approaches can be implemented which will meet health requirements, including fail-safe operation. However, because present national drinking water standards are not intended for direct potable reuse waters, comprehensive standards and criteria should include specific requirements for direct reuse applications." (U.S. EPA, 1980)

5. *Ground-Water Recharge.* "Important benefits can be obtained by ground-water recharge. In addition to providing an economical means of storage with reduced evapotranspiration, subsurface passage removes some contaminants and retards the movement of others by means of filtration, biodegradation, volatilization, sorption, chemical precipitation, and ion exchange. Its use as part of a system to produce potable reuse water is encouraged." (U.S. EPA, 1980)
6. *Non-Potable Options*. "In the United States there are now more than 500 successful wastewater reuse projects utilizing non-potable options: such options are the preferred method of reuse and should be considered in the decision-making process before the potable reuse option. However, a variety of steps need to be taken before non-potable options can be given maximum utilization." (U.S. EPA, 1980)

Workshop Recommendations

The principal recommendations resulting from this workshop were as follows:

1. "Development of comprehensive standards and criteria to define potable water regardless of source.
2. Undertaking a detailed characterization of potential sources of reclaimed water covering variability, frequency and concentration ranges for the various contaminants.
3. Undertaking a major effort to examine unknown or inadequately known organic chemical components.
4. Conduct of toxicological concentrate studies as a key element in a decision-making protocol involving many factors.
5. More stringent microbiology requirements.
6. Serious consideration of ground-water recharge options for potable reuse.
7. Serious consideration of non-potable reuse options for extending available public water supply." (U.S. EPA, 1980)

2-3 DIRECT POTABLE REUSE WORKSHOP, 2010

In 2010, WateReuse California held the *Direct Potable Reuse Workshop* with the California Urban Water Agencies and National Water Research Institute (NWRI), as cosponsors. The workshop was held in Sacramento, CA on April 26-27, 2010 (CUWA et al., 2010).

Purpose of Workshop

The objective of the Direct Potable Reuse Workshop was to identify information gaps that need to be addressed so that direct potable reuse regulations can be developed as appropriate.

Organization of Workshop

The workshop was organized into parts involving presentations of prepared introductory white papers and breakout group deliberations. Two white papers were sponsored in advance of the workshop. NWRI sponsored the development of *Regulatory Aspects of Direct Potable Reuse in California* (Crook, 2010) and WateReuse California sponsored the development of *Public and Political Acceptance of Direct Potable Reuse* (Nellor and Millan, 2010). In addition, research topics developed at the WateReuse Research Foundation (WRRF) Research Needs Workshop (WRRF, 2009) were summarized. A discussion period followed each presentation.

In the second part of the workshop, participants were separated into four groups, based on areas of expertise, to deliberate on the following four focus areas:

1. Treatment,
2. Monitoring,
3. Regulatory, and
4. Public Acceptance.

Workshop Findings

Information gaps in the following subject areas were addressed at the workshop in the context of the four focus areas identified above:

- Public acceptance.
- Communication between water supply chain agencies, and the

public/customers.

- Microbial and chemical constituents of concern.
- Effectiveness and reliability of treatment unit processes.
- Multiple barriers of protection.
- Monitoring needs (treatment processes and product water).
- Use of indicators/surrogates for both microbial and chemical constituents.
- Redundancy in treatment.
- Management and operational controls.
- Permitting issues.

Workshop Recommendations

The results of the workshop were summarized in a report (CUWA et al., 2010). The principal outcome of the workshop was the identified need to develop a workplan based on the workshop recommendations, including research topics (an important element of this report), funding sources, and appropriate timing, which is the subject of this report.

2-4 REVIEW OF WORKSHOPS' FINDINGS AND CONCLUSIONS

In assessing the findings of the three workshops, the similarities are striking. Many, if not all, of the issues identified in the 1975 workshop were still being debated and discussed in the 1980 workshop and are still being debated and discussed in the 2010 workshop. The most significant technological changes between the 1975 and 1980 workshops and the 2010 workshop are in the areas of biological and chemical analysis and engineering technology. The rapid development of analytical capabilities in the areas of microbiology, toxicology, and chemical analysis, with specific emphasis on trace organic constituents is well beyond what was imagined in the early workshops. The technological changes have similarly been remarkable, especially in the areas of membrane technology and advanced oxidation.

With the treatment technologies now available, as discussed in Chapters 3 and 4, it is possible to remove chemical and microbial constituents of concern to very low and what are believed to be insignificant levels with regard to human health. With ongoing technological developments, even more robust treatment process performance will be achieved. What remains to be technologically resolved to obtain regulatory approval for DPR is related to: (1) the need for and size of engineered buffers, (2) system reliability, and (3) appropriate monitoring techniques; these subjects are examined in Chapter 4. In each of the three workshops, public acceptance was identified as a barrier to DPR; this issue is further examined in Chapter 5. The needed research for both technological and public acceptance issues is proposed in Chapter 6.

At the April 2010 workshop, a number of legal and regulatory challenges were identified regarding regulatory authority for DPR under California's current laws and regulations. For example, until water recycling requirements are established for DPR, DPR is prohibited under California Water Code section 13524. In addition, further clarification is needed to define the point at which recycled water transitions from legal authority under state and federal wastewater laws to water laws. This situation is particularly complex because recycled water is treated as a waste for purposes of permitting under various sections of the California Water Code. The manner in which recycled water is "discharged" will also have an impact on applicable water quality requirements. For example, if the recycled water is directly introduced into a water treatment plant or distribution system, only drinking water laws and regulations would apply, albeit with potentially added scrutiny as part of a water supply's source water assessment. If recycled water is introduced into a reservoir immediately upstream of a water treatment plant's intake, then both wastewater and drinking water laws would apply, and in some cases the applicable wastewater quality standards might be more stringent than drinking water requirements. It is expected that these kinds of issues will be explored as part of the Senate Bill 918 panel deliberations regarding DPR feasibility.

3
REVIEW OF DIRECT POTABLE REUSE PROJECTS

An overview of projects that are examples of DPR, without an environmental buffer, is presented in this chapter. The projects described include examples that (1) have been undertaken in the past, (2) are currently in operation, or (3) are under design/construction. The importance of these examples is that the treatment process flow diagrams and treatment technologies employed have been accepted by various regulatory authorities as being able to produce safe potable drinking water, and that the implementation of these projects has been accepted by the public. Although not an example of DPR, the Orange County Water District (OCWD) Groundwater Replenishment System (GWRS) is also included because the purified water that is produced for groundwater recharge represents an example where the water is safe for direct potable reuse and can serve as a benchmark for other suitable technologies (Burris, 2010). The seven selected projects to be reviewed are:

1. City of Windhoek, Namibia,
2. Pure Cycle Corporation, Colorado,
3. Denver Potable Reuse Demonstration Project,
4. National Aeronautics and Space Administration (NASA) International Space Station,
5. Village of Cloudcroft, New Mexico,
6. Big Springs, Texas, and
7. Orange County Water District GWRS, California.

The treatment process flow diagrams and the specific technologies used will serve as a basis for the development of alternative treatment strategies in Chapter 4, which, in turn, will serve as the basis for identifying unresolved questions concerning DPR.

The focus of the following review is primarily on treatment technologies and not specific constituents, microbial properties, toxicological properties, or public acceptance. Based on the reported studies, it is clear that with existing proven technologies, the production of safe potable drinking water is achievable. What needs to be researched are the methods and facilities that are necessary to provide a measure of reliability that will satisfy regulators and secure public acceptance. These measures are likely to be in excess of what is now provided by most water treatment systems.

3-1 CITY OF WINDHOEK, NAMIBIA

The City of Windhoek is the capital of Namibia, the most arid country in Sub-Saharan Africa. The Country has a surface area of 825,000 km^2 (319,000 mi^2) and has a total population of 2.2 million, making it one of the least populated countries in the world. The population of Windhoek is approximately 250,000. Since 1968, Windhoek has been adding highly-treated reclaimed water to its drinking water supply system. The blending of reclaimed water with potable water takes place directly in the pipeline that feeds its potable water distribution network.

The reclaimed water meets Namibia Drinking Water Guidelines, World Health Organization Guidelines, and South Africa Rand Guidelines. The project is operated whereby intermediate treated water criteria have to be maintained at certain unit process. Failure to meet these criteria precludes the delivery of final reclaimed water into the distribution system.

Treatment Process Flow Diagram

The initial Goreangab Treatment Plant (see Figure 3-1a), now called the “Old” Goreangab Plant, went through a series of upgrades with the last upgrade undertaken in 1997 as illustrated on Figure 3-1b. The design of the new plant is based on the experience gained over 30 years of water reclamation and reuse, but also includes new processes such as ozonation and ultrafiltration. Before the latter two processes were adopted, they were pilot tested over a 30-month period, to verify the performance with this specific raw water.

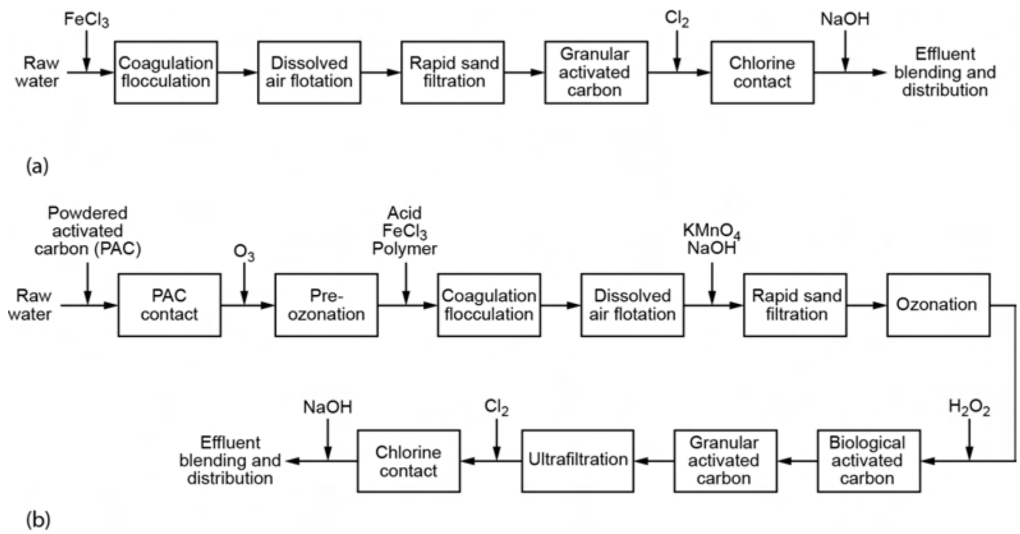

Figure 3-1

Water Reclamation Process Flow Diagrams at the Goreangab Water Reclamation Plant in Windhoek, Namibia. (a) original process flow diagram and (b) the new 1997 process flow diagram. Adapted from du Pisani (2005); Lahnsteiner and Lempert (2005).

Lessons Learned

From the Windhoek experience it is evident that highly treated municipal wastewater (reclaimed water) can be reused successfully for potable purposes. In the case of Windhoek, a combination of factors, with the lack of alternative water sources probably the most notable, makes DPR a viable option, even in financial terms. It is furthermore evident that the technology exists to produce water reliably that meets all drinking water guidelines and to provide the user with an acceptable level of confidence as to the risk of DPR.

3-2 PURE CYCLE CORPORATION

In the late 1970's, the Pure Cycle Corporation developed a complete water recycling system for the production of potable drinking water. A number of these systems were installed in Colorado at individual homes during the period 1976 through 1982. The systems operated successfully for a number of years (Harding, 2011). Ultimately, the company could no longer service them for financial reasons and their use was discontinued. It is interesting to note that even after the company could no longer service the systems, owners of the systems petitioned the state to allow them to continue to use the water recycling systems.

Treatment Process Flow Diagram

The pictorial drawing of the treatment process taken from the Patent issued to the Pure Cycle Corporation is shown on Figure 3-2. A schematic block diagram of the process flow diagram is shown on Figure 3-3. The operation of the system can be described as follows. First, household wastewater is discharged to a holding tank. Then, water from the holding tank passes through a grinder (optional) and is pumped to a buffer tank which has two compartments. One compartment serves as a holding tank for untreated wastewater, with a capacity of one days flow, and the second serves as a holding tank for waste solids from the biological treatment process. Wastewater from the holding tank is then pumped to the biological treatment process, which is comprised of biological treatment section and a filtration section.

The biological treatment section employs rotating disks to which bacteria are attached (commonly known as a rotating biological contactor). The filter process employs rotating disks covered with a porous cloth media which serves as an effluent filter (similar to current cloth filters). The biologically treated and filtered wastewater is then pumped to an ultrafiltration membrane unit (or a dual bed filtration unit, as identified in the patent). Effluent from the membrane filter is then passed through a dual bed ion-exchange column, which also includes organic absorbents. Effluent from the ion exchange process is passed through a UV unit for additional protection against pathogens before being discharged to a clean water storage tank for domestic use. Additional details may be found in the original patent (U.S. Patent, 1979). The entire system was highly instrumented and controlled with a microprocessor with three principal elements: monitor, control, and alarm, details of which may be found in the U.S. Patent.

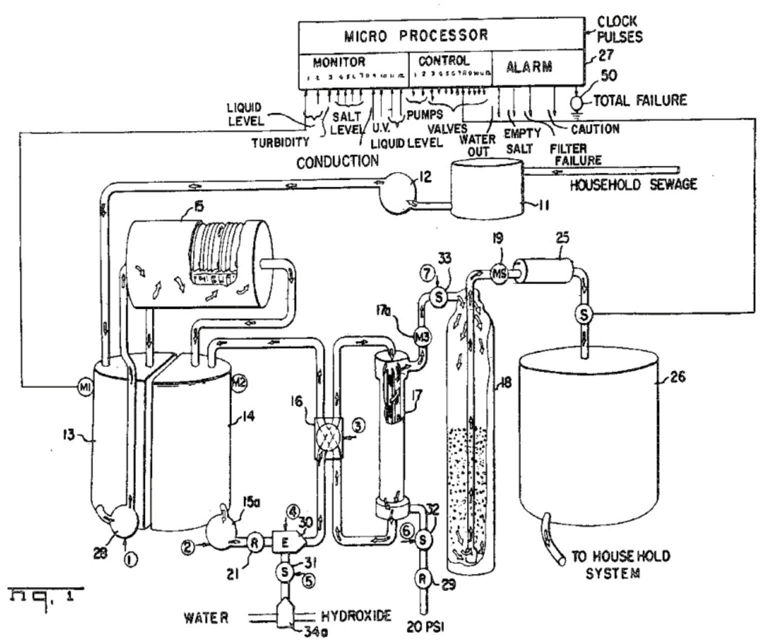

Figure 3-2

Pictorial view of Pure Cycle Corporation closed water-recycling system process flow diagram (From U.S. Patent No. 4,145,279)

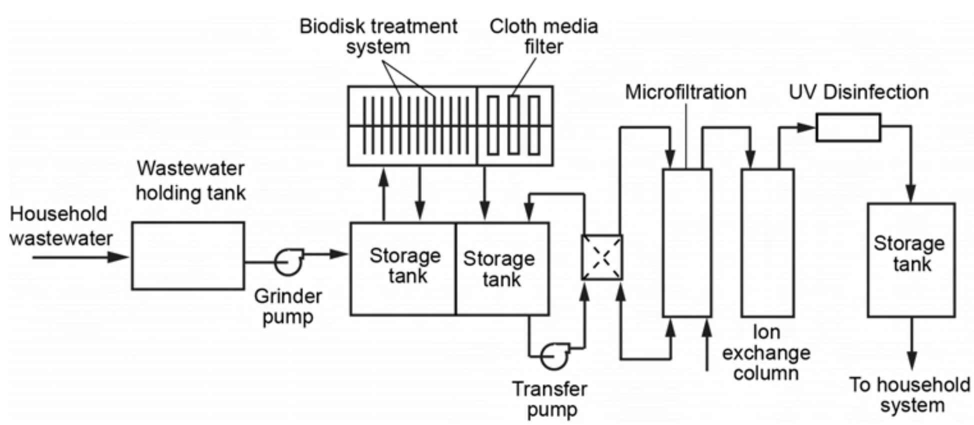

Figure 3-3

Schematic view of Pure Cycle Corporation closed water-recycling system process flow diagram (Adapted from U.S. Patent No. 4,145,279)

Lessons Learned

Using the unit processes available in the late 1970s, it was possible to put together a treatment system that produced potable drinking water from wastewater. The inclusion of a holding tank for flow equalization allowed the biological treatment process to operate at a constant flow rate, which reduced treatment variability. The biological treatment system was essentially the same as current biological treatment systems. The microfiltration unit was essentially the same as used today, except there has been a significant improvement in the formulation, design, and fabrication (and, thus, effectiveness) of membranes. The ion exchange process used in the Pure Cycle system has been replaced with reverse osmosis in most recent advanced treatment designs, although some agencies are reexamining the use of ion exchange. The Pure Cycle systems would probably still be in use if the economics of servicing them were more favorable.

3-3 DENVER POTABLE REUSE DEMONSTRATION PROJECT

In the period from 1985 to 1992, the City of Denver conducted a potable reuse demonstration project. The objective of the project was to examine the feasibility of converting secondary effluent from a wastewater treatment plant to water of potable quality that could be piped directly into the drinking water distribution system. The influent to the potable reuse demonstration plant was unchlorinated secondary effluent treated at the Denver Metropolitan Wastewater Reclamation District's regional wastewater treatment facility. The treatment processes at this facility consisted of screening, grit removal, primary sedimentation, activated sludge, secondary sedimentation, and nitrification for part of its influent. However, the portion fed to the demonstration plant was not nitrified. Final product water from the demonstration plant was never used for DPR, but stored and shown as part of the project's public outreach program.

Treatment Process Flow Diagram

The 3,785 m^3 (1 Mgal/d) potable reuse demonstration plant (0.38 m^3/d [0.1 Mgal/d] after carbon adsorption) as illustrated in Figure 3-4, employed advanced

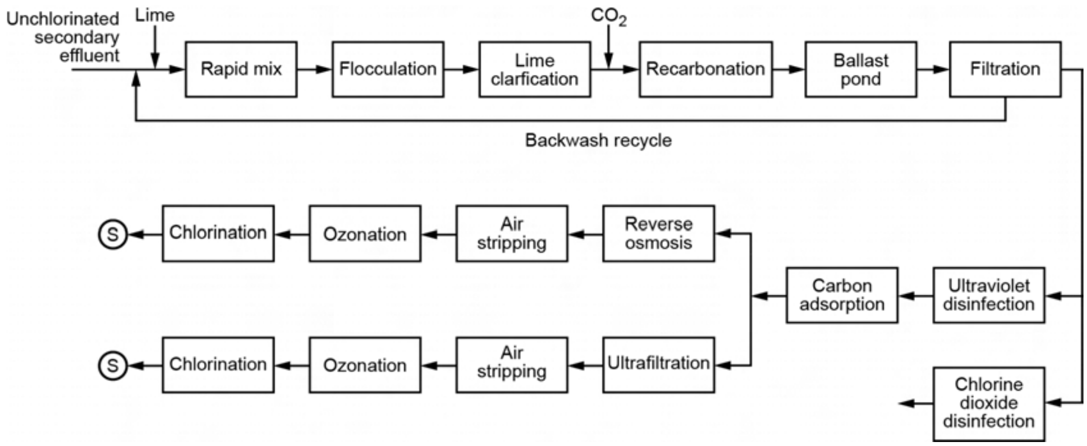

Figure 3-4

Treatment process flow diagram for the Denver, CO potable water reuse demonstration project (Adapted from Lauer and Rogers, 1998).

treatment consisting of multiple treatment processes and operations to achieve the desired high constituent removal. The various processes included high-pH lime treatment, sedimentation, recarbonation, filtration, UV irradiation, carbon adsorption, reverse osmosis, air stripping, ozonation, chloramination, and ultrafiltration. Initial treatment at the potable water demonstration plant consisted of aeration, followed by a high-pH lime treatment, and then by addition of ferric chloride to aid the sedimentation process. Following sedimentation, recarbonation was used to adjust the pH to approximately 7.8. A tri-media filter system followed the chemical treatment step. The filtration system removed turbidity to 0.5 NTU.

Lessons Learned

Conducted over a 13 year period, it was possible to demonstrate the reliable production of potable water from unchlorinated secondary treated municipal wastewater by means of advanced water treatment. The long-term operation of the research treatment facility provided valuable information regarding the effectiveness of various advanced water treatment processes for the removal of natural and anthropogenic constituents from water. Based on comprehensive physical, chemical and microbiological testing, the product water was found to be comparable to the existing City of Denver potable water supply. No adverse health effects were identified based on extensive toxicity and carcinogenicity studies as well as reproductive studies. A public outreach/education program was conducted as part of the project. A 1985 survey indicated that a majority of the public was not supportive of potable water reuse; however a 1990 focus group urged the utility to move forward with the project (Lohman and Milliken, 1985). Additional information on the Denver project can be found in Lauer and Rogers (1998).

3-4 INTERNATIONAL SPACE STATION

To expand the International Space Station (ISS) crew size from three to six members, it was necessary to develop regenerative Environmental Control and Life Support Systems (ECLSS). The ECLSS is comprised of the Water Recovery System (WRS) and the Urine Processor Assembly (UPA) (Carter, 2009). These two systems are used to produce potable water from a combination of condensate and urine collected on ISS. Although not directly applicable to DPR of recycled water, this example is included to illustrate the range of technologies that have been applied to the purification of wastewater.

Treatment Process Flow Diagrams

The treatment process flow diagrams for the two water treatment modules on the ISS are described below.

Water Recovery System

A schematic of the water recovery system is shown on Figure 3-5. The WRS is used to treat condensate from the temperature and humidity control system and distillate from the urine recover system. Water from these two sources is stored in a wastewater holding tank. From the holding tank gas is removed from the water before it is pumped through a filter to remove particulate matter. Effluent from the particulate filter is next passed through filtration beds, operated on series, where inorganic and organic constituents are removed. From the filtration beds water is passed through a catalytic reactor to remove low molecular organic constituents not removed by the filtration process.

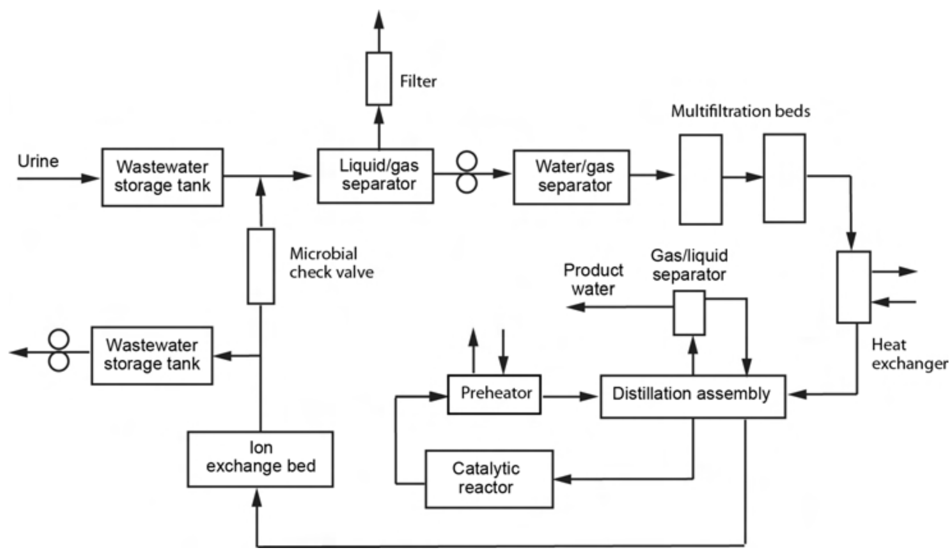

Figure 3-5

Treatment process flow diagram for the treatment of condensate from the temperature and humidity control system and distillate from the urine recovery system on the International Space Station (Adapted from Carter, 2009).

Low molecular organic constituents are removed by thermal oxidation in the presence of oxygen and a catalyst. A regenerative heat exchanger is used to recover heat from the catalytic reactor for enhanced efficiency. A water/gas separator is to remove excess oxygen and oxidation byproducts before the process water is returned to the water distribution system. An ion exchange bed is used to remove dissolved oxidation byproducts from the water. Iodine is added to the water from the ion exchange bed before it is discharged to the product water storage tank. If the treated water does not meet specifications, the water is diverted and passed through the process again.

Urine Processor Assembly

A schematic of the urine treatment module on the ISS is illustrated on Figure 3-6. As shown, urine from the urinal facilities on the ISS is transferred to a wastewater storage tank. From the storage tank urine is blended with water from the recycle filter tank. The blended water is transferred to the distillation unit with a positive displacement pump (i.e., peristaltic pump). Following distillation, the saturated vapor is transferred to a water gas separator where water is separated from the

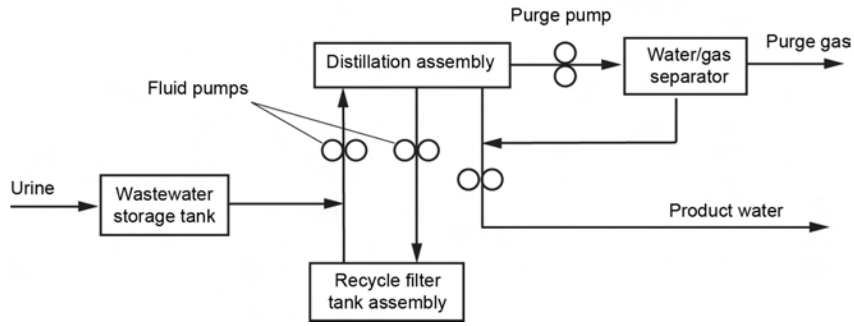

Figure 3-6

Treatment process flow diagram for the treatment of urine on the International Space Station (Adapted from Carter, 2009).

vapor. The condensate from the evaporator and the water from the water/gas separator are blended and pumped to the water distribution system (Carter, 2009).

Lessons Learned

Because of the complexity of these systems, it has been a challenge to achieve long-term reliability. Following a successful demonstration period, water from the water recovery system was approved for consumption by the ISS crew in April, 2009. While the urine separation system can produce potable water, it has not yet been certified because of operation difficulties with the distillation unit and the recycle filter tank assembly. Work is currently under way to resolve the operating issues (Carter, 2009). For any future DPR projects, the lesson from the ISS systems is that use of existing, proven technology would improve reliability.

3-5 VILLAGE OF CLOUDCROFT, NEW MEXICO

The village of Cloudcroft, NM is a small mountain community, located south of Albuquerque, NM at an elevation of 8,600 ft. The permanent population is about 850, but increases to more than 2,000 during the weekends and holidays. The average water demand is about 180,000 gal/d (gallons per day) with a peak demand of about 360,000 gal/d. The water sources include springs and wells, which have experienced reduced flows due to drought conditions. The community had resorted to water hauling on the weekends. Recognizing that a long-term alternative was needed, a plan was developed to augment the potable water system with purified (highly treated) wastewater. The plan involved blending 100,000 gal/d of purified wastewater with a slightly greater (51%) amount of spring water and/or well water. The blended water is placed in a storage reservoir (blending tank) with a detention time of about two weeks. Water from the storage reservoir is treated before being placed into the distribution system. The plant is scheduled to begin operation in the fall quarter of 2011.

Treatment Process Flow Diagram

The process flow diagram treatment is shown on Figure 3-7. As shown, the advanced wastewater treatment plant employs a membrane bioreactor followed by disinfection followed by reverse osmosis and advanced oxidation. The purified water is then blended with natural waters (spring/ground water) and placed in a blending/buffer (storage) tank. Water from the reservoir is then treated by ultrafiltration, UV disinfection, passed through activated carbon, and disinfected again before being introduced into the distribution system.

In reviewing the proposed treatment process for Cloudcroft, it is interesting to note that many of the unit processes employed are similar to those employed in the OCWD system (see subsequent discussion).

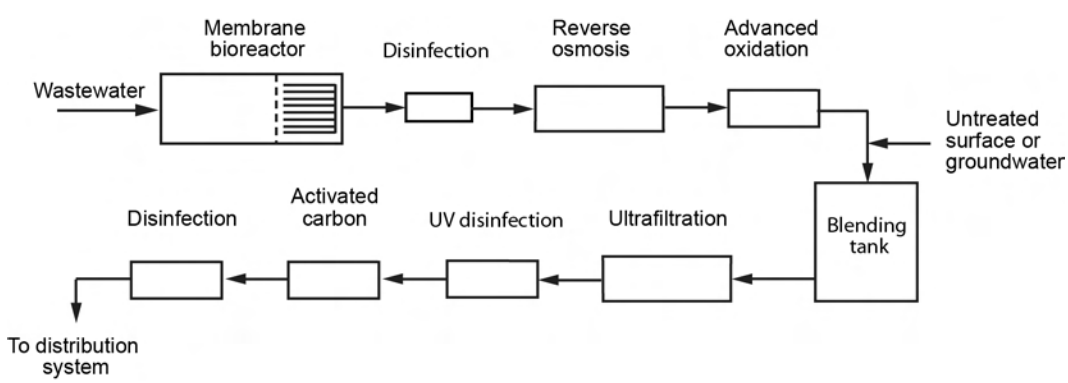

Figure 3-7

Schematic of Cloudcroft, NM DPR treatment process flow diagram (Adapted from Livingston, 2008).

Lessons Learned

Acceptance of the Cloudcroft reuse system by the health authorities was predicated on three conditions: (1) the wastewater had to be treated with reverse osmosis and advanced oxidation, (2) the highly treated water had to be blended with a greater parentage (51%) of natural surface or groundwater and held in a storage reservoir, and (3) the blended water had to be treated through a water treatment plant before being introduced into the distribution system. Note that the potable water treatment system is superior to most conventional systems due to the use of ultrafiltration (i.e., microbial barrier) and other barriers. Blending the highly treated water with natural water allowed the health authorities to define the process as “indirect potable reuse.” Operation of the potable reuse system was to have started in the fall of 2009. Unfortunately, construction problems have delayed the completion of the project, which is now scheduled to go on line in the fall of 2011. Public enthusiasm and backing for the project remains high (Livingston, 2011).

3-6 BIG SPRINGS, TX

Subject to extensive periods of limited rainfall, the communities in the Permian Basin of West Texas, have experienced a number of serious water supply issues. Although water reclamation has been practiced for a long period of time, the drought conditions have forced the communities to look for other water supply sources. To this end, the Colorado River Municipal Water District (CRMWD), which supplies water to a number of cities within the basin, has undertaken an initiative to *"reclaim 100% of the water, 100% of the time."* Key elements of the initiative are: (1) to implement facilities to capture wastewater effluent before it is discharged, (2) to build local and regional treatment facilities to reclaim the captured water, and (3) to implement facilities to blend the reclaimed water with other water supply sources. The first project to be undertaken by the CRMWD is Big Springs, TX. The plan is to capture 2.5 Mgal/d of filtered secondary effluent, treat the effluent with advanced treatment, blend the treated water in the CRMWD raw water transmission line, and treat the blended water in the CRMWD water treatment plant before distribution. Construction is scheduled to commence in 2011 and facility startup is scheduled for early 2012 (Sloan et al., 2009).

Treatment Process Flow Diagram

The Big Springs water reclamation flow diagram is shown on Figure 3-8. As shown, the advanced wastewater treatment plant, used to treat effluent diverted from the wastewater treatment facility, employs membrane filtration followed by reverse osmosis and advanced oxidation. The water, which has been subjected to advance treatment, is then blended with raw water in the CRMWD raw water transmission line. The blended water is then treated in a conventional water treatment facility. Concentrate (brine) from the reverse osmosis process is discharged to a brackish stream for which a concentrate discharge permit had to be obtained.

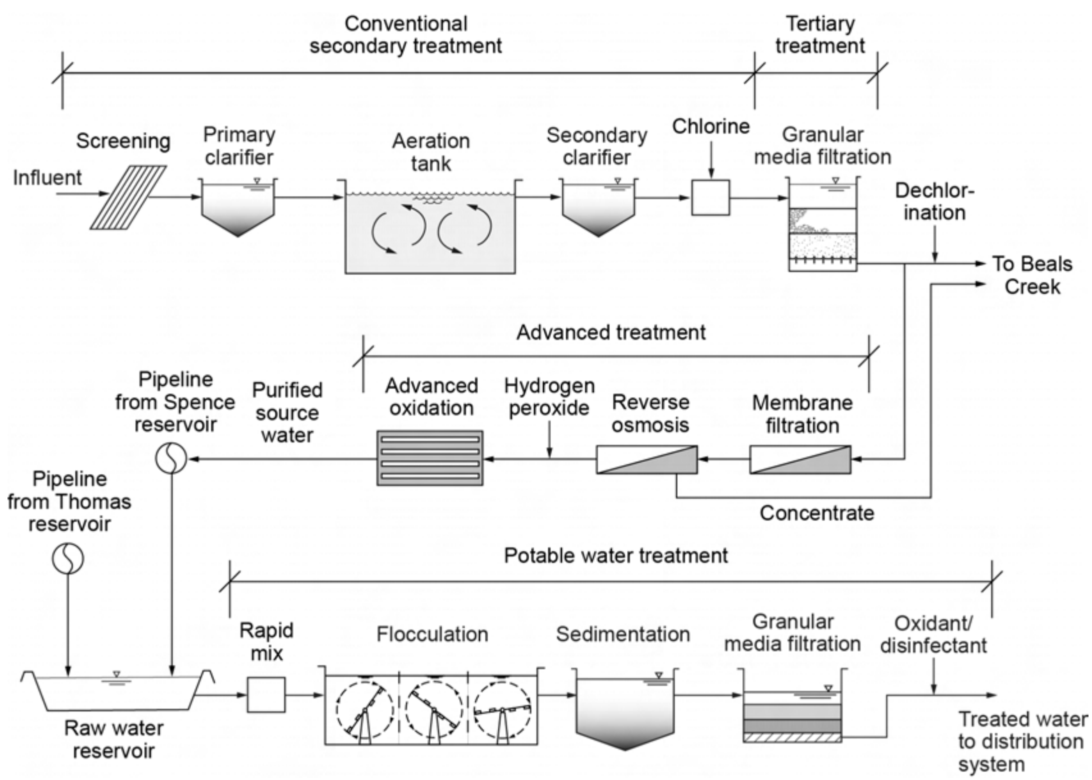

Figure 3-8
Schematic of Big Springs, TX treatment process flow diagram
(Adapted from Sloan et al., 2009).

Lessons Learned

The important factors in the CRMWD decision to move forward with the project included:

1. Seasonality of nonpotable reuse options, which limit the volume of water that could be recycled,
2. Limited number of potentially large users,
3. Large transmission distances because of low-density development,
4. Limited landscaping due to the arid conditions,
5. High total dissolved solids (TDS) concentrations in the treated effluent, especially chloride,
6. Opportunity to recycle year round by blending with raw water sources; and
7. Alternative sources of supply are far away and at a lower elevation resulting in high transmission costs (Sloan et al., 2009).

The implementation of this project involved an ongoing public education program coupled with a feasibility study and close cooperation with the Texas Commission for Environmental Quality (TCEQ). In their deliberations, the TCEQ conducted an extensive evaluation before accepting the project. As part of the acceptance process, the TCEQ developed comprehensive operation, monitoring and reporting requirements, which are described in their acceptance document in the form of a letter to the district. Because of the thoroughness of this document, it is included in Appendix B of this report for easy reference.

3-7 ORANGE COUNTY WATER DISTRICT

In closing this chapter on DPR projects, it is appropriate to consider the OCWD's groundwater replenishment system (GWRS) that went into operation in 2007. Currently, GWRS is the largest water reclamation facility of its kind in the world employing the latest advanced treatment technologies. The GWRS is considered here because the product water, as reported by Burris (2010), has been studied exhaustively and determined to be highly purified, meeting all applicable numeric drinking water standards.

Treatment Process Flow Diagram

The source of water for GWRS is undisinfected secondary effluent from the Orange County Sanitation District (OCSD). The advanced water treatment facility (AWTF) process flow diagram, shown on Figure 3-9, includes the following unit processes: microfiltration, cartridge filtration, reverse osmosis, advanced oxidation (UV photolysis and hydrogen peroxide), carbon dioxide stripping, and lime addition. The product water is discharged to existing spreading basins and sea water barrier injection wells. Purified water and other sources of dilution water introduced to the spreading basins mix with water from other sources and percolates into the groundwater aquifers, where it eventually becomes part of Orange County's drinking water supply. Water pumped to the injection wells serves as a barrier to salt water intrusion and also becomes part of the drinking water supply.

Lessons Learned

The product water from the GWRS meets and/or exceeds, all of the CDPH requirements for potable water and the Santa Ana Regional Water Quality Control Board requirements for IPR. The performance of the facility has validated the effectiveness of the process flow diagram shown on Figure 3-9. Because of initial concerns for public acceptance and safety, an extensive public outreach program was conducted to demonstrate the safety of GWRS product water and groundwater quality. Extensive monitoring on an ongoing basis is integral part to the program to assure the safety of the purified water.

3-8 REVIEW OF DIRECT POTABLE REUSE SYSTEMS

The DPR treatment systems reviewed above incorporate a number of different unit processes grouped in configurations to remove the particulate, colloidal, and dissolved inorganic and organic constituents found in the effluent from wastewater treatment facilities or other water sources. It should be noted that while all of the treatment processes remove dissolved organic constituents, only specific treatment processes provide for the removal of total dissolved solids (TDS).

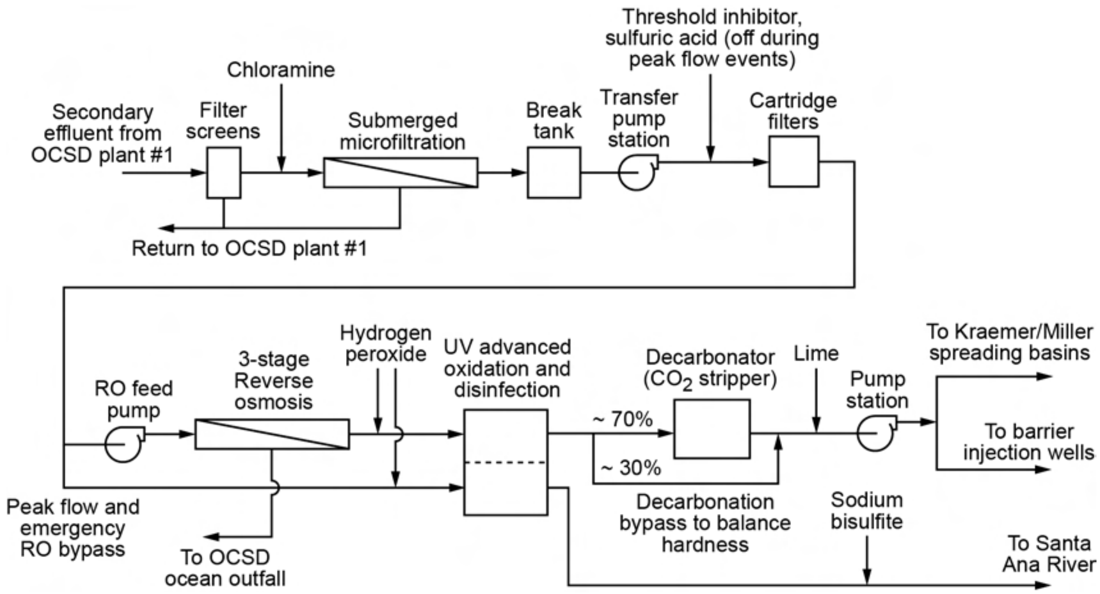

Figure 3-9
Schematic flow diagram for 2.65 x 10^4 m^3/d (70 Mgal/d) advanced water treatment facility at the Orange County Water District, Fountain Valley, CA

The only difference between the OCWD system and a conceptual DPR system is that recycled water from the OCWD system is introduced into an environmental buffer for a minimum of six months, where it is presumed that it may receive some additional treatment and lose its identity as recycled water. However, because of the high level of purification, further treatment in the environment is not required. Thus, the OCWD system could, with the addition of an engineered buffer, be used for DPR, either by introduction into the water supply distribution system directly or to the head works of a water treatment facility. With one minor exception, the system developed for Cloudcroft, New Mexico (see Figure 3-7) is similar to the OCWD system. The principal difference is that purified water is blended with other water supply sources in a blending tank and then treated further (to remove contaminants added by the natural water) before introduction to the water supply distribution system. It is important to acknowledge that the Cloudcroft design was specifically intended so that the project could be classified as IPR, even though arguably it could be considered a type of DPR project. The distinction between IPR and DPR points out the need to further investigate the relevance of engineered storage buffers.

In the future, an almost unlimited number of different configurations of unit processes could be proposed for treatment of wastewater for DPR. Because evaluating the merits of each individual configuration is not within the scope of this report, the quality of the water produced using the technology used by the OCWD is proposed as a benchmark against which other treatment process configurations can be evaluated with one exception; namely TDS, which is likely to be a site specific, project-by-project issue. It is clear, however, that (1) the need for and size of engineered buffers, (2) system reliability, and (3) appropriate monitoring techniques will have to be evaluated for each proposed treatment process configuration.

4
TECHNICAL ISSUES IN DIRECT POTABLE REUSE

Treated wastewater that is discharged to the environment (except for discharges to the ocean) is invariably taken up as water supply, perhaps within hours of discharge, and is referred to commonly as unplanned, or *de facto*, potable reuse. The effects of treatment, dilution, time, and commingling with environmental water are considered by many to be adequate for the conversion of treated water into a potable water supply source. Conversely, planned potable reuse systems, where wastewater is processed to a quality suitable for water supply, are often deemed too controversial as a result of public perception and/or political considerations. However, as water supply becomes more limited, treatment technology improves, and the public becomes better informed of the nature of their local water supplies, increased emphasis will be placed on the planned augmentation of drinking water supplies with highly treated wastewater.

As a result of the development and demonstration of full-scale advanced treatment processes, the use of purified water that has been recovered from municipal wastewater directly for potable purposes is now receiving increased interest as a viable alternative for DPR. It is also recognized that there is a continuum of possibilities for potable reuse ranging from direct injection into potable water distribution systems (DPR) to long-term storage in the environment prior to reuse (IPR). While the focus of this chapter is on the direct discharge (with blending) to a potable water system, the concepts are equally applicable to systems with a high recycled water contribution (RWC) with limited retention time in the environment. It is expected that systems with short environmental retention times prior to potable reuse will also need to incorporate the concepts discussed in this section.

The purpose of this chapter is to develop a framework for the identification of knowledge gaps that will form the basis for the research topics discussed in Chapter 6. This chapter includes an introduction to DPR systems, a discussion of engineered storage buffers, measures to improve reliability, monitoring systems, and anticipated future developments in DPR. In addition, a summary review of research issues and needs for the implementation of DPR, derived from the material presented in this chapter, is presented at the end of this chapter.

4-1 INTRODUCTION TO DPR SYSTEMS

An overview of general water supply and treatment alternatives is shown on Figure 4-1. Direct potable reuse, as illustrated with the dark line on Figure 4-1, is inclusive of both the introduction of highly treated reclaimed water either directly into the potable water supply distribution system downstream of a water treatment plant, or into the raw water supply immediately upstream of a water treatment plant. As shown on Figure 4-1, in addition to conventional secondary and/or tertiary facilities, the principal elements that comprise a DPR system include (1) advanced wastewater treatment processes, (2) facilities for balancing water chemistry, (3) engineered buffers for flow retention and quality assurance, and (4) blending of purified water with other natural waters. Each of these elements is considered briefly in the following discussion. The relationship of these elements to the multiple barrier concept developed for water treatment is also considered.

Advanced Wastewater Treatment Processes

There has been a rapid increase in the development of technologies for the purification of water, including improvements in systems such as reverse osmosis, electrodialysis, and distillation for demineralization and the removal of trace constituents, as well as in processes to accomplish advanced oxidation, such as ozonation alone or with hydrogen peroxide, UV alone or with hydrogen peroxide, and other combinations of ozone and UV to accomplish photolysis and/or high levels of hydroxyl radical production. Examples of advanced treatment processes used for the removal or destruction of trace constituents

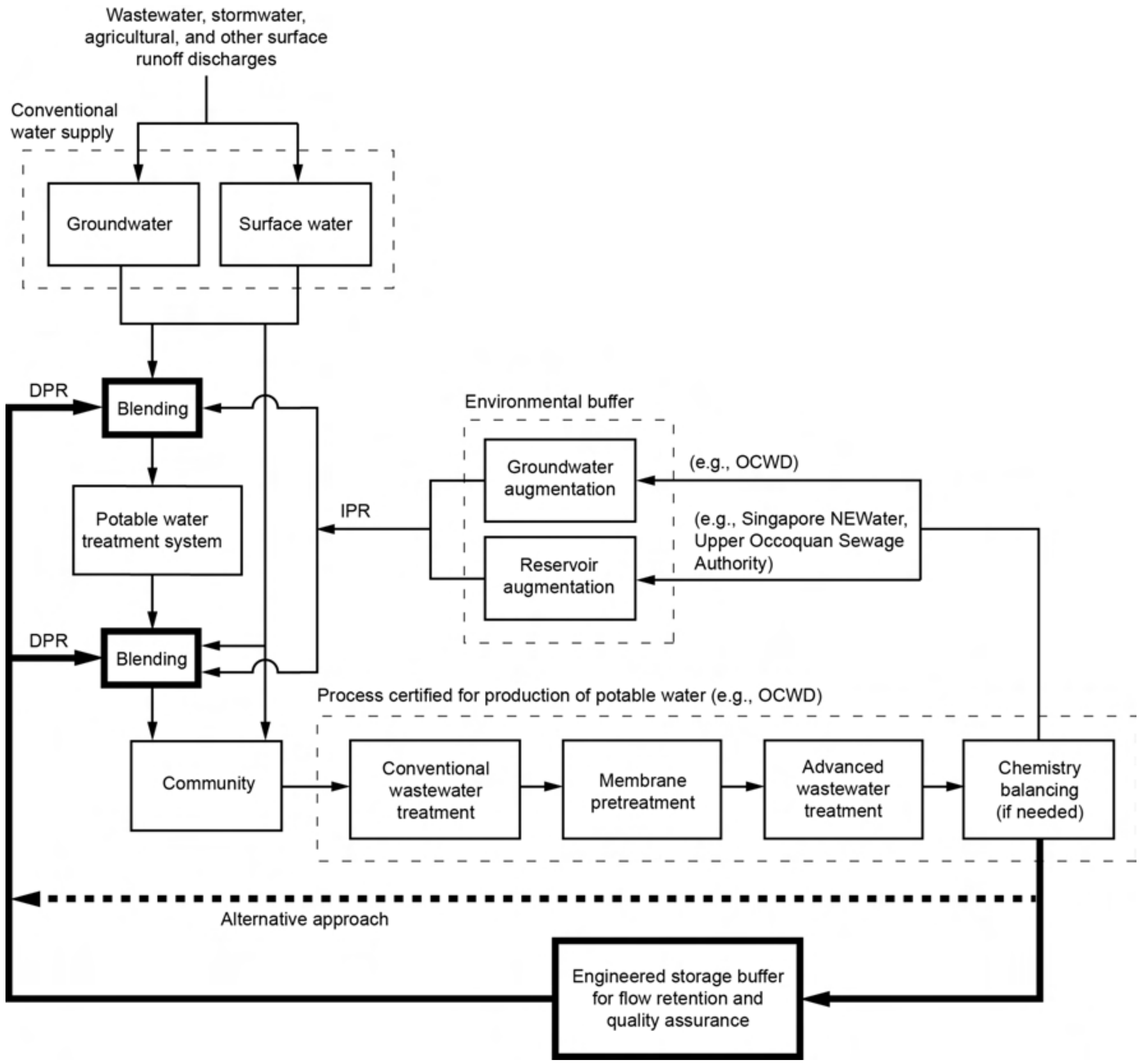

Figure 4-1

Summary of opportunities for direct and indirect potable reuse. The bold solid line corresponds to a system in which an engineered storage buffer is used to replace an environmental buffer. The bold dashed line corresponds to a DPR system in which an engineered storage buffer is not used.

with and without reverse osmosis are shown on Figure 4-2. With the exception of flow equalization and the engineered buffer, to be discussed subsequently, the flow scheme shown on Figure 4-2a is representative of the process configuration employed currently at the OCWD GWRS for production of potable supply. As the purified water from OCWD's GWRS meets or exceeds all potable drinking water standards and reduces unregulated chemicals that are known or suspected to be

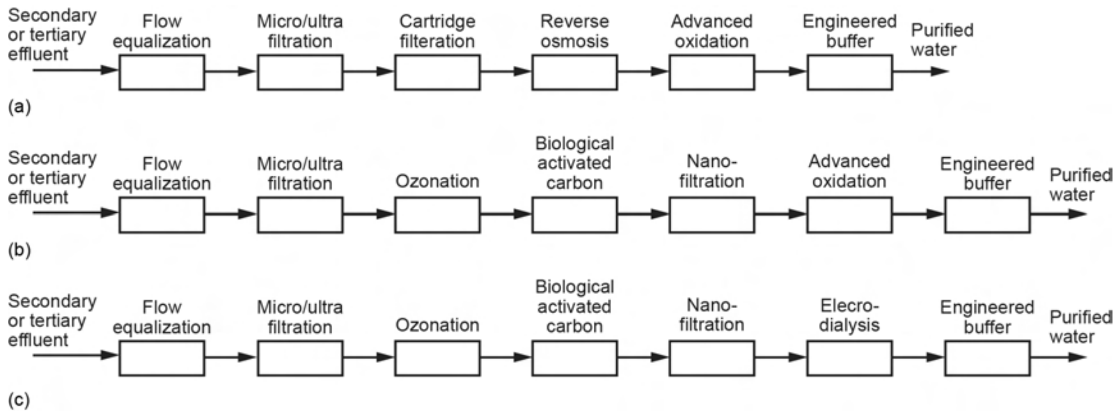

Figure 4-2

Potable reuse treatment scenarios: (a) process employing reverse osmosis, (b) process employing nanofiltration, and (c) process employing nanofiltration and electrodialysis

of health concern to non-measurable or *de minimus* levels, it is considered to be safe for direct human consumption (Burris, 2010).

Because of the cost and logistical issues associated with the management of brines from reverse osmosis systems, especially in inland locations, there is an interest in the development of advanced processes that are able to remove or convert trace constituents without physical separation of constituents from the product water. Two proposed flow diagrams both without reverse osmosis are shown on Figures 4-2b and 4-2c. It should be noted that the DPR system currently in use in the City of Windhoek, Namibia (see Chapter 3-2) does not use reverse osmosis.

Balancing Water Chemistry

Following demineralization, purified water may need to be remineralized for public health concerns (e.g. absence of magnesium and calcium), to enhance taste, to prevent downstream corrosion (e.g., calcium saturation index), and to minimize damage to soils (e.g., sodium adsorption ratio) and crops (e.g., magnesium deficiency). Balancing can be accomplished by recarbonation and addition of trace minerals and salts or by blending with other water supply sources. Proprietary blending processes are also available. Blending with a portion of the brine is often used in seawater desalination. The level of chemical balancing required will depend on the characteristics of the product water, the volumetric blending ratio with other water sources, and the chemistry of the other water sources.

Balancing of water chemistry in a DPR system could be conducted at various locations in the water system, including just prior to the engineered storage buffer, after storage in the buffer, or after blending with alternative supplies. It is important to verify the quality of the chemicals used for water chemistry balancing to ensure that contaminants are not being introduced into the purified water inadvertently.

Engineered Storage Buffer for Flow Retention and Quality Assurance

Storage buffers can be environmental (i.e., natural) or engineered (i.e., constructed) facilities used between wastewater treatment systems and potable water systems to, in general, compensate for process variability, reliability, and unknowns. For example, a process with a large degree of variability in product water quality may require a large buffer to allow sufficient time to detect and respond to process deficiencies prior to introduction into the potable supply. Alternately, a process that has a small degree of variability in product water quality (including raw source water quality) taking into consideration the level of blending with other water sources (see next section) may require only a small or no buffer facility. Both environmental and engineered storage buffer systems for flow retention and quality assurance are described in greater detail below.

Blending with Other Water Supply Sources

The amount of blending with other water supply sources will depend on a number of site-specific factors, including the availability of alternative water supply sources, regulatory requirements, and public acceptance. Like the environmental buffer, blending facilitates a loss of identity for the product water and, therefore, may diminish some public opposition. However, it is important to note that blending with alternative water supply sources should not be considered to be necessary for public health protection, with the exception of mineral balance as discussed above, as it is assumed that the purified water will be of the highest quality and the alternative source water may be subject to contamination if derived from environmental sources. It has also been proposed that blending of recycled water with other water supply sources could take place prior to introduction into an advanced treatment process, thus providing treatment purification of the entire water supply.

Multiple Barriers

Fundamental to the practice of planned potable reuse is the use of multiple barriers to ensure the quality of the product water. It is important to note that the treatment systems discussed above are consistent with the multiple barrier concept, which has been the cornerstone of the safe drinking water program and consists of coordinated technical, operational, and managerial barriers that help prevent contamination at the source, enhance treatment, and ensure a safe supply of drinking water for consumers. Although no single barrier is perfect, significant protection is afforded when a number of independent barriers are combined in series. Ideally, the failure of a single barrier does not result in the failure of the system. Thus, the use of multiple barriers results in an overall high level of reliability. Based on this concept, the management, operational, and technological barriers for direct potable reuse shown on Figure 4-3, provides a significant level of protection from the system being out of compliance.

For potable reuse applications, multiple barriers, as shown on Figure 4-3, include: (1) consumer and business education, (2) source control for dischargers to the wastewater collection system, (3) equalization of flow and constituent concentrations and monitoring for selected constituents, (4) robust and redundant conventional secondary and tertiary treatment processes, (5) equalization and monitoring for enhanced process reliability and detection of selected constituents (6) robust and redundant advanced treatment, and (7) an engineered buffer for quality assurance. It should be noted that conventional, tertiary, and advanced treatment contain multiple barriers within themselves. The optional conventional potable water treatment system, depicted on Figure 4-3, provides a further set of barriers but is not needed unless purified water is blended with other water supplies that require treatment.

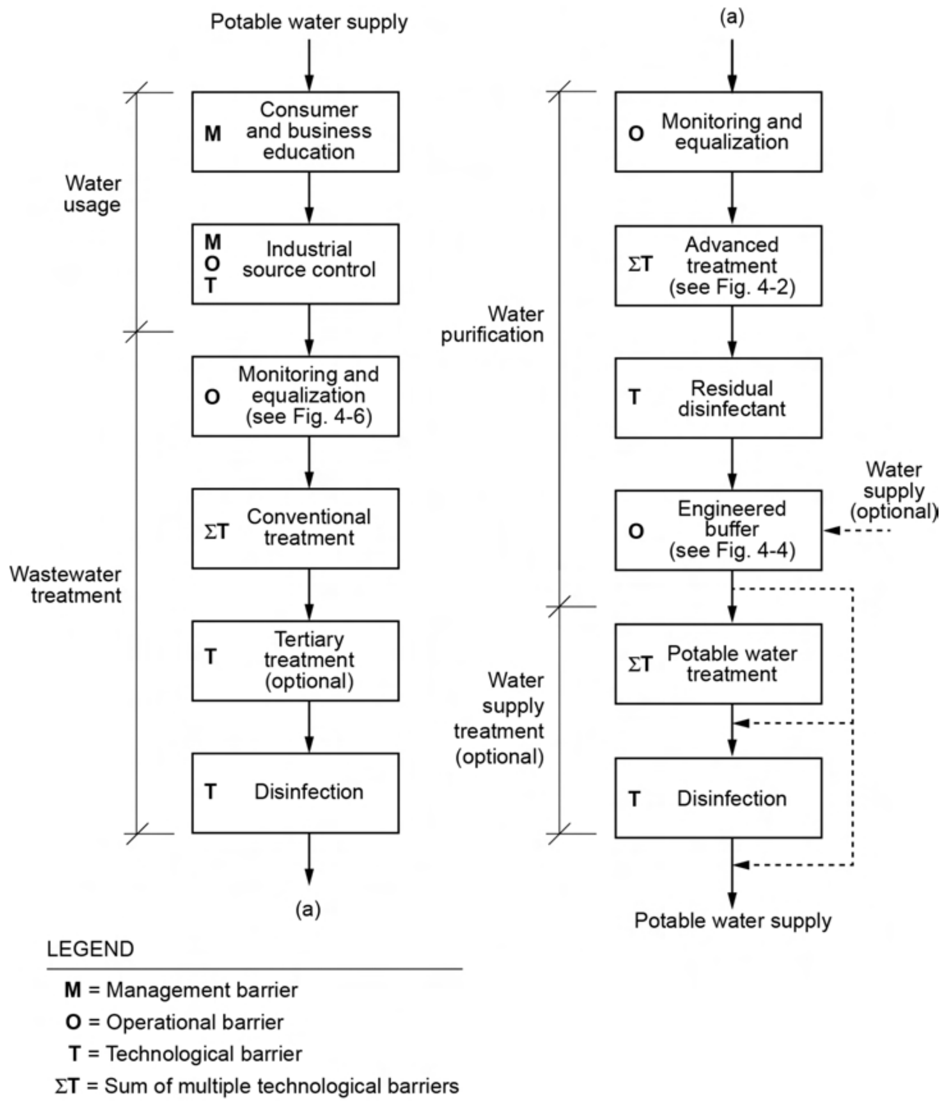

Figure 4-3

Illustration of management, operational, and technological barriers in direct potable reuse. As noted on the diagram, the barriers associated with conventional, tertiary, advanced, and potable treatment processes are comprised of a number of individual barriers.

4-2 ENGINEERED STORAGE BUFFERS FOR FLOW RETENTION AND QUALITY ASSURANCE

As noted in the introduction to this chapter, the key difference between IPR systems that employ advanced water treatment (AWT) and the proposed DPR systems is the utilization of an environmental (quality assurance) buffer, especially in the case where the purified water will be added directly to the water supply distribution system. For example, as described previously, the advanced treatment system in operation at the OCWD GWRS has been determined to produce recycled water that meets current drinking water standards. While OCWD currently injects and percolates recycled water into a groundwater basin that serves as an environmental buffer, it is reasonable to expect that the OCWD facility could be converted to a DPR system with addition of a buffer for quality assurance. The questions that need to be addressed are (1) is it necessary to add an engineered storage buffer to replace the environmental buffer and (2) what are the appropriate treatment performance monitoring requirements for evaluating quality assurance. Thus, the design and integration associated with the engineered buffer system is a key research area required for the development of DPR projects.

Environmental buffer

Environmental buffers include surface water and groundwater systems that are used for the temporary storage of recycled water prior to reuse. A large natural buffer promotes a loss of identity for recycled water, which can have an important psychological impact, time for the natural breakdown of constituents present in partially treated wastewater, and time to react to a constituent of concern that is detected in the water. A retention time of six months is specified in the draft CDPH regulations (CDPH, 2008) developed for indirect potable reuse through groundwater recharge using recycled water regardless of the level of treatment (tertiary and AWT). The six-month time period was based on the assumption that one log of virus reduction could be achieved for each month of residence time in the groundwater aquifer, thus, achieving an overall virus reduction of six logs. The six-log virus reduction was thought to be needed to meet public health concerns, which was relevant when tertiary effluent was being applied. The draft regulations also specify requirements for the initial RWC, which is limited to either 20% for tertiary treatment or 50% for AWT at project startup, with provisions for increasing the RWC, in part, based on the removal of total organic carbon (TOC) achieved during soil aquifer treatment or AWT. Requirements are in development for surface water augmentation using recycled water.

The rationale for the draft CDPH groundwater recharge regulations was developed during a time when analytical monitoring technology for chemical constituents was not as well developed as it is today, and TOC was used as a gross measurement of organic constituents in the recycled water (Crook et al., 2002). Early drafts of the groundwater recharge regulations limited the organic matter of wastewater origin to 1 mg/L in the groundwater at the point where it can be used as a drinking water source. This level was based on a recommendation of a California scientific advisory committee on groundwater recharge. It was the opinion of the panel that, at a TOC concentration of 1 mg/L, the gross level of organic contamination would be reduced to levels such that there would be little chance that any specific organic chemical would be present at levels that would constitute a health hazard (State of California, 1987). The TOC level (which is used to determine the allowable RWC) has since been reduced to 0.5 mg/L in the draft recharge regulations. The TOC in OCWD product water is consistently below 0.5 mg/L. The performance of current wastewater treatment processes and their reliability have significantly improved in recent years, as has the capability to detect and measure chemical constituents at extremely low concentrations, and the existing standards requiring passage through an environmental buffer for an extended period of time may no longer be warranted.

When water is introduced to the environment it is subject to evaporative losses and various forms of potential contamination, including commingling with urban and agricultural runoff, animal waste, and/or dissolution of compounds present in sediments and aquifers. It is, therefore, expected that purified water obtained from a combination of properly operated advanced treatment processes will result in a shift to an engineered storage buffer that provides an adequate safety factor and keeps control of the purified water quality with the water agency.

Another consideration related to large environmental buffers is that if a constituent is detected at levels of concern in the product water, a significant amount of time may be required before the off-speculation water can be extracted fully from the buffer and retreated, discharged, or used for nonpotable applications, even after problems in the treatment process have been corrected.

Engineered Storage Buffer

As described previously, when there are many unknowns and issues related to treatment reliability, it was deemed necessary to place treated wastewater into an environmental buffer to provide natural treatment and loss of identity, and a relatively long retention period (six months) to allow time for corrective action in the event that the product water does not meet all regulatory requirements. However, when water is treated to a high level of purity, placement into an environmental system does not necessarily result in improved water quality, and can instead expose the purified water to potential environmental contaminants. Thus, when purified water can be produced with a system with proven performance and reliability and the quality can be validated rapidly, a relatively small engineered storage buffer, if any, may be sufficient for use prior to discharge directly into the potable water system.

The engineered buffer consists of a well-defined, natural or constructed, confined aquifer or storage facility. Important features of the engineered buffer include:

1. Fully controlled environment,
2. Contained to prevent contamination and evaporative losses,
3. No source of contaminants from within the buffer itself,
4. Ability to divert flow out of the buffer as needed,
5. Accommodation of monitoring and sampling equipment,
6. Well-characterized and optimized hydraulics, and
7. High level of security.

Several proven and conceptual engineered buffer designs are shown on Figure 4-4. As shown, the buffer can be a standalone facility or incorporated into the transport and distribution system, depending on site-specific factors and needs.

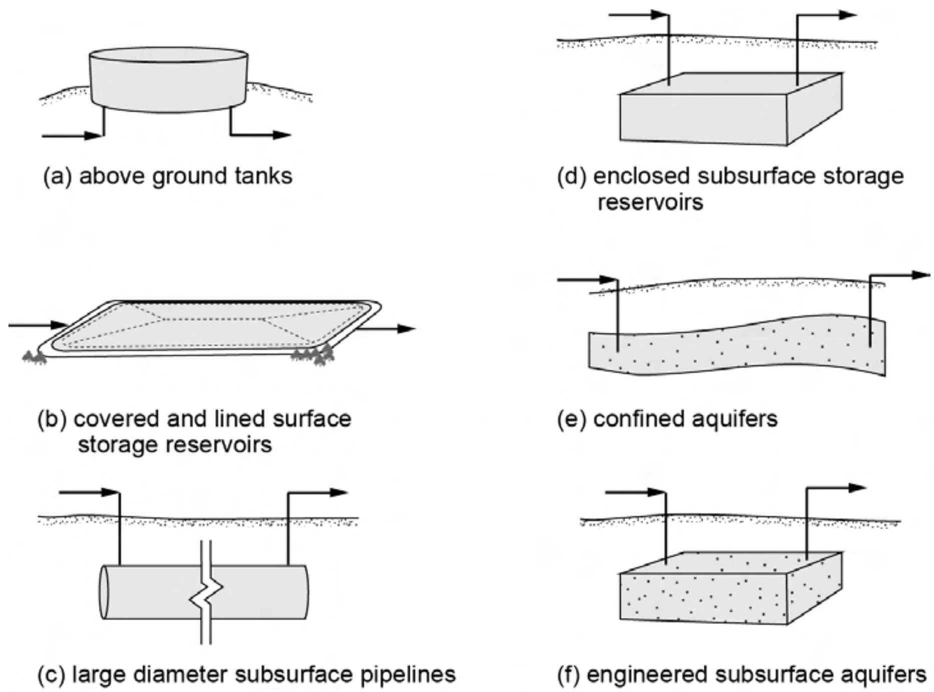

Figure 4-4
Proven and conceptual engineered buffer systems: (a) above ground tanks, (b) covered and lined surface storage reservoirs, (c) large diameter subsurface pipelines, (d) enclosed subsurface storage reservoirs, (e) confined aquifers, (f) engineered aquifers.

The specific design of the engineered storage buffer will be a function of several factors, including:

1. Site specific constraints,
2. Capabilities of the monitoring and constituent detection system,
3. Flow rate and degree of flow equalization required, and
4. Required safety factors.

In general, the storage requirements will be controlled by the time required for constituent analysis and overall reliability of the monitoring system. Purified water must be retained in the buffer for sufficient time to validate the quality of the water for specified constituents and surrogate measures prior to blending into a potable water system. Thus, there is a need to identify key monitoring parameters that can be evaluated expediently to verify system performance and product water quality. In the event that off-speculation product water is detected in the buffer, it would be necessary to divert the off-speculation batch to an alternate (pre-determined) discharge location or metered back into a specified point in the AWT treatment process.

A buffer storage system composed of several tanks may provide a higher level of control than using a larger single storage tank; however, this scheme may result in increased monitoring and process control costs. For example, in a system composed of four storage tanks with a monitoring system that requires 24 hours to validate water quality, one-quarter of the flow could be placed into one of the tanks and held until analytical results were available.

One implication of the engineered buffer concept is that, with some additional infrastructure, a system like that of OCWD's could blend the purified water directly with the area's water supply system, allowing for greater flexibility in system operation. For example, when there are periods of purified water production in excess of the immediate potable demand, purified water could be placed into the groundwater aquifer for long-term storage and travel to remote well locations.

4-3 MEASURES TO ENHANCE RELIABILITY

The conversion of existing wastewater treatment facilities for incorporation into potable reuse systems will require increased scrutiny and possibly upgrades to wastewater management infrastructure and related activities. In general, conventional wastewater treatment systems will need to be designed or modified to optimize their overall performance to enhance the reliability of the water purification system. Measures that can be taken to enhance the reliability of a DPR system include: enhanced source control, enhanced physical screening, upstream flow equalization, elimination of untreated return flows, switching mode of operation of biological treatment processes, improved performance monitoring systems, and the use of pilot test facilities for the ongoing evaluation of new technologies and process modifications.

Source Control

The control of substances that are not compatible with recycled water systems is an important aspect of water reuse projects. Some wastewater constituents, including a variety of radionuclides, industrial chemicals, pesticides, pharmaceuticals, and compounds found in consumer products have been found to pass through conventional wastewater treatment systems with little or no removal. The presence of these substances in recycled water, typically in trace amounts, will continue to be a significant factor in public and regulatory acceptance. These constituents also limit the applicability of recycled water or require a significant investment to remove during treatment. In addition, where surface waters are used as a discharge location for treated wastewater, there is potential for detrimental ecological impacts. In its 2008 draft groundwater recharge regulations, the CDPH included a number of specific requirements for enhanced source control programs, including tools to identify and rapidly address contaminants of concern and outreach programs to manage and minimize the discharge of contaminants of concern at the source.

Agencies that administer source control programs for DPR should ensure that they have regulatory authority and management actions under their wastewater ordinances to address constituents of concern. These program elements include: outreach, focused inspection, monitoring, permitting, enforcement programs, imposition of industry-specific treatment or best management practices, diversion of waste, and onsite pretreatment systems that limit the discharge of difficult to treat constituents.

Enhanced Fine Screening

The benefits of enhanced screening include (1) removal of constituents that can impede treatment performance (e.g., solid phase oils and grease, rags, plastic materials, etc.) and (2) alteration of the wastewater particle size distribution, which enhances the kinetics of biological treatment. For example, to enhance the performance of membrane bioreactors, the influent wastewater must first be screened with an 800 μm screen. Similar requirements should be used for conventional activated sludge processes, and, especially, those used in water recycling treatment trains.

Elimination of Untreated Return Flows

Currently, return flows from sludge thickeners, sludge dewatering (e.g., centrifuges and belt presses), sludge stabilization (e.g., digester supernatant), and sludge drying facilities are returned to the wastewater treatment plant headworks for reprocessing. In many instances these return flows contain constituents that deteriorate overall plant performance (e.g., nitrogenous compounds, colloidal material and total dissolved solids). The presence of nitrogenous compounds in return flows often impacts the ability of the biological treatment process to achieve low levels of nitrogen, which, in turn, affects the performance of microfiltration membranes. Separate systems for the treatment of return flows are now being installed at a number of treatment plants that need to meet more stringent discharge requirements. In biological treatment plants to be used in conjunction with advanced treatment facilities for DPR, return flows should be processed separately.

Flow Equalization

Flow equalization is a method used to improve the performance and variability of the downstream treatment processes and to reduce the size and cost of treatment facilities. Flow equalization can occur in the secondary treatment process as illustrated on Figure 4-5 or preceding advanced treatment as illustrated previously on Figure 4-2. The principal benefits for biological wastewater treatment systems from flow equalization include: (1) enhanced biological treatment, because shock loadings are eliminated or can be minimized, spikes or high concentrations of inhibiting substances can be diluted, and pH can be stabilized; (2) reduced process variability, (3) enhanced removal of trace constituents, (4) improved performance of secondary sedimentation tanks following biological treatment through improved consistency in solids loading; (5) reduced surface area requirements for effluent filtration, improved filter performance, and more uniform filter-backwash cycles are possible by lower

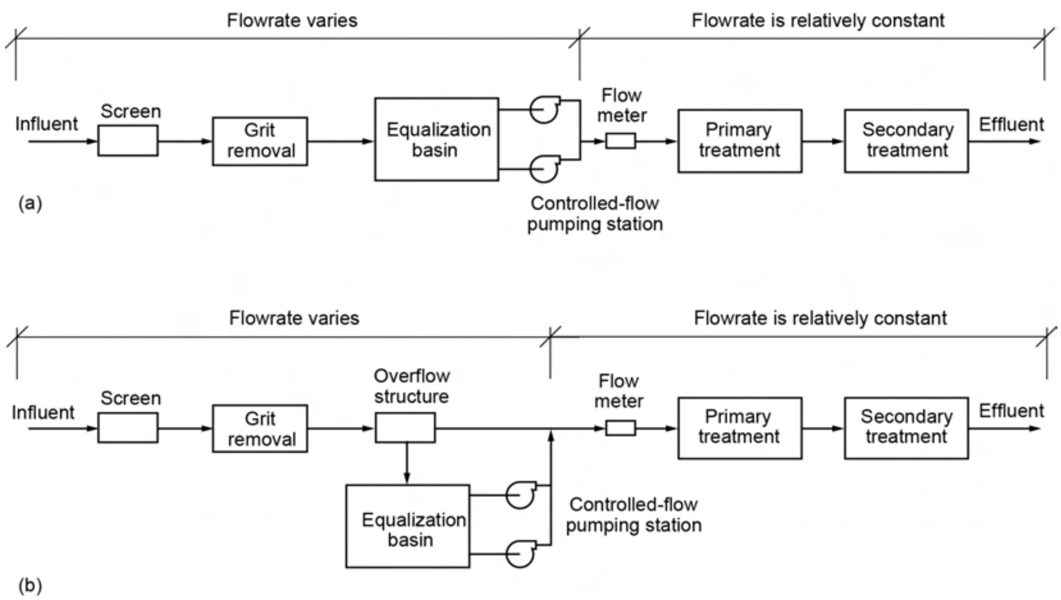

Figure 4-5

Typical wastewater-treatment plant flow diagram incorporating flow equalization: (a) in-line equalization and (b) off-line equalization. (Adapted from Tchobanoglous et al., 2003).

hydraulic loading; (6) improved operation and reliability of disinfection systems; and (7) in chemical treatment, damping of mass loading improves chemical feed control and process reliability (Tchobanoglous et al., 2003). In advanced wastewater treatment, the principal benefits include: (1) reduced variability of incoming water quality; (2) enhanced performance at constant flow operation; and (3) reduced wear and tear on membranes caused by fluctuating flows and loads.

Operational Mode for Biological Treatment

To enhance the performance of advanced treatment facilities employing membranes and reverse osmosis, the biological treatment process should be operated in a nitrification or nitrification/denitrification mode. It has been observed that the performance of microfiltration membranes is enhanced significantly when wastewater has been treated in an activated sludge process operated such that nitrogen in the form of ammonia is nitrified (oxidized). In fact, it is well established operationally that for a membrane bioreactor to function properly the activated sludge process must be operated to nitrify completely. If the activated sludge process does not nitrify completely, biological clogging of the membranes can occur resulting in decreased performance and increased operational costs. Because there is a potential to form disinfection byproducts and N-nitrosodimethylamine (NDMA) when the activated sludge process is operated in either the nitrification or nitrification/denitrification mode, the process must be monitored and controlled properly.

Improved Performance Monitoring

The food processing industry has, over the years, applied a variety of techniques including the Pareto principle, preservation and control measures, and statistical quality control charts to assure the safety of food products. In 1971, the hazard analysis critical control point (HACCP) concept was introduced to the public, food industry, and regulators. As presented in 1971, the HACCP concept was based on the following three principles, derived from work done in the late 1950s and early 1960s by the Pillsbury Company in collaboration with NASA and the U.S. Army Natick Laboratories to develop food for the space program (WHO, 1997; Charisis, 2004):

1. Assessment of hazards associated with growing, harvesting processing and manufacturing, distribution, marketing, preparation, and/or use of a given raw material or food product.
2. Determination of critical control points required to control any identified hazards.
3. Establishment of procedures to monitor critical control points.

The HACCP method, as it is known today, was published in 1992 and has evolved significantly from the initial form and now involves the following steps:

1. Conduct a hazard analysis,
2. Identify critical control points,
3. Establish preventive measures with critical limits,
4. Establish procedures to monitor critical control points,
5. Establish corrective actions,
6. Establish verification procedures, and
7. Establish record keeping procedures.

Over the past 40 years, the HACCP method and other similar programs have been applied to a number of industries. The use of HACCP is becoming more common in the environmental field (NRMMC et al., 2006). A report delineating the application of the HACCP method for distribution system monitoring was prepared for the U.S. EPA in 2006 (U.S. EPA, 2006). In 2009, the WateReuse Research Foundation funded a project *Utilization of HACCP Approach for Evaluating Integrity of Treatment Barriers for Reuse* (WRF-09-03) to develop an approach for monitoring and managing microbial water quality in reclaimed water, based on the HACCP method. The use of performance evaluation techniques such as HACCP should be a critical element of any ongoing performance monitoring and control program, especially when the wastewater treatment facility is producing water for advance treatment for DPR.

Ongoing Pilot Testing

Because of the rapid development of new technologies for water purification and the limited data available to benchmark these new technologies, it is recommended that permanent pilot scale test facilities be incorporated into the design of advanced treatment processes for DPR. In addition to the evaluation and validation of new technologies and proposed process modifications, the pilot facilities can be used to investigate operational and reliability issues that arise from time to time in the operation of full scale facilities. Considerations in setting up a pilot-plant test program include: (1) a clear understanding of the reason for conducting the pilot-plant tests (e.g., prediction of process performance and reliability), (2) the scale of the pilot plant that is required to establish performance and reliability data, (3) physical design factors, (4) design of the pilot testing program, and (5) nonphysical features such the degree of innovation involved, process complexity, and materials of construction.

4-4 MONITORING AND CONSTITUENT DETECTION

While there have been a number of recent improvements in online monitoring and constituent detection, it is not, at present, feasible to provide real-time monitoring of all constituents of concern. However, the identification of surrogate and indicator constituents that can be used to assess performance reliability of key unit processes can be used in place of direct measurements for all constituents of interest.

Types of Monitoring

The two basic types of monitoring systems that are applied are real-time and off-line. Real time measurements are used for the constant acquisition of water quality data or other process parameters and are used extensively in tracking the performance and operation of individual unit processes. For example, membrane processes may include real-time monitoring of pressure, particle size, TDS, ultraviolet absorbance (UVA), and/or TOC to assure membrane integrity. Off-line measurements are conducted in a laboratory to verify the measurements made by real-time monitoring equipment and for the detailed characterization of individual constituents such as NDMA and 1,4-dioxane, and for different classes of constituents.

Monitoring Strategies

An Indicator compound is an individual constituent that represents certain physiochemical and biodegradable characteristics of a family of constituents of concern that are relevant to fate and transport during treatment. Therefore, indicators can be used to predict the presence or absence of other constituents provided that the indicator is removed by similar mechanisms and to the same degree as the other constituents. A surrogate compound is a bulk parameter that can serve as a measure of performance for individual unit processes or operations. Some surrogate parameters that are measured continuously, such as UVA, conductivity, and TOC, can be correlated with the removal of individual or groups of constituents. The use of indicators and surrogates is somewhat site specific and will need to be established for individual treatment operations (Drewes et al., 2010). However, after these parameters are established they can be used to enhance the monitoring program through rapid detection programs. The ability to detect constituents of concern rapidly will reduce the overall size of the engineered buffer facilities that are used for quality assurance.

Monitoring Locations

Monitoring at specific locations is used: (1) to assess process performance and reliability, (2) for process control, and (3) to verify compliance with public health or other regulatory requirements. Suggested monitoring locations are illustrated on Figure 4-6 and are summarized in Table 4-1.

Monitoring at the Engineered Buffer

As described previously, the engineered storage buffer is a key monitoring location because it may be the final safeguard prior to distribution in the potable water system. Thus, the development of the monitoring program needs to be planned carefully to ensure that all constituents of importance can be assessed in the product water with sufficient speed and accuracy to justify the size and design of the buffer facilities. It is at this point that off-speculation water would be diverted to an alternate location, such as the wastewater treatment facility or a specified point in the purification process.

4-5 FUTURE DEVELOPMENTS IN DPR

An important element for developing future DPR projects is defining what constitutes an acceptable treatment process train and identifying the corresponding knowledge gaps that would provide a basis for CDPH to develop implementation and approval criteria. For purposes of this discussion only, it is assumed that any advanced treatment process train should be equipped with

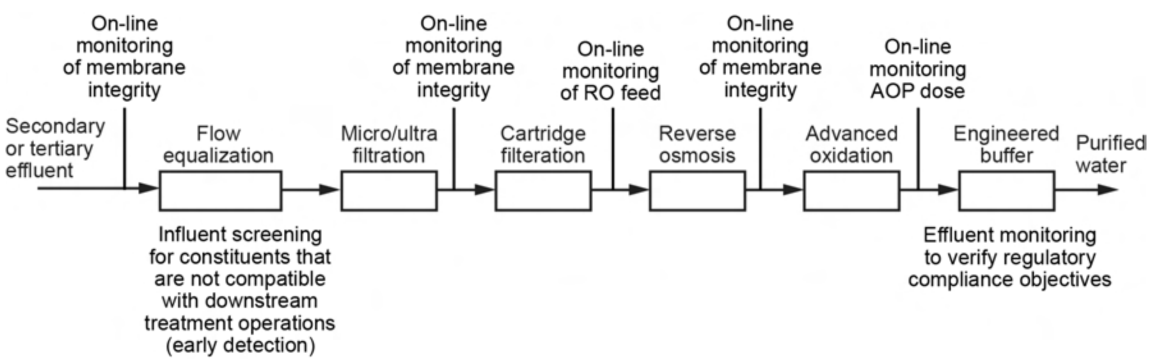

Figure 4-6

Representative sampling locations DPR treatment process flow diagram

flow equalization and monitoring of the influent to the advanced process as well as development of an engineered buffer and monitoring system for the advanced treatment-treated effluent. It is also reasonable to expect that as further advancements take place in the development of future treatment technologies and monitoring capabilities, the size of the engineered buffer can be reduced or the buffer could be eliminated. Thus, there is a need to maintain flexibility in the development of DPR regulations to accommodate the inevitable technology breakthroughs that will take place in the future. Examples of future developments are illustrated on Figure 4-7 and discussed below.

Table 4-1

Summary of monitoring locations in DPR systems

Monitoring location	Description
	Process control
Influent	• Influent monitoring can provide data on constituents of concern that can be used to reject flow from the process or make process modifications that will facilitate constituent removal. • It is recommended that all advanced treatment operations incorporate on-line flow equalization facilities to facilitate flow compositing and retention while monitoring activities are conducted.
	Process performance and reliability
Individual processes	• Critical treatment operations can be monitored to ensure that the desired level of performance is being achieved on a continuous basis. For example, data on the rejection of TDS or TOC in a reverse osmosis system can be used to ensure that the process is meeting performance expectations and, when there is a reduction in performance, appropriate operation and maintenance activities can be implemented to maintain quality standards.
	Water quality assurance and compliance
Effluent	• Due to limitations associated with real-time monitoring systems, it is necessary to provide flow retention of the purified water to assure that the water quality has met all applicable standards prior to discharge to a potable water system. • The primary purpose of an engineered storage buffer is to retain purified water for sufficient time so that required analytical procedures needed for quality assurance can be completed and verified.

New Wastewater Treatment Processes

With the range of research currently being conducted, it is reasonable to assume new and improved biological wastewater treatment processes will be developed. In the future, it is conceivable that the activated sludge treatment process might be replaced by a series of membrane processes (see Figure 4-7a).

Blending with Natural Waters

Depending on the circumstances, it may be appropriate to blend purified water with natural water before treatment by advanced water treatment facilities employing ultrafiltration and UV disinfection (see Figure 4-7b). The flow diagram for the Cloudcroft, NM, DPR system, as described in Section 3-5 in Chapter 3, employs this type of arrangement.

New Advanced Treatment Technology

As noted previously, in locations where the cost and logistical issues associated with the management of brines from reverse osmosis systems are overwhelming, a variety of new advanced treatment processes are currently under development for the oxidation of trace organics, without the removal of dissolved solids (see Figure 4-7c). It is likely that enhanced biological treatment processes will be developed to complement new types of advanced treatment technologies.

Redundant Reverse Osmosis

The process flow diagram shown on Figure 4-7d, which incorporates redundant reverse osmosis processes, is presented to demonstrate that essentially any level of reliability can be achieved with commercially available technology. With a redundant treatment step and improved monitoring it may be possible to eliminate the need for the engineered buffer.

4-6 SUMMARY OF ISSUES FOR IMPLEMENTATION OF DPR

Based on the material presented in this chapter, a number of issues can be identified that must be resolved and/or considered before DPR can become a reality. The principal issues are summarized in Table 4-2. In reviewing the various issues, it is clear that a number of them are interrelated. For example, as noted previously, *the design and integration associated with the engineered buffer system is a key research area required for the development of DPR projects.* More specifically, the sizing of an engineered buffer, which could be built today, is directly related to the response times for the monitoring results to become available. With improved on-line monitoring equipment and methods, the capacity of the engineered storage buffer could be reduced significantly or even eliminated.

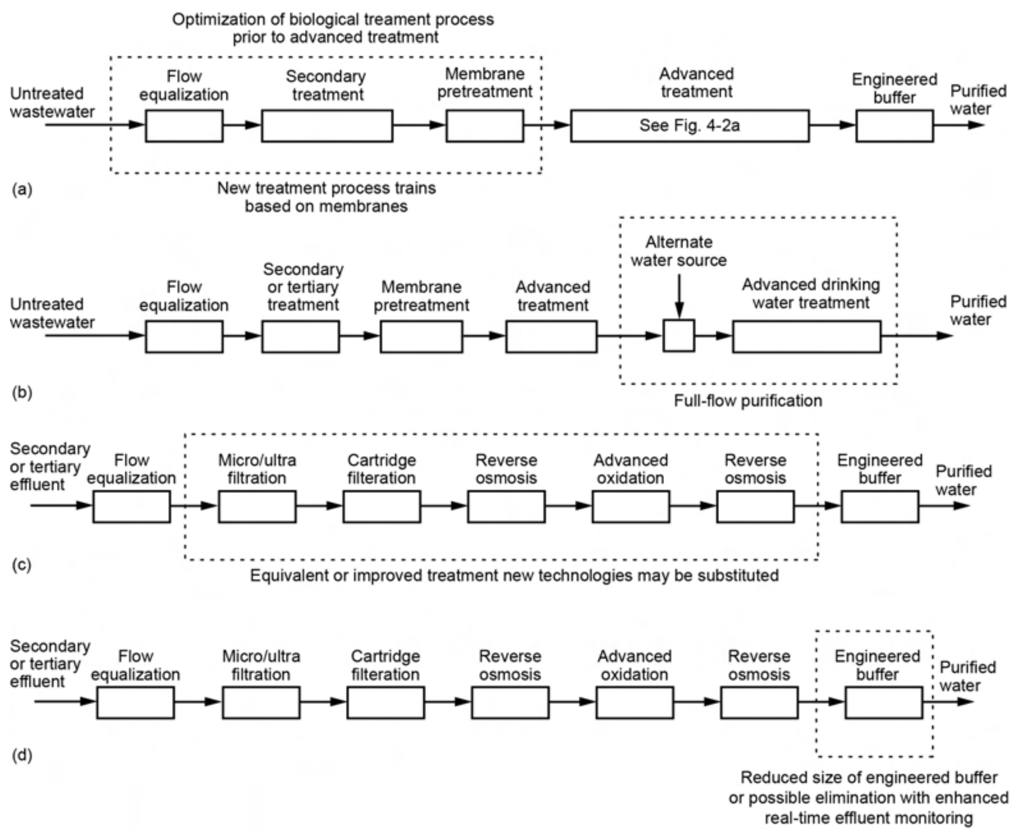

Figure 4-7
Potential potable reuse treatment scenarios: (a) new biological treatment process, (b) blending with natural waters, (c) new advanced wastewater treatment technology, and (d) redundant barrier employing reverse osmosis.

Table 4-2
Technical issues in the implementation of direct potable reuse

Consideration	Comments / questions
Source control	• Identification of constituents that may be difficult to remove (depends on technologies used). • Development of baseline sources and concentrations of selected constituents. • Define the improvements that need to be made to existing source control programs where DPR is to be implemented
Influent monitoring	• Development of influent monitoring systems, including constituents, parameters, and monitoring recommendations. • Investigate potential benefits of various influent monitoring schemes that may be used for early detection of constituents. • Consideration of how influent monitoring data could be used to adapt treatment operations depending on variable influent characteristics.
Flow equalization	• Determination of the optimum location and type (in- or off-line) in secondary treatment process with respect to enhanced reliability and removal of trace constituents. • Determination of optimum size of flow equalization before advanced treatment. • Quantify the benefits of flow equalization on the performance and reliability of biological and other pretreatment processes
Wastewater treatment	• Quantify benefits of optimizing conventional (primary, secondary, and tertiary) processes to improve overall reliability of entire system. • Quantify the benefits of complete nitrification or nitrification and denitrification on the performance of membrane systems used for DPR applications
Performance monitoring	• Determine monitoring schemes to document reliability of treatment performance for each unit process and validate end-of-process water quality.
Analytical/monitoring requirements	• Selection of constituents and parameters that will require monitoring, including analytical methods, detection limits, quality assurance/quality control methods, and frequency. • Determination of how monitoring systems should be designed in relation to process design. • Development of appropriate monitoring systems for use with alternative buffer designs.
Advance wastewater treatment (water purification)	• Develop baseline data for treatment processes employing reverse osmosis. OCWD can be used as a benchmark. • Development of alternative treatment schemes with and without demineralization that can be used for water purification. • Quantify benefit of second stage (redundant) reverse osmosis.

Continued on following page

Table 4-2 Continued

Consideration	Comments / questions
Engineered storage buffer	• Development of sizing guidelines based principally on existing analytical, detection, and monitoring capabilities to assess technical and economic feasibility of utilizing engineered storage buffer. • Characterize the impact of existing monitoring response times on the safety and economic feasibility of implementing an engineered storage buffer.
Balancing mineral content	• Development of recommendations for balancing water supply mineral content in consideration of site-specific factors, such as magnesium and calcium. • Determination of potential impacts of various water chemistries on infrastructure and public acceptance. • Development of specifications for chemicals used for balancing water quality.
Blending	• Development of guidance on what level of blending, if any, is required based on the quality of the purified water and alternative water sources. • Investigation of the significance of and rationale for blend ratios in terms of engineered buffer, protection of public health, public acceptance, and regulatory acceptance. • Investigation of potential impacts of purified water on drinking water distribution system, e.g., corrosion issues, water quality impacts, etc.
Emergency facilities	• Stand-by power systems in the event of power loss or other emergency. • Availability of all replacement parts and components that would be required in the event of a process breakdown. • Process redundancy so that treatment trains can be taken off-line for maintenance. • Facilities for the by-pass or discharge of off-speculation water in the event that the water does not meet the established quality requirements.
Pilot testing	• Utilization of a review panel for advice and recommendations on the design, operation, monitoring plan for a project's pilot system to ensure that it will be representative of the proposed full-scale system. • Development of monitoring protocol for collection of baseline data for "raw" water input to AWT pilot plant; how much testing and for what duration (e.g., 6 mo. to 1 yr.). • Development of pilot study design so that results can be used to assess reliability with proposed source water.

5
PUBLIC ACCEPTANCE ISSUES IN DIRECT POTABLE REUSE

The purpose of this chapter is to review past and current knowledge on public acceptance of DPR. This review is based on information available from ongoing or planned DPR projects, the 2009 WRRF Research Needs Workshop (WRRF, 2009), the white paper by Nellor and Millan (2010), and the report on the 2010 Direct Potable Reuse Workshop (CUWA et al., 2010). Research needs in public acceptance issues that must be addressed if DPR is to be a viable water supply option are given in Sections 6-6 through 6-8 in the following chapter.

5-1 PUBLIC PERCEPTION OF DPR PROJECTS

Background information on the Windhoek, Cloudcroft, and Big Springs DPR projects was provided in Chapter 3. A combination of factors has made DPR a viable option for each of these communities, with the lack of alternative water supply sources being the most notable. Other important factors in the development of these DPR projects include availability of advanced water treatment technologies, monitoring, improved water quality, emergency shutdown capabilities, and public outreach/acceptance.

For the two projects being implemented in the U.S., DPR was accepted without dispute. Outreach for Cloudcroft included public meetings, involvement with wastewater master planning and implementation, Village Council meetings, and ensuring that business leaders understood the need for the project, with the result that there was broad support for the project (Livingston, 2008). Outreach for Big Springs included public meetings, radio interviews with call-in, newspaper articles, and use of the internet to highlight water scarcity and the need for improved water quality and to describe the proposed reclamation concept (Sloan et at., 2010). The public outreach effort in Big Springs is ongoing. To date, public reaction to the Big Springs DPR project has been generally positive or at least neutral.

The role of unplanned, or *de facto*, potable reuse in the context of planned potable reuse was discussed in Chapter 4. Often, communities considering potable reuse are unaware of the role of unplanned reuse in their overall water supply. The purpose of WateReuse Research Foundation Project "*Effect of Prior Knowledge of 'Unplanned' Potable Reuse on the Acceptance of 'Planned' Potable Reuse*" (WRF-09-01) is to evaluate how acceptance of planned potable reuse changes when people are informed about the long history and everyday reality of unplanned potable reuse. The project, to be completed in 2012, is designed to address both IPR and DPR, thereby providing insight into the relationship between public acceptance with or without an environmental buffer.

5-2 CHALLENGES FOR DIRECT POTABLE REUSE

A number of challenges related to public perception and acceptance of DPR in California have been identified based on (1) a review of prior studies regarding public opinion and strategies about potable reuse; (2) what has been learned from successful and unsuccessful IPR projects; (3) what has been learned about communicating with the public regarding constituents of emerging concern (CEC) such as pharmaceuticals, personal care products, and endocrine disrupting chemicals; and (4) recommendations from experts with experience on planning and implementing IPR projects (Nellor and Millan, 2010). One of the primary conclusions of the review was that DPR is expected to face the same public acceptance challenges faced by IPR. Contingent on CDPH approving regulations that would allow DPR, the following four challenges should be addressed prior to seeking public support for DPR:

1. The water reuse community must itself support DPR before seeking public acceptance. At the present time, support within the California water reuse community is not universal, which will confound efforts to request public support.

2. A standard public involvement program should be developed for potable reuse that builds on lessons learned from IPR projects, research regarding CEC risk communications, and current efforts on how to communicate about water, including terminology and messages. This challenge will be aided by WRF-07-03 (“Talking about Water – Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination”) that is (1) assessing the influence of words, images and concepts on the public perception of recycled water; (2) identifying preferred terminology; and (3) determining if improved knowledge and understanding of the water cycle, water science, and technology improves acceptance. This study is scheduled to be completed in June 2011.
3. Public outreach/participation tools should be developed to provide a complete picture of the water cycle, including the ubiquitous presence of CECs and their relative risk. Agreement must be reached among the water reuse community about how to explain the water cycle and the role of water reuse, and to communicate effectively about perceived risks. As discussed in Chapter 3, while advanced water treatment technologies can remove constituents of concern to low and what are believed to be insignificant levels with regard to human health, the public and regulators still consider CECs to be an issue that must be addressed for DPR, particularly in terms of relative risk.
4. California will need to develop regulations for DPR before projects can move forward and be embraced by the public. Even if technology can be proven safe, technology in the absence of regulatory oversight and controls can catalyze mistrust and fear, even though purified water is known to be safe.

5-3 IMPLEMENTATION STRATEGIES FOR DIRECT REUSE

Participants at the 2010 Direct Reuse Workshop identified five tasks as the highest priorities in addressing public acceptance issues related to implementing DPR in California as shown in Table 5-1.

Table 5-1
Public acceptance issues in the implementation of direct potable reuse

Issue	Description	Possible Resources[a]
Develop appropriate terminology	• Develop water recycling terminology that is understandable by stakeholders and consistent with regulations to instill credibility and product confidence. • Examples where resolution of key terms is needed include product water, non-potable reuse, and direct versus indirect potable reuse.	• WRF-07-03 ("Talking about Water – Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination")
Survey stakeholders	• Identify stakeholders. • Determine purpose of surveys. For example how the public differentiates between DPR and IPR; the role of natural treatment and environmental buffers in public acceptance; opposition to DPR; why the public accepts DPR. • Develop survey questions.	• WRF-09-01 ("Effect of Prior Knowledge of 'Unplanned' Potable Reuse on the Acceptance of 'Planned' Potable Reuse")
Develop messages	• Use agreed upon terminology and information obtained from stakeholder surveys. • Identify audience (should include supporters, opponents, water reuse community, water community). • Identify key objectives and contents of messages.	• Hawley et al., 2008 • WRF-09-07 ("Risk Assessment Study of PPCPs in Recycled Water to Support Public Acceptance")
Develop a communications strategy	• Determine when to initiate outreach so that efforts are proactive and consider all supply alternatives. • Incorporate experience learned from successful and unsuccessful potable reuse projects and other critical factors. • Identify the types of information and methods of communication that will be most useful. • Identify strategies for community leaders/decision makers and the press. • Identify strategies to work with opponents.	• WRF-01-004: An interactive website to help community's plan and introduce potable reuse projects
Implement the communications strategy	• Use the information developed by the prior tasks.	

[a] *Descriptions for WateReuse Research Foundation projects are available at: http://www.watereuse.org/sites/default/files/u8/Total_Project%20List101910.pdf.*

6
RESEARCH NEEDS IN DIRECT POTABLE REUSE

Issues that must be considered in the implementation of DPR were identified previously in Table 4-2 and Table 5-1. From the list of issues identified in Tables 4-2 and 5-1, eight have been selected as being the most critical with respect to the development of guidance for evaluating and, if appropriate, implementing DPR. Five of the eight proposals are technology based and three are related to public acceptance. For these eight, draft research proposals have been prepared and are presented below. It is anticipated that if these proposals are developed into full RFPs, they would be modified and expanded consistent with the research program of the WateReuse Research Foundation and/or other funding organizations. The specific research topics are:

1. Sizing of engineered storage buffer,
2. Treatment train reliability,
3. Blending requirements,
4. Enhanced monitoring techniques and methods,
5. Equivalent advanced treatment trains,
6. Communication resources for DPR,
7. Acceptance of direct potable reuse, and
8. Acceptance of potable reuse.

6-1 RESEARCH TOPIC: SIZING OF ENGINEERED STORAGE BUFFER

Full Title

Design Considerations for Sizing Engineered Storage Buffers

Rationale

The availability of an engineered storage buffer is a key element in direct potable reuse, using current treatment and monitoring techniques. The engineered buffer is designed to provide a final monitoring point where the water quality can be validated for potable reuse before being introduced either directly into the potable water supply distribution system downstream of a water treatment plant. The engineered storage buffer must be of sufficient capacity to allow for the measurement of specific constituents to be assured that the quality of water provided meets all applicable public health standards. An engineered storage buffer may not be needed where the purified water is blended with the raw water supply immediately upstream of a water treatment plant. Engineered buffers can be placed at any point in the water purification process, but are essential prior to introduction into the potable water distribution system, based on current technology. In the future, with enhanced treatment reliability measures and monitoring techniques, an engineered storage buffer may not be necessary.

Objectives

The specific objectives of this proposed research project are to:

1. Develop procedure and guidance for the design of engineered storage buffers based on current treatment performance, reliability, analytical, detection, and monitoring capabilities.
2. Develop operational strategies for managing off-speculation product water.
3. Define the impact of monitoring response times for selected constituents on the economic feasibility of implementing an engineered buffer.
4. Evaluate the design of monitoring systems that can be used to minimize the size of the engineered storage buffer.

Benefits

The engineered storage buffer is the final remaining piece of infrastructure needed in the development of direct potable reuse systems using current treatment and monitoring techniques. Reducing the volumetric capacity of the storage buffer to a reasonable size will allow for the recycling of large amounts of water, both in locations that do not have either suitable groundwater aquifers or surface storage reservoirs of sufficient capacity to comply with existing retention time requirements, and when DPR has been determined to be the most technically and economically viable option.

6-2 RESEARCH TOPIC: TREATMENT TRAIN RELIABILITY

Full Title

Impacts of Treatment Train and Process Operation Modifications to Enhance the Performance and Reliability of Secondary, Tertiary, and Advanced Treatment Systems

Rationale

Enhanced screening, flow equalization, the elimination of untreated return flows, and switching from conventional to nitrification/denitrification mode of operation of the activated sludge process are process modifications that can be used to improve the performance and variability of the downstream biological treatment processes and to reduce the size and cost of treatment facilities.

Objectives

The specific objectives of this proposed research project are to:

1. Assess the benefits of improved screening of raw wastewater on biological treatment reliability and performance.
2. Determine the optimum location and type (in-line or off-line) of flow equalization with respect to performance and reliability of biological treatment processes.
3. Determine the impact of flow equalization on the biological removal of trace constituents.
4. Determine the impact of switching from conventional to NDN mode of operation of the activated sludge process on the removal of trace constituents.
5. Assess the impact on process variability and reliability of eliminating the return of untreated return flows, especially on nitrification and denitrification.
6. Determine the optimum size of flow equalization before advanced treatment if influent flow equalization is not used.

Benefits

Although each of the interventions cited above will have benefits, the impact of flow equalization and the removal of untreated return flows is perhaps the greatest. The principal benefits of flow equalization and the removal of untreated return flows for biological wastewater treatment systems include: (1) enhanced biological treatment, because shock loadings are eliminated or can be minimized, inhibiting substances can be diluted, and pH can be stabilized; (2) reduced process variability, (3) enhanced removal of trace constituents, (4) improved performance of secondary sedimentation tanks following biological treatment through improved consistency in solids loading; (5) reduced surface area requirements for effluent filtration, improved filter performance, and more uniform filter-backwash cycles are possible by lower hydraulic loading; and (6) in chemical treatment, damping of mass loading improves chemical feed control and process reliability. In advanced wastewater treatment, the principal benefits include: (1) reduction or elimination of shock loading, (2) enhanced performance at constant flow operation, and (3) reduced wear and tear on membranes caused by fluctuating flows and loads.

6-3 RESEARCH TOPIC: BLENDING REQUIREMENTS

Full Title

Evaluation of Blending Requirements for Purified Water.

Rationale

The amount of blending with other water supply sources will depend on a number of site specific factors, including the availability of alternative water supply sources, regulatory requirements, and public acceptance. Blending, like the use of an environmental buffer, facilitates a loss of identity for the product water and, therefore, may diminish some public opposition. However, it is important to note that blending with alternative water supply sources should not be considered to be necessary for water quality improvement as it is assumed that the recycled water will be of the highest quality and the alternative source water may be subject to contamination if derived from environmental sources. Depending on the circumstances, it may be appropriate to blend tertiary effluent with natural water before treatment by advanced water treatment facilities employing reverse osmosis and advance oxidation.

Objectives

The specific objectives of this proposed research project are to:

1. Develop guidance on what level of blending, if any, is required based on purified water quality and different water sources.
2. Assess various blend ratios and rationale for high blend rates.
3. Assess potential impacts of purified water on drinking water distribution systems (e.g., corrosion issues).
4. Develop recommendations for balancing water supply mineral content in consideration of site-specific factors, such seasonal water quality changes in alternative water supply sources.
5. Determine potential impacts of various water chemistries on infrastructure and public acceptance.
6. Develop specification for chemicals used for balancing water quality.

Benefits

The principal benefits of this research are to define the criteria and requirements for blending reverse osmosis purified water with other water supply sources of varying water quality in DPR applications to meet specific water quality objectives.

6-4 RESEARCH TOPIC: ENHANCED MONITORING TECHNIQUES AND METHODS

Full Title

Enhanced Monitoring Techniques and Methods for Direct Potable Reuse

Rationale

As described previously, the engineered storage buffer is a key monitoring location because it may be the final barrier prior to distribution in the potable water system. Thus, the development of the monitoring program needs to be planned carefully to ensure that all constituents of importance can be assessed in the product water with sufficient speed and accuracy to justify the size and design of the buffer facilities. It is at this point that off-speculation water could be diverted to an alternate location, such as the wastewater treatment facility, a specified point in the purification process, or to a site where the water could be used for a nonpotable application.

Objectives

The specific objectives of this proposed research project are to:

1. Determine constituents and parameters that will require monitoring, including analytical methods, time to obtain results, reliability of method, detection limits, and frequency.
2. Determine how monitoring systems should be designed in relation to process design.
3. Develop appropriate monitoring system for use with alternative buffer designs.
4. Evaluate monitoring techniques and surrogate parameters used in other industries utilizing high purity water for use in DPR applications.
5. Pilot test selected monitoring techniques for DPR applications, if appropriate.

Benefits

The principal benefit would be to allow the design of engineered buffers of reasonable size to facilitate the reuse of significant amounts of water now discharged to the ocean (or elsewhere). Discharge of water to the ocean will become of greater concern as it is anticipated that 80% of the world's population will live within 200 km (124 mi) of a coastal area by 2025.

6-5 RESEARCH TOPIC: EQUIVALENT ADVANCED TREATMENT TRAINS

Full Title

Equivalency of Advanced Wastewater Treatment Trains and Processes for Direct Potable Reuse

Rationale

As noted previously, in locations where the cost and logistical issues associated with the management of brines from reverse osmosis systems are overwhelming, a variety of new advanced treatment processes are currently under development for the oxidation of trace organics and selective demineralization. It is likely that enhanced biological treatment processes will be developed to complement new types of advanced wastewater treatment technologies.

Objectives

The specific objectives of this proposed research project are to:

1. Develop baseline data and criteria for treatment processes employing reverse osmosis (e.g., OCWD can be used as a benchmark).
2. Develop alternative treatment schemes, with and without demineralization, that can be used for the production of purified water for DPR.
3. Evaluate alternative treatment trains with respect to constituent removal, economics, process residuals, reliability, and long-term sustainability.

Benefits

The development of equivalency criteria will make it possible to apply a variety of alternative treatment technologies, currently available and/or under development, for DPR. The availability of non-reverse osmosis processes for advanced treatment will be of great benefit to inland communities seeking to implement DPR.

6-6 RESEARCH TOPIC: COMMUNICATION RESOURCES FOR DPR

Full Title

Develop Standard Terminology, Messaging, and Communication Materials for Planning and Implementation of DPR

Rationale

Implementation of DPR at the statewide level requires discussion and buy-in from policy makers, legislators, regulators, and the public. Prior to engaging in this dialog, it will be necessary to develop standardized terminology, and effective messaging and communication materials that can be used in discussions regarding DPR and its role as part of the California water supply. Standardized terminology is needed because, at present, different agencies tend to use different terms when describing the same concept related to water reuse, and, especially, with respect to DPR and IPR. Based on public opinion studies, the use of appropriate terminology and clear communication (e.g., messaging) are of fundamental importance with regard to public acceptance of potable reuse. Based on preliminary results from WRF 07-03, it has been found that the greatest change in public opinion, that occurred with clear knowledge and understanding about water quality, was the acceptance of DPR. Regrettably, water industry communications are full of technical jargon and fail to put water use and reuse in perspective. This failure in communication creates a situation where it is easy to confuse the public about what is being communicated and it is also easy to stigmatize water's quality by the history of where it once was rather than the fact that it is safe to drink.

Objectives

1. Develop standardized terminology for water reuse including DPR and IPR that is understandable by stakeholders and consistent with regulations to instill credibility and product confidence.
2. Use the outcome of the terminology and public perception research to develop the effective messaging and communications materials for different stakeholders.
3. The communication materials should also include information that can be used to develop functional outreach materials.
4. To ensure that the information developed is pertinent for use in California and takes into consideration how Californians prefer to receive information, focus group testing or surveys may be needed
5. Conduct workshops with the California water industry to ensure cooperative use of the material developed.

Benefits

Development of standardized terminology and effective communication materials will enable communities in California to understand the concept of DPR. The information developed in this project will also be vital for outreach and policy decisions regarding DPR. This project would build on the results of WRF-07-03, "*Talking about Water: Words and Images that Can Enhance Public Acceptance of Water Recycling and Desalination*", and WRF-09-01, "*Effect of Prior*

Knowledge of 'Unplanned' Potable Reuse on the Acceptance of 'Planned' Potable Reuse."

6-7 RESEARCH TOPIC: ACCEPTANCE OF DIRECT POTABLE REUSE

Full Title

California Direct Potable Reuse Summit

Rationale

Currently there is disagreement within the California water community (water and wastewater) about pursuing DPR based on (1) skepticism that DPR is a viable option, (2) concern about potential negative backlashes on ongoing IPR projects, (3) concern that this effort will direct funds away from non-potable reuse projects, and (4) a belief that it's not safe to directly drink recycled water with or without an engineered storage buffer. The summit will build on discussions held at the 2010 Direct Potable Reuse Workshop, but will be directed specifically at "policy grounding" and to consolidate and/or clarify the water industry's positions regarding DPR.

Objectives

1. Bring together California water professionals for facilitated policy level discussions regarding areas where there may be agreement or disagreement regarding the value or need for DPR as a part of the state's water supply portfolio. This activity is envisioned as a 1 to 2 day meeting with about 20 participants and a facilitator.
2. Participants will be invited that have different perspectives about the value and viability of DPR in California, including California water industry professionals, advisors to politicians and water industry professions, public health regulators, and elected officials that serve on water agency boards.
3. Develop a position statement on DPR in California.
4. Establish a framework for revisiting the position statement over time.

Benefits

This effort is important as it will be unlikely that the public will support a concept that is not supported (or at least not opposed) by the water community. It can also aid in the formation of alliances and the identification of potential sources of funding/support for research and the development of information on DPR implementation.

6-8 RESEARCH TOPIC: ACCEPTANCE OF POTABLE REUSE

Full Title

Effect of Prior Knowledge on the Acceptance of Planned Potable Reuse in California

Rationale

This project would add a second phase to WRF-09-01, "*Effect of Prior Knowledge of 'Unplanned' Potable Reuse on the Acceptance of 'Planned' Potable Reuse*", to provide information specific to California public perceptions of potable reuse. The scope of WRF-09-01 is limited to unplanned potable reuse via surface water, IPR via surface water, and DPR without an engineered storage buffer; California is not included as part of the focus group testing or survey research. The proposed study would add a second phase WRF-09-01 to determine how acceptance of planned potable reuse changes when people are informed about the long history and everyday reality of unplanned potable reuse in California. The study would use and modify the materials and methodologies developed for WRF-09-01 and apply them to communities in California for water supplies derived from surface water and groundwater. The scenarios tested would include unplanned potable reuse (surface water and groundwater), IPR (groundwater recharge and surface water augmentation), and DPR (with and without an engineered storage buffer). It will provide insight of public perceptions regarding different models of potable reuse.

Objectives

1. Modify background explanation of the water cycle developed for WRF-09-01 to address unplanned potable reuse via surface water and groundwater.
2. Develop real-world unplanned potable reuse scenarios for California that address surface water and groundwater.

3. Develop scenarios for unplanned potable reuse, IPR, and DPR to be tested by two to three focus groups in different California communities. Each focus group would consist of one sub-group that receives background information on the water cycle and one sub-group that does not.
4. Based on the outcome of focus groups, conduct survey research to validate whether the conclusions drawn from the focus group meetings can be considered representative of the broader public in California.

Benefits

The results of this study would help to clarify whether communities considering the use of recycled water for potable reuse (both IPR and DPR) would be more accepting of water recycling if they had prior knowledge and understanding of 'unplanned' water reuse via discharges of treated wastewater into water supply sources. This project will, therefore, either validate or refute the proposition that information and messages related to prior knowledge of consumption of wastewater in drinking water via unplanned reuse enhances or effects public acceptance of planned IPR and DPR. The results of this study will also be used to assess whether communities are more willing to accept potable reuse if it involves environmental buffers and/or engineered storage buffers.

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Appendix A
Text: Senate Bill 918

Senate Bill No. 918

An act to amend Sections 13350 and 13521 of, and to add Chapter 7.3 (commencing with Section 13560) to Division 7 of, the Water Code, relating to water recycling.

LEGISLATIVE COUNSEL'S DIGEST

SB 918, Pavley. Water recycling.

(1) Existing law establishes the State Water Resources Control Board and the California regional water quality control boards as the principal state agencies with authority over matters relating to water quality. Existing law requires the State Department of Public Health to establish uniform statewide recycling criteria for each varying type of use for recycled water where the use involves the protection of public health.

This bill would require the State Department of Public Health to adopt uniform water recycling criteria for indirect potable water reuse for groundwater recharge, as defined, by December 31, 2013. The bill would require the department to develop and adopt uniform water recycling criteria for surface water augmentation, as defined, by December 31, 2016, if a specified expert panel convened pursuant to the bill finds that the criteria would adequately protect public health. The bill would require the department to investigate the feasibility of developing uniform water recycling criteria for direct potable reuse, as defined, and to provide a final report on that investigation to the Legislature by December 31, 2016. The bill would require the department, in consultation with the State Water Resources Control Board, to report to the Legislature from 2011 to 2016, inclusive, as part of the annual budget process, on the progress towards developing and adopting the water recycling criteria for surface water augmentation and its investigation of the feasibility of developing water recycling criteria for direct potable reuse. The bill would require the State Water Resources Control Board to enter into an agreement with the department to assist in implementing the water recycling criteria provisions.

(2) Existing law imposes specified civil liabilities for violations of water quality requirements, and requires all funds generated by the imposition of those liabilities to be deposited in the Waste

Discharge Permit Fund. Existing law requires these moneys to be expended by the State Water Resources Control Board, upon appropriation by the Legislature, to assist California regional water quality control boards and other public agencies in cleaning up or abating the effects of waste on waters of the state.

This bill would require those funds to additionally be made available, upon appropriation by the Legislature, to the state board for purposes of assisting with the development and adoption of the water recycling criteria.

The people of the State of California do enact as follows:

SECTION 1. Section 13350 of the Water Code is amended to read:

13350. (a) A person who (1) violates a cease and desist order or cleanup and abatement order hereafter issued, reissued, or amended by a regional board or the state board, or (2) in violation of a waste discharge requirement, waiver condition, certification, or other order or prohibition issued, reissued, or amended by a regional board or the state board, discharges waste, or causes or permits waste to be deposited where it is discharged, into the waters of the state, or (3) causes or permits any oil or any residuary product of petroleum to be deposited in or on any of the waters of the state, except in accordance with waste discharge requirements or other actions or provisions of this division, shall be liable civilly, and remedies may be proposed, in accordance with subdivision (d) or (e).

(b) (1) A person who, without regard to intent or negligence, causes or permits a hazardous substance to be discharged in or on any of the waters of the state, except in accordance with waste discharge requirements or other provisions of this division, shall be strictly liable civilly in accordance with subdivision (d) or (e).

(2) For purposes of this subdivision, the term “discharge” includes only those discharges for which Section 13260 directs that a report of waste discharge shall be filed with the regional board.

(3) For purposes of this subdivision, the term “discharge” does not include an emission excluded from the applicability of Section 311 of the Clean Water Act (33 U.S.C. Sec. 1321) pursuant to Environmental Protection Agency regulations interpreting Section 311(a)(2) of the Clean Water Act (33 U.S.C. Sec. 1321(a)(2)).

(c) A person shall not be liable under subdivision (b) if the discharge is caused solely by any one or combination of the following:

(1) An act of war.

(2) An unanticipated grave natural disaster or other natural phenomenon of an exceptional, inevitable, and irresistible character, the effects of which could not have been prevented or avoided by the exercise of due care or foresight.

(3) Negligence on the part of the state, the United States, or any department or agency thereof. However, this paragraph shall not be interpreted to provide the state, the United States, or any department or agency thereof a defense to liability for any discharge caused by its own negligence.

(4) An intentional act of a third party, the effects of which could not have been prevented or avoided by the exercise of due care or foresight.

(5) Any other circumstance or event that causes the discharge despite the exercise of every reasonable precaution to prevent or mitigate the discharge.

(d) The court may impose civil liability either on a daily basis or on a per gallon basis, but not on both.

(1) The civil liability on a daily basis shall not exceed fifteen thousand dollars ($15,000) for each day the violation occurs.

(2) The civil liability on a per gallon basis shall not exceed twenty dollars ($20) for each gallon of waste discharged.

(e) The state board or a regional board may impose civil liability administratively pursuant to Article 2.5 (commencing with Section 13323) of Chapter 5 either on a daily basis or on a per gallon basis, but not on both.

(1) The civil liability on a daily basis shall not exceed five thousand dollars ($5,000) for each day the violation occurs.

(A) When there is a discharge, and a cleanup and abatement order is issued, except as provided in subdivision (f), the civil liability shall not be less than five hundred dollars ($500) for each day in which the discharge occurs and for each day the cleanup and abatement order is violated.

(B) When there is no discharge, but an order issued by the regional board is violated, except as provided in subdivision (f), the civil liability shall not be less than one hundred dollars ($100) for each day in which the violation occurs.

(2) The civil liability on a per gallon basis shall not exceed ten dollars ($10) for each gallon of waste discharged.

(f) A regional board shall not administratively impose civil liability in accordance with paragraph (1) of subdivision (e) in an amount less than the minimum amount specified, unless the regional board makes express findings setting forth the reasons for its action based upon the specific factors required to be considered pursuant to Section 13327.

(g) The Attorney General, upon request of a regional board or the state board, shall petition the superior court to impose, assess, and recover the sums. Except in the case of a violation of a cease and desist order, a regional board or the state board shall make the request only after a hearing, with due notice of the hearing given to all affected persons. In determining the amount to be imposed, assessed, or recovered, the court shall be subject to Section 13351.

(h) Article 3 (commencing with Section 13330) and Article 6 (commencing with Section 13360) apply to proceedings to impose, assess, and recover an amount pursuant to this article.

(i) A person who incurs any liability established under this section shall be entitled to contribution for that liability from a third party, in an action in the superior court and upon proof that the discharge was caused in whole or in part by an act or omission of the third party, to the extent that the discharge is caused by the act or omission of the third party, in accordance with the principles of comparative fault.

(j) Remedies under this section are in addition to, and do not supersede or limit, any and all other remedies, civil or criminal, except that no liability shall be recoverable under subdivision (b) for any discharge for which liability is recovered under Section 13385.

(k) Notwithstanding any other law, all funds generated by the imposition of liabilities pursuant to this section shall be deposited into the Waste Discharge Permit Fund. These moneys shall be separately accounted for, and shall be expended by the state board, upon appropriation by the Legislature, to assist regional boards, and other public agencies with authority to clean up waste or abate the effects of the waste, in cleaning up or abating the effects of the waste on waters of the state, or for the purposes authorized in Section 13443, or to assist in implementing Chapter 7.3 (commencing with Section 13560).

SEC. 2. Section 13521 of the Water Code is amended to read:

13521. The State Department of Public Health shall establish uniform statewide recycling criteria for each varying type of use of recycled water where the use involves the protection of public health.

SEC. 3. Chapter 7.3 (commencing with Section 13560) is added to Division 7 of the Water Code, to read:

CHAPTER 7.3. DIRECT AND INDIRECT POTABLE REUSE

13560. The Legislature finds and declares the following:

(a) In February 2009, the state board unanimously adopted, as Resolution No. 2009-0011, an updated water recycling policy, which includes the goal of increasing the use of recycled water in the state over 2002 levels by at least 1,000,000 acre-feet per year by 2020 and by at least 2,000,000 acre-feet per year by 2030.

(b) Section 13521 requires the department to establish uniform statewide recycling criteria for each varying type of use of recycled water where the use involves the protection of public health.

(c) The use of recycled water for indirect potable reuse is critical to achieving the state board's goals for increased use of recycled water in the state. If direct potable reuse can be demonstrated to be safe and feasible, implementing direct potable reuse would further aid in achieving the state board's recycling goals.

(d) Although there has been much scientific research on public health issues associated with indirect potable reuse through groundwater recharge, there are a number of significant unanswered questions regarding indirect potable reuse through surface water augmentation and direct potable reuse.

(e) Achievement of the state's goals depends on the timely development of uniform statewide recycling criteria for indirect and direct potable water reuse.

(f) This chapter is not intended to delay, invalidate, or reverse any study or project, or development of regulations by the department, the state board, or the regional boards regarding the use of recycled water for indirect potable reuse for groundwater recharge, surface water augmentation, or direct potable reuse.

(g) This chapter shall not be construed to delay, invalidate, or reverse the department's ongoing review of projects consistent with Section 116551 of the Health and Safety Code.

13561. For purposes of this chapter, the following terms have the following meanings:

(a) "Department" means the State Department of Public Health.

(b) "Direct potable reuse" means the planned introduction of recycled water either directly into a public water system, as defined in Section 116275 of the Health and Safety Code, or into a raw water supply immediately upstream of a water treatment plant.

(c) "Indirect potable reuse for groundwater recharge" means the planned use of recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system, as defined in Section 116275 of the Health and Safety Code.

(d) "Surface water augmentation" means the planned placement of recycled water into a surface water reservoir used as a source of domestic drinking water supply.

(e) "Uniform water recycling criteria" has the same meaning as in Section 13521.
13561.5. The state board shall enter into an agreement with the department to assist in implementing this chapter.

13562. (a) (1) On or before December 31, 2013, the department shall adopt uniform water recycling criteria for indirect potable reuse for groundwater recharge.

(2) (A) Except as provided in subparagraph (C), on or before December 31, 2016, the

department shall develop and adopt uniform water recycling criteria for surface water augmentation.

(B) Prior to adopting uniform water recycling criteria for surface water augmentation, the department shall submit the proposed criteria to the expert panel convened pursuant to subdivision (a) of Section 13565. The expert panel shall review the proposed criteria and shall adopt a finding as to whether, in its expert opinion, the proposed criteria would adequately protect public health.

(C) The department shall not adopt uniform water recycling criteria for surface water augmentation pursuant to subparagraph (A), unless and until the expert panel adopts a finding that the proposed criteria would adequately protect public health.

(b) Adoption of uniform water recycling criteria by the department is subject to the requirements of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code. 13563. (a) (1) The department shall investigate and report to the Legislature on the feasibility of developing uniform water recycling criteria for direct potable reuse.

(2) The department shall complete a public review draft of its report by June 30, 2016. The department shall provide the public not less than 45 days to review and comment on the public review draft.

(3) The department shall provide a final report to the Legislature by December 31, 2016. The department shall make the final report available to the public.

(b) In conducting the investigation pursuant to subdivision (a), the department shall examine all of the following:

(1) The availability and reliability of recycled water treatment technologies necessary to ensure the protection of public health.

(2) Multiple barriers and sequential treatment processes that may be appropriate at wastewater and water treatment facilities.

(3) Available information on health effects.

(4) Mechanisms that should be employed to protect public health if problems are found in recycled water that is being served to the public as a potable water supply, including, but not limited to, the failure of treatment systems at the recycled water treatment facility.

(5) Monitoring needed to ensure protection of public health, including, but not limited to, the identification of appropriate indicator and surrogate constituents.

(6) Any other scientific or technical issues that may be necessary, including, but not limited to, the need for additional research.

(c) (1) Notwithstanding Section 10231.5 of the Government Code, the requirement for submitting a report imposed under paragraph (3) of subdivision (a) is inoperative on December 31, 2020.

(2) A report to be submitted pursuant to paragraph (3) of subdivision (a) shall be submitted in compliance with Section 9795 of the Government Code.

13563.5. (a) The department, in consultation with the state board, shall report to the Legislature as part of the annual budget process, in each year from 2011 to 2016, inclusive, on the progress towards developing and adopting uniform water recycling criteria for surface water augmentation and its investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse.

(b) (1) A written report submitted pursuant to subdivision (a) shall be submitted in compliance with Section 9795 of the Government Code.

(2) Pursuant to Section 10231.5 of the Government Code, this section is repealed on January 1, 2017. 13564. In developing uniform recycling criteria for surface water augmentation, the department shall consider all of the following:

(a) The final report from the National Water Research Institute Independent Advisory Panel for the City of San Diego Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project.

(b) Monitoring results of research and studies regarding surface water augmentation.

(c) Results of demonstration studies conducted for purposes of approval of projects using surface water augmentation.

(d) Epidemiological studies and risk assessments associated with projects using surface water augmentation.

(e) Applicability of the advanced treatment technologies required for recycled water projects, including, but not limited to, indirect potable reuse for groundwater recharge projects.

(f) Water quality, limnology, and health risk assessments associated with existing potable water supplies subject to discharges from municipal wastewater, stormwater, and agricultural runoff.

(g) Recommendations of the State of California Constituents of Emerging Concern Recycled Water Policy Science Advisory Panel.

(h) State funded research pursuant to Section 79144 and subdivision (b) of Section 79145.

(i) Research and recommendations from the United States Environmental Protection Agency Guidelines for Water Reuse.

(j) Other relevant research and studies regarding indirect potable reuse of recycled water.

13565. (a) (1) The department shall convene and administer an expert panel for the purposes of advising the department on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation and investigation of the feasibility of developing uniform water recycling criteria for direct potable reuse.

(2) The expert panel shall be comprised, at a minimum, of a toxicologist, an engineer licensed in the state with at least three years' experience in wastewater treatment, an engineer licensed in the state with at least three years' experience in treatment of drinking water supplies and knowledge of drinking water standards, an epidemiologist, a microbiologist, and a chemist.

(3) Members of the expert panel may be reimbursed for reasonable and necessary travel expenses.

(b) (1) The department may appoint an advisory group, task force, or other group, comprised of no fewer than nine representatives of water and wastewater agencies, local public health officers, environmental organizations, environmental justice organizations, public health nongovernmental organizations, and the business community, to advise the department regarding the development of uniform water recycling criteria for direct potable reuse.

(2) Environmental, environmental justice, and public health nongovernmental organization representative members of the advisory group, task force, or other group may be reimbursed for reasonable and necessary travel expenses. 13566. In performing its investigation of the feasibility of developing the uniform water recycling criteria for direct potable reuse, the department shall consider all of the following:

(a) Recommendations from the expert panel appointed pursuant to subdivision (a) of Section 13565.

(b) Recommendations from an advisory group, task force, or other group appointed by the department pursuant to subdivision

(b) of Section 13565.

(c) Regulations and guidelines for these activities from jurisdictions in other states, the federal government, or other countries.

(d) Research by the state board regarding unregulated pollutants, as developed pursuant to Section 10 of the recycled water policy adopted by state board Resolution No. 2009-0011.

(e) Results of investigations pursuant to Section 13563.

(f) Water quality and health risk assessments associated with existing potable water supplies subject to discharges from municipal wastewater, stormwater, and agricultural runoff.

13567. An action authorized pursuant to this chapter shall be consistent, to the extent applicable, with the federal Clean Water Act (33 U.S.C. Sec. 1251 et seq.), the federal Safe Drinking Water Act (42 U.S.C. Sec. 300f et seq.), this division, and the California Safe Drinking Water Act (Chapter 4 (commencing with Section 116270) of Part 12 of Division 104 of the Health and Safety Code).

13569. The department may accept funds from any source, and may expend these funds, upon appropriation by the Legislature, for the purposes of this chapter.

Appendix B
Texas Commission of Environmental Quality Letter to Big Springs, Texas

File PWS 1140038/CO
RN105692891
CN602515967
File PWS 0680002/CO
RN101386613
CN600338354
File PWS 1140001/CO
RN101389492
CN600668693
File PWS 1590001/CO
RN101392082
CN600632905
File PWS 1650001/CO
RN101384899
CN600246813
File PWS 2080001/CO
RN101384568
CN600128938

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

May 26, 2010

Mr. Ignacio Cadena, P.E.
Freese and Nichols, Inc.
4055 International Plaza, Suite 200
Fort Worth, Texas 76109

Subject: Exception Request to Use Membrane Treated Reclaimed Wastewater from the Big Spring Wastewater Treatment Plant as a Raw Water Source for Public Drinking Water Systems
Wastewater Reclamation Pilot Study Report
Colorado River Municipal Water District Big Spring Regional Water Reclamation Project - PWS ID. No. 1140038
Howard County, Texas

Dear Mr. Cadena:

We have completed our review of the submitted wastewater reuse pilot study report with your cover letter dated February 2, 2010, and e-mails received in May of 2010. The Colorado River Municipal Water District (CRMWD) Big Spring Regional Water Reclamation Project (reclamation facility) is requesting an exception to the requirements for the raw water source. The Texas Commission on Environmental Quality's (TCEQ) requirements for public water system (PWS) raw water sources are contained within Title 30 of the Texas Administrative Code (30 TAC) §290.41. This review is only for the proposed use City of Big Spring Wastewater Treatment Plant (WWTP) effluent that has been treated by hollow fiber (HF) microfiltration (MF) or ultrafiltration (UF) membranes followed by reverse osmosis (RO) membranes (integrated membrane) at the CRMWD reclamation facility to be used as a raw water source for the City of Big Spring (PWS ID 1140001), City of Snyder (PWS ID 2080001), City of Odessa (PWS ID 0680002), City of Stanton (1590001) and the City of Midland (PWS ID 1650001) Surface Water Treatment Plants (SWTP). Based on our review, we are **granting** this request for an exception.

The proposed project's purpose is to supplement the raw water received for drinking water treatment at the above municipalities. The raw water source for these systems is provided via a Colorado River Municipal Water District raw water pipeline. At this time, the raw surface water is carried by this pipeline from OH Ivie Reservoir, EV Spence Reservoir, and Lake JB Thomas to each PWS. The proposed project would supplement the surface water sources by introducing reclaimed treated wastewater effluent to the pipeline. Ten to fifteen percent of the pipeline water would be the reclaimed water. The CRMWD reclamation facility would take the effluent from the Big Spring WWTP, treat it with hollow fiber (HF) membranes, reverse osmosis (RO) and potentially Ultraviolet Light and release the treated water into the raw water pipeline. This letter is a review of the pilot study for the membrane

P.O. Box 13087 Austin, Texas 78711-3087 512-239-1000 Internet address: www.tceq.state.tx.us

portion of the CRMWD reclamation facility. The letter sets design, operation, reporting, calibration and record keeping requirements for the proposed facility which is a source of raw water for drinking water facilities.

The 30 TAC 290 Subchapters D, E and F rules only apply to public water systems. The CRMWD reclamation facility will produce only the source water for public water systems; therefore, many of the requirements for facilities that produce finished drinking water found in Subchapters D, E and F are not applicable. The following conditions are TCEQ site-specific minimum operation, design, reporting, calibration and record keeping requirements for the proposed innovative integrated membrane CRMWD reclamation facility which will produce an alternative raw water source for public drinking water system facilities and are based on the pilot study data supplied.

<u>OPERATIONAL REQUIREMENTS</u>

1. The CRMWD reclamation facility can only discharge source water into the CRMWD raw water pipeline when:

   a. The WWTP effluent turbidity is below 10 Nephelometric Turbidity Units (NTU). If the WWTP effluent turbidity level is above 10 NTU the water must be sent back the WWTP. As described in the Freese and Nichols, Inc pilot study report on page 30, turbidity levels above 10 NTU may cause performance issues with the HF membranes.
   b. The HF membrane units have passed the most recent direct integrity test (DIT). Each HF membrane unit must pass a DIT with a sensitivity of 4.0-log and a resolution to detect a 3.0 micron breach every seven days, and after each chemical clean-in-place (CIP) procedure, to assure similar water quality from the CRMWD reclamation facility as is seen in the CRMWD raw water pipeline. If a HF membrane unit fails a DIT, it must be taken off line, inspected and, if necessary, repaired. The HF membrane unit cannot be returned to service until it passes a subsequent DIT. The pilot study HF membrane test units with a DIT sensitivity of 4.0-log removal produced water with the same levels (non-detectable) of *Cryptosporidium* oocysts and *Giardia lamblia* cysts as found in the CRMWD raw water pipeline.
   c. The free chlorine residual received from the WWTP is above 1.0 mg/L. If the residual falls below 1.0 mg/L there may not be enough viral inactivation achieved to provide the non-detectable viral levels achieved during the pilot study. If the chlorine residual is below 1.0 mg/L the water must be sent back to the WWTP.

2. If the CRMWD reclamation facility produces source water when in violation of the conditions in Item #1, TCEQ must be contacted within 24 hours by telephone at (512) 239-4691 or email at pdws@tceq.state.tx.us and immediately notify all PWSs utilizing the source water. Within five working days, submit written notification regarding the problem that required the CRMWD reclamation facility, or part of the facility, to be taken out of service, the corrective actions taken, quantity of any unacceptable water discharged to the CRMWD raw water pipeline and PWSs using the water at that time to:

   Technical Review and Oversight Team
   TCEQ – MC 159
   PO Box13087
   Austin, TX 78711-3087

3. The system must conduct a DIT at least once every seven days and after each clean-in-place (CIP) procedure to verify that the integrity of the membranes has not been compromised and continuous removal of *Cryptosporidium* oocysts and *Giardia lamblia* cysts is being achieved.

4. The DIT must be conducted using a procedure approved by the executive director including resolution and sensitivity requirements. The DIT must show a 4.0-log removal sensitivity. The calculations of the direct integrity test values are described on page 12 in *DIT Resolution and* LRV_{DIT} *Sensitivity Calculations* under the HF Membrane Details section.

5. The CRMWD reclamation facility must immediately conduct a DIT on any HF membrane unit that produces filtered water with a turbidity level above 0.15 NTU on two consecutive 5-minute readings.

6. Continuous indirect integrity monitoring of each HF unit's filtrate turbidity levels must be measured using the Hach Model FilterTrak method 10133 laser turbidimeter, or an acceptable TCEQ alternative. The results must be recorded every 5 minutes.

7. The influent to the CRMWD reclamation facility must have continuous chlorine monitoring. The results must be recorded every 30 minutes.

8. The flow to the HF membrane units must be monitored continuously and the results must be recorded every 30 minutes.

9. The performance of the individual RO units shall be continuously monitored by conductivity meter or total dissolved solids meters. The highest confirmed reading shall be recorded each day.

10. Data collected from on-line instruments may be recorded electronically by a SCADA system or on a strip chart recorder. The recorder must be designed so that the operator can accurately determine the value of the readings at the required monitoring interval.

11. If there is a failure in the continuous monitoring equipment, grab sampling must be conducted every four hours in lieu of continuous monitoring, but for no more than five working days following the failure of the equipment.

12. If conductivity or total dissolved solids levels of an RO unit's permeate are 20% larger than the last reading then the RO unit must be removed from service, the problem repaired and an acceptable conductivity or total dissolved solids achieved in the permeate before discharge to the CRMWD raw water pipeline can be resumed.

13. All monitoring required as a condition of this exception in this letter must be conducted using methods that conform to the requirements of §290.119.

14. A plant operations manual that meets the requirements of §290.42(l) must be kept on site and must be made available to TCEQ staff upon request.

15. A Class B surface water operator must be employed by the CRMWD reclamation facility. Class C surface water operators can operate the CRMWD reclamation facility if the Class B operator is on call. Operators having both a water and wastewater license may work in the CRMWD reclamation facility and Big Spring WWTP, but not during the same shift to prevent the introduction of contaminants.

16. The TCEQ will not issue approval for discharge of CRMWD reclamation facility into the CRMWD raw water pipeline until after chemical analytical results are received from the TCEQ contract laboratory. After receiving notification of completion of construction, the TCEQ will schedule a contractor to collect the necessary samples at the required sample tap located on the reclamation facility discharge to the CRMWD raw water pipeline. These samples will be analyzed for the required minerals and metal constituents. They will be analyzed for certain organic chemicals such as volatile compound and pesticides. Based on the results of these analyses, the required sampling frequency and constituents analyzed for any receiving PWSs' points of entries to distribution systems may be modified.

17. Once the CRMWD reclamation facility is producing source water, Long Term 2 Enhanced Surface Water Treatment Rule (LT2) source water sampling must be performed on the blended source water for all of the public water systems that have the potential to receive this source water as described in §290.111(b). CRMWD must contact each of the PWSs that can receive source water from the reclamation facility to notify them of the new source water monitoring requirement. CRMWD must also notify the Technical Review and Oversight Team (MC-159) in writing when the reclamation facility begins producing source water at:

TCEQ Technical Review & Oversight Team (MC 159)
P.O. Box 13087
Austin, Texas 78711-3087

18. Results of pilot study sampling show an increase in total trihalomethane (TTHM) and nitrate levels above those seen in the raw water pipeline. The CRMWD must notify all of the PWSs that have the potential to receive the reclaimed water as source water of the levels found so that the PWSs can assess the impact to their finished drinking water compliance.

19. The CRMWD will be required to disinfect new or repaired facilities in accordance with American Water Works Association (AWWA) regulations as described in §290.46(g).

20. The CRMWD reclamation facility HF Filtrate tank and the water storage tank used to store fully treated water must be inspected annually by the facility's licensed water operators or a contract inspection service as described in §290.26(m).

21. All electrical wiring must be securely installed in compliance with a local or national electrical code.

22. The CRMWD reclamation facility must maintain internal procedures to notify TCEQ immediately if an emergency event would negatively impact the delivery of source water. A list of such events is located in §290.46(w)

23. All backflow prevention assemblies that are required by this letter shall be tested upon installation and then once every 12 months as described in §290.44(h)(4).

24. The CRMWD reclamation facility will be investigated by TCEQ periodically to assure the conditions of this letter are met. The investigation will be a public water system source investigation, not a wastewater investigation because the effluent of the CRMWD reclamation facility is being discharged into a pipeline, not a water body.

<u>DESIGN REQUIREMENTS</u>

25. Engineering specifications and drawings must be submitted for review and approval prior to construction beginning as described in §290.39(h)(1). These specifications and drawings shall include all related piping, treatment facilities, storage, industrial connections and transmission lines from the Big Spring WWTP to the CRMWD raw water pipeline. These documents are to be submitted to:

    TCEQ Utilities Technical Review Team (MC 159)
    P.O. Box 13087
    Austin, Texas 78711-3087

26. In the future, the CRMWD reclamation facility must notify TCEQ prior to making any significant change as described in §290.39(j).

27. All waste discharge must be in accordance with federal and state requirements as described in §290.42(i). For assistance, please contact TCEQ's Wastewater Permitting Section (MC 148) for information required for the proper disposal of generated waste and any required discharge permit at (512) 239-2369.

28. A full-scale HF membrane system with Pall Microza® Model UNA-620A HF MF membrane modules (See the <u>HF Membrane Details</u> section on page 11 for further details.) must be installed with the following design specifications:

    a. Pre-treatment facilities consisting of a 400 micron strainer;
    b. Pall Microza® Model UNA-620A HF MF membrane modules with the following specifications:
        i. A HF MF pressure membrane module six inches in diameter, approximately 80 inches (in) in length and containing polyvinylidene fluoride (PVDF) fibers with a total feed side surface area of 538-square feet (sf);
        ii. A membrane fiber nominal pore size of 0.1 microns;
        iii. Outside-to-inside flow mode with dead-end operation;
        iv. Allowable transmembrane pressure (TMP) operating range of 1 to 43.5 pounds per square-inch (psi);
        v. Allowable operating temperature range of 0° to 40° C;
        vi. A 1,000 mg/L chlorine tolerance; and
        vii. Manufacture's allowable feed water turbidity level spike of 600 NTU.
    c. Facilities to allow a filtrate duration of 20 minutes;
    d. Facilities for a backwash cycle procedure on each HF MF membrane unit every 20 minutes using a Simultaneous Air Scrubbing and Reverse Filtration (SASRF) procedure for 60 seconds followed by Forward Flush (FF) for 20 seconds;
    e. Facilities to conduct both a sodium hypochlorite and 1% citric acid enhanced filtrate maintenance (EFM) wash procedure utilizing RO permeate as make up water. One EMF will be conducted once every 24 hours for a duration of 30 minutes;
    f. Facilities to conduct a HF MF membrane unit chemical clean-in-place (CIP) procedure no less than once every 30 days for a duration of approximately six hours utilizing RO permeate as make up water;
    g. Facilities to provide an average instantaneous filtrate flux rate of 37.2 gallons per square-foot per day (gfd) (temperature corrected to 20° C);

29. A full-scale RO membrane system of Toray TML 10 RO elements, or another TCEQ acceptable Toray element (See the <u>RO Membrane Details</u> section on page 14 for further details) must be installed in pressure vessels arranged in a two-stage configuration with twice as many pressure vessels and elements in each Stage 1 as are in the corresponding Stage 2 (2:1 array) with the following specifications:

   a. Toray TML 10 RO elements model with the following specifications:
      i. 4-inch diameter or if a larger Toray membrane is used, the elements must have the same leaf length as the pilot TML 10;
      ii. A leaf length of 40 inches;
      iii. An active membrane area of 75 sf;
      iv. Minimum salt rejection of 99%;
      v. Recovery rate of 75%;
      vi. Maximum operating temperature of 113° F;
      vii. Maximum allowed continuous free chlorine value of non-detectable;
      viii. An operating pH range of 2 to 11;
      ix. A pH cleaning range of 1 to 12;
      x. A maximum operating pressure of 600 psi;
      xi. A maximum pressure drop per element of 20 psi; and
      xii. A maximum silt density (SDI) of 5.
   b. Facilities for dechlorination of the water prior to the RO membrane units must be provided;
   c. Facilities to assure complete dechlorination was achieved must be provided;
   d. Facilities to feed antiscalent must be provided;
   e. Facilities for performing an RO membrane unit CIP procedure using both caustic and acid heated solutions; and
   f. Facilities to achieve an average flux rate of 10.1 gfd.

30. The CRMWD reclamation facility must be located at least 500 feet from any wastewater treatment units or lands irrigated with sewage effluent.

31. The CRMWD reclamation facility shall be located at a site that is accessible by an all-weather road as described in §290.42(a)(3).

32. All water discharged to the CRMWD raw water pipeline must be treated by the HF and RO membrane processes. This means, the CRMWD reclamation facility units must be designed to treat all of the WWTP effluent received. Blending of WWTP effluent with reclamation facility effluent is not allowed.

33. No return of decanted water or solids to the beginning of the CRMWD reclamation facility is proposed. If recycle return is desired in the future, please contact the TCEQ Technical Review & Oversight Team (MC 159) at the following address:

    TCEQ Technical Review & Oversight Team (MC 159)
    P.O. Box 13087
    Austin, Texas 78711-3087

34. The CRMWD reclamation facility, including all filtrate and permeate storage tanks, shall be enclosed by an intruder-resistant fence as described in §290.42(m). The gates shall be locked during periods of darkness and when the plant is unattended.

35. Chemical storage facilities shall comply with the applicable requirements in §290.42(f)(1).

36. Chemical feed facilities shall comply with the applicable requirements in §290.42(f)(2).

37. Pipe galleries shall provide ample working room, good lighting, and good drainage provided by sloping floors, gutters, and sumps. Adequate ventilation to provident condensation and to provide humidity control is also required as detailed in §290.42(d)(12).

38. The identification of piping shall be accomplished by the use of labels or various color of paint as described in §290.42(d)(13).

39. Sanitary facilities for water works installations must be provided as described in §290.42(h).

40. The safety requirements of §290.42(k)(1) must be followed.

41. No cross-connection shall be permitted to exist between the WWTP effluent and the CRMWD reclamation facility effluent or any stage of prior treatment as described in §290.42(d)(2).

42. All reclaimed customer connections between the CRMWD reclamation facility and the CRMWD raw water pipeline shall be provided with backflow/backsiphonage protection to eliminate the possibility of chemical contamination and pathogen recontamination as described in §290.44(h)(1)(A).

43. Separation distances between the treated reclaimed water distribution/transmission piping and potable water piping shall be as specified in §290.44(e).

44. Separation distances between the treated reclaimed water distribution/transmission piping and wastewater collection mains and other potential sources of recontamination shall be as described in §290.44(e).

45. Sampling taps must be located after the CRMWD reclamation facility's source water (WWTP effluent) storage tank, on the HF membrane filtrate storage tanks' effluent, RO membrane permeate storage tanks' effluent and the CRMWD reclamation facility's discharge piping to the CRMWD raw water pipeline as described in §290.43(c) and §290.42(d)(14). These sample taps must be readily accessible to the plant operators and TCEQ representatives.

46. All treatment chemicals and media used in the full-scale facility must conform to American National Standard Institute/National Sanitation Foundation (ANSI/NSF) Standard 60 for direct additives and ANSI/NSF Standard 61 for indirect additives and be certified by an organization accredited by ANSI as described in §290.42(j). This includes dechlorination compounds, disinfectants, anti-scalants, acids, caustics and other membrane cleaning chemicals.

47. Flow measuring devices will be required on the feed to each HF membrane unit, the HF membrane backwash supply, the combined HF membrane filtrate, each RO permeate line, and on the final and the reclamation facility discharge piping to the CRMWD pipeline as described in §290.42(d)(5).

48. The CRMWD reclamation facility must be designed to conduct and record continuous turbidity monitoring of the WWTP effluent.

49. The HF membrane system must be designed to conduct and record continuous indirect integrity monitoring on each HF membrane unit using the Hach Model FilterTrak method 10133 laser turbidimeter, or an acceptable TCEQ alternative as described in §290.42(g)(3)(C).

50. The RO membrane system must be designed to conduct and record continuous conductivity or total dissolved solids on each RO membrane unit.

51. The HF and RO membrane systems must be designed so that membrane units' feed water, filtrate, backwash supply, waste and chemical cleaning piping shall have cross-connection protection to prevent chemicals from all chemical cleaning processes from contaminating other membrane units in other models of operations. This may be accomplished by the installation of a double block and bleed valving arrangement, a removable spool system, or other alternative methods approved by the executive director.

52. The CRMWD reclamation facility's feed water must receive the same pretreatment, at a minimum, under full-scale operation as received during this pilot study. The treatment is provided at the Big Spring WWTP and is as follows: Raw wastewater is first screened and degritted, then flows to a primary clarifier. Primary effluent then proceeds to a single rock media trickling filter for biological stabilization and then is pumped to the aeration basin for additional biological treatment. The contents of the aeration basin flow to the final clarifier, where the active biomass is separated from the treated effluent and recycled to the aeration basin. The effluent is chlorinated and then passes through a sand filter. The filtered effluent containing the chlorine residual was the source water for the pilot study.

53. The CRMWD reclamation facility must be designed with a continuous chlorine analyzer to check chlorine residual received from the WWTP.

54. The CRMWD reclamation facility must be designed to conduct and record the results of direct integrity tests (DIT) as described in §290.42(g)(3)(B). The DIT values are calculated as described on page 12 in the *DIT Resolution and LRV_{DIT} Sensitivity Calculations* under the HF Membrane Details section.

55. An adequately equipped laboratory must be available so that daily tests such as disinfectant residual, turbidity, pH, conductivity or total dissolved solids, and all other tests required by the conditions of this letter may be performed.

56. The water storage tank used to store fully treated water before it is sent to the CRMWD raw water pipeline must meet the requirements of §290.43(c).

CALIBRATION

57. Conductivity or dissolved solids meters used to monitor the RO membrane units' permeate shall be calibrated with solution of known concentrations at least once every 90 days.

58. Flow measuring devises and rate-of-flow controllers shall be calibrated at least once every 12 months.

59. pH meters shall be properly calibrated as described in §290.46(s)(2)(A).

60. Turbidimeters shall be properly calibrated as described in §290.46(s)(2)(B).

61. Chemical disinfectant residual analyzers, such as chlorine, shall be properly calibrated as described in §290.46(s)(2)(C).

62. Pressure monitors used for DIT measurements shall be calibrated or verified every at least once every 12 months.

REPORTING

63. The TCEQ will require the CRMWD reclamation facility to record the following daily:
    a. The maximum flow rates to the HF membrane units;
    b. The maximum flow to the RO membrane units;
    c. The lowest chlorine residual at the entry to the reclamation facility;
    d. The highest confirmed turbidity in the HF membrane effluent;
    e. Any HF membrane unit DIT's starting test pressure, end pressure, duration of the test and decay pressure rate in pounds per square inch per minute (psi/min);
    f. Any corrective actions taken, such as pinning, to correct a failed HF membrane DIT;
    g. Any CIP that has been performed on a HF or RO membrane unit;
    h. The highest confirmed conductivity or total dissolved solids measurement for each RO membrane unit;
    i. The amount of each chemicals used;
    j. The amount of water treated; and
    k. The maximum flow rate of reclaimed water discharged into the CRMWD raw water pipeline.

64. The TCEQ will require the CRMWD reclamation facility to record the following:
    a. The dates that storage tanks and other facilities were cleaned; and
    b. The maintenance records for the system equipment and facilities.

65. The CRMWD reclamation facility shall record the daily data required in Item #63 in a format of their choosing. The records must be completed in ink, typed or computer printed and must be signed by a Class B Surface Water Operator. The TCEQ Membrane Monthly Operating Report can be used to record some of the required items, but this format is not required. It can be downloaded from:

    http://www.tceq.state.tx.us/permitting/water_supply/pdw/swmor/swmor/mmor_v2.html

66. The CRMWD reclamation facility shall keep the daily operations and maintenance records for each month at the CRMWD reclamation facility for review by TCEQ staff during periodic TCEQ investigations.

67. The TCEQ will require the reclaimed wastewater to be identified as a raw water source on the consumer confidence report (CCR) for any PWS using this water as a raw water source.

68. If the CRMWD reclamation facility produces source water when in violation of the conditions in Item #1, it must contact TCEQ within 24 hours by telephone at (512) 239-4691 or email at pdws@tceq.state.tx.us and immediately notify all PWSs utilizing the source water.

Within five working days, submit written notification regarding the problem that required the CRMWD reclamation facility, or part of the facility, to be taken out of service, the corrective actions taken, quantity of any unacceptable water discharged to the CRMWD raw water pipeline and PWSs using the water at that time to:

Technical Review and Oversight Team
TCEQ – MC 159
PO Box13087
Austin, TX 78711-3087

69. Data on system ownership and management shall be provided as detailed in §290.46(p)(1).

<u>RECORD KEEPING</u>

70. The following records must be retained for at least two years:
  a. The amount of chemical used each day;
  b. The volume of water treated each day;
  c. The dates that storage tanks and other facilities were cleaned; and
  d. The maintenance records for the system equipment and facilities.

71. The following records must be retained for at least three years:
  a. Turbidity monitoring results for the individual HF membrane units; and
  b. The calibration records for laboratory equipment, flow meters, on-line turbidimeters, on-line conductivity or total dissolved solids meters, and disinfectant residual analyzers.

72. This letter must be retained while the exception is valid and then for at least five years after the exception is no longer in valid.

73. Results of inspections of all water storage facilities must be retained for at least five years.

74. The following records must be retained for at least ten years:
  a. The daily maximum flow rates to the HF membrane units;
  b. The daily maximum flow to the RO membrane units;
  c. The lowest daily chlorine residual at the entry to the reclamation facility;
  d. The highest daily confirmed turbidity in the HF membrane effluent;
  e. Any HF membrane unit DIT's starting test pressure, end pressure, duration of the test and decay pressure rate in pounds per square inch per minute (psi/min);
  f. Any corrective actions taken, such as pinning, to correct a failed DIT;
  g. Each CIP performed on a HF or RO membrane unit;
  h. The highest daily confirmed conductivity or total dissolved solids measurement from each RO membrane unit;
  i. The amount of each chemicals used daily;
  j. The amount of water treated daily;
  k. The daily maximum flow of reclaimed water discharged into the CRMWD raw water pipeline; and
  l. The results of all chemical analyses.

75. Accurate and up-to date detailed plans and specification for the facility shall be maintained at the system until the facility is decommissioned.

HF MEMBRANE DETAILS

Pall Microza® Model UNA-620A MF Membrane Details

Based on approximately 30 days of operation (Cycle #7 of the pilot study report), from October 8, 2009 through November 10, 2009, of the Pall HF MF membrane test unit, the TCEQ finds that the following piloted operating parameters are accepted to yield a maximum of 17,959 gallons per day (GPD) of total filtrate water at 20° C per 538 sf membrane module.

1. Pre-treatment consists of a 400 micron strainer;

2. The water is not dechlorinated until after the HF membrane unit, thus the treatment unit has a 1 to 5 mg/L chlorine residual across the membranes;

3. The maximum recorded turbidity from the submitted turbidity data was approximately 80 NTU, but the CRMWD reclamation facility is choosing to divert the wastewater back to the WWTP is the turbidity is over 10 NTU. Based on this choice, the maximum allowable feed water turbidity for the treatment plant will be 10 NTU;

4. Pall Microza® Model UNA-620A HF MF membrane modules with the following specifications:
    a. A HF MF pressure membrane module six inches in diameter, approximately 80 inches (in) in length and containing polyvinylidene fluoride (PVDF) fibers with a total feed side surface area of 538-square feet (sf);
    b. A membrane fiber nominal pore size of 0.1 microns;
    c. Outside-to-inside flow mode with dead-end operation;
    d. Allowable transmembrane pressure (TMP) operating range of 1 to 43.5 pounds per square-inch (psi);
    e. Allowable operating temperature range of 0° to 40° C;
    f. A 1,000 mg/L chlorine tolerance; and
    g. Manufacture's allowable feed water turbidity level spike of 600 NTU.

5. A filtrate duration of 20 minutes;

6. A backwash cycle using a Simultaneous Air Scrubbing and Reverse Filtration (SASRF) frequency of once every 20 minutes at a flow rate of 8 gallons per minute (gpm) of filtrate and of 3 standard cubic feet per minute (SCFM) of air for a duration of 1.0 minute, followed by a Forward Flush (FF) at a flow rate of 18 gpm of feed water for a duration of 20 seconds;

7. A sodium hypochlorite enhanced filtrate maintenance (EFM) wash procedure once every 24 hours for a duration of 30 minutes with either 500 parts per million (ppm) sodium hypochlorite solution circulated or 1% citric acid for 30.0 minutes followed by a SASRF and FF for a total filtrate water use of 15 gallons per module. RO permeate is used for EMF make up volume. In times of poor water quality, such as wastewater treatment plant upsets, a EMF utilizing 1000 ppm sodium hypochlorite instead of 400 ppm sodium hypochlorite were performed. It is not expected that the 1000 ppm sodium hypochlorite EMF will be needed in full-scale because water with over 10 NTU will be returned to the WWTP;

8. A total of 1,331.4 minutes per day in filtrate mode and 108.8 minutes per day in SASRF, FF, and EFM;

9. A minimum chemical CIP frequency of no less than once every 30 days for a duration of

approximately six hours. The CIP uses a heated 1% caustic and sodium hypochlorite pH 11 solution re-circulated through the membranes and filtrate piping for 2 hours with a subsequent air scrub and feed side rinse. The process is repeated with a heated 1% citric acid pH 3 solution re-circulated for 1 hour. RO permeate is used for the CIP make up volume;

10. An average instantaneous filtrate flux rate of 37.2 gfd (temperature corrected to 20° C); and

11. A gross filtrate production of 18,499 GPD and an in-plant use of filtrate of 540 GPD to yield a net filtrate of 17,959 GPD per a 538-sf module at 20° C available for future customer use.

Based on our understanding of the submitted Pall pilot study data, for a 1.0 MGD design, 56 Pall UNA-620A HF membrane modules would be necessary.

The TCEQ determines the capacity HF membrane facilities based on an instantaneous filtrate flux corrected to 20° C. This amount is determined by subtracting the total in-plant use of filtrate (for backwashing membranes and maintenance cleaning such as EFM's, and any other in-plant use) from the gross potential filtrate production of a membrane unit in service for a 24-hour period of operation.

$$\text{Pall's filtrate flux}_{\text{at feed water temperature}} = \frac{(\text{filtrate flux}_{\text{at 20 C}})*0.9826}{0.0004481*T^2 - 0.03946*T + 1.5926}$$

Where T is the HF membranes' feed water temperature in degrees centigrade, and filtrate flux $_{\text{at 20°C}}$ is 37.2 gfd.

**** Please note this is a Pall specific formula. It must be used at your facility, and can not be used with other manufactures membrane units. ****

DIT Resolution and LRV_{DIT} Sensitivity Calculations

During the pilot study, the permeate from the integrated membrane system had non-detectable levels of *Cryptosporidium* and *Giardia*. The pressure decay rates during the pilot study DITs established a 4.0-log removal of *Cryptosporidium* and *Giardia*. To verify that the HF membranes are intact and able to remove 4.0-log *Cryptosporidium* and *Giardia*, DITs must be performed ever seven days on the full-scale system. To assure that the pressure decay test you perform can confirm the 4.0-log *Cryptosporidium* and *Giardia* removals, the TCEQ must review the calculations and values used to perform the testing. The full-scale facility will have different values, but TCEQ has reviewed the calculation methods provided with the pilot report. We generally agree with the calculation methods and will discuss each one separately below. The values used in the full-scale facility must be submitted for review and approval before the plant is placed in operation.

These following values must be provided:

1. The maximum backpressure (BP_{max}) on the system during the DIT on each HF membrane unit;
2. The minimum test pressure (P_{test}) for each HF membrane unit;
3. The volume of pressurized air in the system during the test (V_{sys}) in each HF membrane unit;
4. The air-liquid conversion ration (ALCR);
5. The HF membrane unit capacity filtrate flow (Q_p);
6. The smallest rate of pressure decay that can be reliably measured (ΔP_{test});
7. The volumetric concentration factor (VCF); and
8. The upper control limit (UCL) for the decay limit that will verify the integrity of the HF membrane unit and the granted log removal values (LRV).

Calculation methods using EPA's Membrane Filtration Guidance Document (EPA 815-R-06-009) must be submitted. Without acceptable calculations methods, removal credit can not continue to be awarded. Please contact your engineer or membrane vendor for assistance with required values.

DIT Resolution

Equation 4.1 (for a 3.0 micron defect): $P_{test} = (0.193 * \kappa * \sigma * \cos\theta) + BP_{max}$

1. We agree with the use of the most conservative membrane specific pore shape correction factor (κ) of 1, the surface tension at the air-liquid interface (σ) of 74.9 dynes/cm, and the liquid-membrane contact angle (θ) of 0 degrees. The BP_{max} of 3.0 pounds per square inch (psi) is acceptable for the pilot unit. Please provide the BP_{max} for the full-scale unit before you begin producing source water.

2. By using equation 4.1 and the values in number 1 you calculated a P_{test} of 17.5 psi for the pilot study unit. This value is acceptable for the pilot study. Please provide the P_{test} for the full-scale unit before you begin producing source water.

DIT sensitivity

3. Please provide the actual V_{sys} in liters (L) for each full-scale HF membrane units before you begin producing source water.

   V_{sys} is used in equation 4.9 of the US EPA's Membrane Filtration Guidance Manual to verify that the sensitivity of the DIT will be equal to or greater than the required log removal credit for *Cryptosporidium* and *Giardia* of 4.0-log. The V_{sys} of 10.59 L is acceptable for the pilot study unit.

   Equation 4.9: $LRV_{DIT} = \log [(Q_p \times ALCR \times P_{atm}) \div (\Delta P_{test} \times V_{sys} \times VCF)]$

4. Please provide all necessary values and calculations to determine the ALCR for the full-scale HF membrane units.

   The ALCR calculation method shown for the pilot is acceptable, but one of the reported values does not appear to be correct. The reported maximum water temperature was reported as 41°F. This should be the maximum water temperature expected in the feedwater to the HF membranes at the facility. Typical high water temperatures for Texas are around 95°F. Using the 95°F an ALCR of 17.4 is calculated for the pilot study unit. Please provide values for the full-scale HF membrane units before you begin producing source water.

5. The design capacity Q_p in liters per minutes (L/min) for each full-scale HF membrane unit is based on the TCEQ's approved flux rate of 37.2 gallons per square foot per day (gfd) per module.

6. Please provide documentation of the pressure measuring devices' sensitivity and manufacturers' accuracy (+/- percent) of the instrument to substantiate the ΔP_{test} in pounds per square inch (psi) for each full-scale HF membrane unit.

7. The VCF of 1.0 for the pilot and full-scale units is acceptable because there is no cross-flow or recirculation piloted or proposed.

8. Please submit the UCL for the full-scale plant for the pressure decay rate that will verify the integrity of the HF membrane unit and the granted LRV. Please use equation 4.17 from the US EPA's Membrane Filtration Guidance Manual. Using this equation, a 4.0 log removal credit (LRC), and the above values TCEQ finds a UCL of 0.13 psi/min for the pilot unit.

   Equation 4.17: $UCL = (Q_p * ALCR * P_{atm}) \div (10^{LRC} * V_{sys} * VCF)$

RO MEMBRANE DETAILS

Toray TML 10 Reverse Osmosis (RO) Membrane Details

Toray TML 10 Reverse Osmosis membranes were piloted in conjunction with the HF MF membrane units in a simulated full-scale design configuration. The Toray RO test unit consisted of six pressure vessels (PV) each containing three RO test elements. Two PV were piloted in parallel with HF MF membrane filtrate water for as their feed water source. Each of these two PVs' concentrate was fed to two more PVs in parallel. The concentrate from the second set of PVs was blended and used as feed water for a fifth PV. The fifth PV's concentrate was fed to the sixth and final PV. The first four PVs simulated two full-scale PVs operating in parallel with six RO elements each and the last two PVs simulated a single full-scale PV containing six RO elements. This is a commonly used pilot study arrangement achieving a 2:2:1:1 test array and simulating a full-scale 2:1 array with 6 membranes per PV.

Based on our review of Cycle #4, performed July 15, 2009 to August 23, 2009, the Toray TML 10 RO membrane elements can be installed under the following conditions:

1. Each array must achieve an average flux rate of 10.1 gfd for the Toray TML 10 RO membrane element's feed side surface area.

2. Each full-scale RO membrane unit must use a two-stage 2;1 array as simulated by the piloted.

   a. All RO elements are to be the same model, or a larger TCEQ acceptable Toray RO element model having the same leaf length, salt rejection, removal efficiency and design (no mixing of non-piloted elements); and
   b. Twice the number of PV and RO elements in each Stage 1 as is in Stage 2.

3. The full-scale RO membranes must meet the following specifications or if a larger Toray membrane is used, must show the same leaf length as the pilot TML 10 model:

   a. 4-inch diameter;
   b. An active membrane area of 75 sf;
   c. Have a leaf length of 40 inches;
   d. Minimum salt rejection of 99%;
   e. Recovery rate of 75%;
   f. Maximum operating temperature of 113° F;
   g. Maximum allowed continuous free chlorine value of non-detectable;
   h. An operating pH range of 2 to 11;
   i. A pH cleaning range of 1 to 12;
   j. A maximum operating pressure of 600 psi;
   k. A maximum pressure drop per element of 20 psi; and
   l. A maximum silt density (SDI) of 5.

4. The full-scale Toray membrane elements, internal surface of the PVs and associated RO membrane unit piping must be NSF 61 certified.
5. ANSI/NSF Standard 60 certified chemicals must be used. It is noted that Hypersperse MDC150 by GE Betz Inc. was used as the RO Anti-scaling product and is ANSI/NSF Standard 60 certified up to 10 mg/L.

6. ANSI/NSF Standard 60 certified sodium bisulfite must be used at a dose necessary to remove all chlorine residual before the RO membranes. During the pilot this dose was 22 mg/L.

7. A CIP must be conducted on each RO membrane unit using ANSI/NSF Standard 60 certified cleaning chemicals and the following procedure:

    a. Perform a flush of the pressure vessels using clean RO permeate or dechlorinated potable water;
    b. Start recirculation of cleaning solution through the system;
        i. Allow low pH ~ 3, 1% citric acid cleaning solution to circulate through the system for approximately 1 hour while maintaining the solution at approximately 95°F;
        ii. Drain the RO unit
        iii. Collect waste and neutralize;
    c. Perform another flush of the system to remove any traces of the cleaning solution;
    d. Repeat the recirculation of the cleaning solution with 0.1% Caustic soda at a pH of 12 for 1 hour at 95°F through the system; and
    e. Flush the system with dechlorinated tap water or permeate.

GENERAL INFORMATION

The pilot study report contained data supporting the use of HF MF or HF UF followed by RO membranes. Two treatment trains were pilot tested:

1. Pall Microza® UNA-620A HF MF followed by Toray TML 10 RO membranes; and
2. Siemens L20V HF UF membranes followed by Hydronautics BW30LE RO membranes.

We have not received all the necessary information to review the Siemens and Hydronautics pilot data, thus only the Pall and Toray data has been reviewed. If you would like us to review the Siemens and Hydronautics pilot data please provide the following:

1. The volume of filtrate water used in each of Siemens maintenance washes (MW);
2. The source of the makeup water for maintenance washes; RO permeate UF filtrate or another source;
3. On page 13 of the Freese and Nichols report it is stated that the MW are performed every 24 hours. In the Siemens report it is stated that the MW are performed every 20 hours. Please report the time between MW; and
4. There is a 140-hour MW and the normal 20-hour MW. It is unclear if the 140-hour MW performed in addition to the 20-hour MW, thus 2 MW performed in that day, or if the 140-hour MW done instead of the 20-hour MW, thus only one MW performed that day. Please clarify.

The source water for the membrane pilot study was the effluent of the Big Spring WWTP. The WWTP is a hybrid plant, including both fixed film and suspended growth biological processes. Raw wastewater is first screened and degritted, then flows to a primary clarifier. Primary effluent then proceeds to a single rock media trickling filter for biological stabilization and then is pumped to the aeration basin for additional biological treatment. The contents of the aeration basin flow to the final clarifier where the active biomass is separated from the treated effluent and recycled to the aeration basin. The effluent is chlorinated and then passes through a sand filter. The filtered effluent containing the chlorine residual was the source water for the pilot study. The effluent of the WWTP is subject to permit number TPDES 10069-001.

This letter is not to be construed as approval to construct for the proposed membrane filtration facility. This letter is only to address acceptance of the pilot study report. Please complete a copy of the Public Water System Plan Review Submittal Form for review of improvements to this surface water source. Every blank on the form must be completed to minimize any delays in review of your project. The document is available on our web site at the address shown below.

http://www.tceq.state.tx.us/assets/public/permitting/watersupply/ud/forms/10233.pdf

This exception for the innovative source approval is subject to periodic review and may be revoked or amended if warranted. All conditions contained in this letter are site-specific minimum operation, design, reporting, calibration and record keeping requirements for the CRMWD proposed reclamation facility as specified in §290.39(l)(4). Failure by the CRMWD reclamation facility to comply with these conditions can result in the water produced no longer being able to be used as a source of raw water for public drinking water facilities.

If you have any questions or need further assistance, please contact Ms. Marlo Wanielista Berg, P.E. of my staff at mberg@tceq.state.tx.us, or at (512) 239-6967.

Sincerely,

Cari-Michel La Caille, Assistant Director
Water Supply Division
Texas Commission on Environmental Quality

CML/mew

cc: Mr. John Grant, General Manager, Colorado River Municipal Water District, PO Box 869, Big Spring, TX 79721- 0869
The Honorable Russ McEwen, Mayor, City of Big Spring, 310 Nolan Street, Big Spring, TX 79720-2657
The Honorable Francene Allen Noah, Mayor, City of Snyder, PO Box 1341, c/o Darrell Callahan Water Superintendent, PO Box 1341, Snyder, TX 79550-1341
The Honorable W. Wesley Perry, Mayor, City of Midland, PO Box 1152, Midland, TX 79702-1152
The Honorable Larry Melton, Mayor, City of Odessa, PO Box 4398, Odessa, TX 79760-4398
The Honorable Lester Baker, Mayor, City of Stanton, PO Box 370, Stanton, TX 79782-0370

Bcc: TCEQ Midland Regional Office – R7
Ms. Vera Poe, P.E., Team Leader, Utilities Technical Review Team – MC159
Ms. Alicia Diehl, PhD, Team Leader, Drinking Water Quality Team – MC155
Mr. Kelly Holligan, Special Assistant, Water Quality Division – MC148

WATEREUSE RESEARCH

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