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AN NWRI WHITE PAPER

Regulatory Aspects of Direct Potable Reuse in California

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About NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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Definitions

As used in this document, the water reuse-related terms listed below have the following meanings:

Direct potable reuse: The introduction of recycled water directly into a potable water distribution system downstream of a water treatment plant (this is the most widely-used definition). Other schemes that may also be considered as direct potable reuse are discussed in Section 3 of this white paper.

Environmental buffer: A natural water body (e.g., reservoir, river, or lake) that physically separates product water from a water recycling facility and the intake to a drinking water plant. For groundwater recharge, an aquifer and/or soil act as the environmental buffer that separates product water from a water recycling facility and a potable water extraction well.

Indirect potable reuse: Augmentation of a drinking water source (surface water or groundwater) with recycled water followed by an environmental buffer that precedes normal drinking water treatment.

Municipal wastewater: Domestic wastewater that may include commercial and industrial wastewater.

Nonpotable reuse: All water recycling applications that do not involve any form of potable reuse.

Planned indirect potable reuse: The discharge of recycled water to a drinking water source of supply with the intended purpose of augmenting the potable supply.

Recycled water: Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for beneficial purposes. California law (Section 13050 [n] of California Water Code) defines recycled water as water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefore considered a valuable resource [State Water Resources Control Board, 2010].

Recycling criteria: The levels of constituents of recycled water, and means for assurance of reliability under the design concept which will result in recycled water safe from the standpoint of public health, for the uses to be made [State Water Resources Control Board, 2010].

Unplanned indirect potable reuse: The discharge of treated municipal wastewater water to a drinking water source of supply as a disposal method rather than as a purposeful means of augmenting a potable water source of supply.

Water reclamation: The act of treating municipal wastewater to make it acceptable for reuse.

Water recycling: The use of treated municipal wastewater (recycled water) for a beneficial purpose.

1. Executive Summary

California's water supplies are derived from a variety of sources, including local and imported surface water, groundwater, desalinated seawater, and recycled water. Water resources are becoming limited, and new strategies are needed to satisfy future water demands. The use of recycled water for nonpotable applications has played an integral role in helping to meet the state's water demands since the early 1900s, and planned indirect potable reuse (IPR) by groundwater recharge of potable aquifers has been practiced in the state since 1962. Direct potable reuse would provide greater flexibility than IPR to augment some potable water supplies, and there is a growing interest among water utilities, water-related associations, and environmental advocacy groups in California to pursue an assessment of research needs, regulatory requirements, public acceptance, and other factors that need to be addressed for direct potable reuse to be considered in the future.

The use of recycled water for direct potable reuse raises a number of issues and requires a careful examination of regulatory requirements, health concerns, project management and operation, and public perception. The purpose of this white paper is to identify issues that would need to be addressed by regulatory agencies and utilities in California interested in pursuing direct potable reuse as a viable option in the future. To date, no regulations or criteria have been developed or proposed for direct potable reuse in California, and the practice generally has been deemed unacceptable in the past by regulatory agencies in the state due to a lack of definitive information related to public health protection. However, direct potable reuse may be a reasonable option to consider based upon significant advances in treatment technology and monitoring methodology in the last decade, health effects data from IPR projects and direct potable reuse demonstration facilities, and water quality and treatment performance data generated at operational IPR projects in the state that have advanced wastewater treatment.

Although there is limited experience with direct potable reuse (there is only one direct potable reuse project in the world), several epidemiological and toxicological health effects studies have been conducted in the last 30 years on recycled water generated at IPR projects and at direct potable reuse demonstration facilities to evaluate the public health implications of potable reuse. While none of the studies indicated that drinking recycled water would present health risks greater than those attributable to existing water supplies, the data from the studies are sparse and the limited nature of the toxicological and epidemiological techniques used for many of the studies prevent extrapolation of the results to potable reuse projects in general. However, some health experts are of the opinion that – if multiple treatment barriers are in place such that all water quality criteria for constituents of concern are reliably met and the chemical composition of the water is well understood – the need for toxicological characterization of the water is low and may not be needed for direct potable reuse projects.

Assessment of the safety of using recycled water for direct potable reuse must consider several factors, such as microbial and chemical quality of the product water, treatment performance and reliability, multiple barriers, monitoring capability, and system operation and management. For direct potable reuse to proceed in California, these factors (and others) present issues that would need to be resolved by regulatory agencies during the development of regulations, policies, and/or guidelines. The principal state agencies involved in regulating water recycling in

California are the California Department of Public Health (CDPH), State Water Resources Control Board (SWRCB), and Regional Water Quality Control Boards (RWQCBs).

Because CDPH serves as the main public health protection arm of state government as it relates to both recycled water and public water systems, it would have the authority and responsibility for determining criteria deemed necessary to ensure the safety of direct potable reuse. Although CDPH has developed draft regulations for IPR via groundwater recharge, direct potable reuse presents complex issues due, in part, to the fact that there would be no environmental buffer prior to the introduction of recycled water directly into a drinking water system after treatment at a water recycling facility. Some key regulatory issues that would need to be resolved should direct potable reuse be considered in the future include:

- *Definition of direct potable reuse*. There needs to be a distinction between what constitutes direct potable reuse versus indirect potable reuse.
- *Environmental buffer*. An environmental buffer is one of the multiple barriers required for IPR projects. Direct potable reuse projects would have no environmental buffer. Means to compensate for the loss of an environmental barrier will likely be required.
- *Multiple barriers*. The number, type, and reliability of treatment processes necessary to ensure that constituents of concern are reduced to acceptable levels in the product water would need to be determined.
- *Dilution*. It is not known if dilution would be required as an added safety factor.
- *Monitoring*. Increased monitoring of treatment process efficiency and product water would likely be required for direct potable reuse, as well as monitoring techniques that provide feedback in real time or at least very rapidly. Real-time online monitoring is desirable but, with the exception of monitoring for surrogates such as total organic carbon (TOC) and electrical conductivity, may not be achievable with existing technology.
- *Assessment of health risks*. It is not clear what type and level of public health risk assessment would be required for direct potable reuse.
- *Independent Advisory Panels*. It is not known if CDPH would require scientific peer review of direct potable reuse projects by independent advisory panels.
- *Applicability of existing CDPH regulations*. An evaluation needs to be made of how existing drinking water statutes, regulations, policies, and permitting processes would apply to direct potable reuse projects.
- *Regulatory responsibility*. The SWRCB, RWQCBs, and CDPH may need to consider clarification of the point at which the water makes the transition from Water Code to Health and Safety Code authority.
- *Communication management*. A communication system for the timely sharing of information must be developed to enable all operating and regulatory agencies involved in direct potable reuse to work together to avoid the distribution of unsafe drinking water.

Some of the above-mentioned issues are interrelated, and the resolution of those issues would need to be considered in the context of how other issues may be affected.

2. Introduction

California's water supplies are derived from a variety of sources, including local and imported surface water, groundwater, desalinated seawater, and recycled water. Water resources are becoming limited due to population increases, droughts, and reductions in imported water allocations. Furthermore, global climate change may exacerbate the problem in the future. Water recycling for nonpotable and indirect potable applications has played an integral role in helping to meet the state's water demands. California's water needs will continue to increase in future years, and new sources of supply are needed to satisfy future water demands.

Planned IPR via the augmentation of groundwater supplies by either surface spreading basins or direct injection has been practiced in California since 1962, and there are several such projects in the state. As indicated in Table 1, the number of IPR projects has increased substantially in the last five years.

Table 1: Indirect Potable Reuse Projects in California

Project/Agency	Type of Indirect Potable Reuse	Start-Up Date
Montebello Forebay Groundwater Recharge Project, Water Replenishment District of Southern California	Groundwater recharge via surface spreading basins	1962
Water Factory 21, Orange County Water District (replaced by the Groundwater Replenishment System in 2008)	Seawater barrier via direct injection	1976
West Coast Basin Barrier Project, West Basin Municipal Water District and Los Angeles County Department of Public Works	Seawater barrier via direct injection	1996
Ely Basin Project, Inland Empire Utilities District (now part of the Chino Basin Groundwater Recharge Project)	Groundwater recharge via surface spreading basins	1997
Alamitos Barrier Project, Los Angeles County Department of Public Works, Water Replenishment District of Southern California, and City of Long Beach	Seawater barrier via direct injection	2005
Harbor Water Recycling Project Dominguez Gap Project, City of Los Angeles	Seawater barrier via direct injection	2006
Chino Basin Groundwater Recharge Project, Inland Empire Utilities Agency	Groundwater recharge via surface spreading basins	2005
Groundwater Replenishment System, Orange County Water District	Groundwater recharge via direct injection and surface spreading basins	2008

CDPH has published draft IPR regulations related to groundwater recharge [California Department of Public Health, 2008]. While the draft groundwater recharge regulations do not address direct potable reuse, several requirements in the draft regulations may be applicable to direct potable reuse as well, although it is likely that some requirements would be modified to be more restrictive.

For IPR via augmentation of water supply reservoirs, it is stated in the California Health and Safety Code (Section 116551) that CDPH shall not issue a permit to a public water system or amend a valid existing permit for the use of a reservoir as a source of supply that is directly augmented with recycled water unless CDPH performs an engineering evaluation of the proposed treatment technology and finds that the proposed technology will ensure that the recycled water meets all applicable primary and secondary drinking water standards and poses no significant threat to public health [State of California, 2009]. Although there currently are no existing planned IPR projects in California involving surface water augmentation and no draft regulations have been developed by CDPH to date, this type of potable reuse is currently being evaluated.

The potential of using recycled water for direct potable reuse is being raised in California in response to the need for new water supplies in water-scarce areas. Direct potable reuse would provide greater flexibility to augment potable water supplies without the need for underground or surface environmental buffers and could result in significant environmental benefits (e.g., reduced discharge of wastewater to the ocean or surface waters and reduced extractions of water from underground aquifers and surface waters). However, direct potable reuse raises a number of issues and requires a careful examination of treatment technology, regulatory requirements, health concerns, project management and operation, and public perception and acceptance. To date, no regulations or criteria have been developed for direct potable reuse anywhere in the U.S.

The purpose of this white paper is to identify specific issues associated with direct potable reuse that would need to be addressed by regulatory agencies (and utilities interested in pursuing direct potable reuse projects) in California if direct potable reuse is to be considered for implementation in the future. This white paper is particularly focused on identifying measures and information needed to ensure public health protection. It is not intended to identify or recommend specific regulatory requirements that may be imposed on direct potable reuse projects. While it is recognized that public acceptance is a significant concern that would have to be addressed, this white paper does not examine the issue of public acceptance. A separate white paper sponsored by WateReuse California is being prepared to address this issue.

3. Direct Potable Reuse Versus Indirect Potable Reuse

The key distinction between indirect and direct potable reuse is that direct potable reuse does not include temporal or spatial separation, such as natural (environmental) buffers between the introduction of recycled water and its distribution as drinking water. IPR is usually defined as the augmentation of a drinking water source (surface water or groundwater) with recycled water, followed by an environmental buffer that precedes normal drinking water treatment, whereas direct potable reuse is generally defined as the introduction of recycled water directly into a potable water distribution system downstream of a water treatment plant. There are other schemes that may also be considered as direct potable reuse, and some alternative definitions for direct potable reuse include the following:

- "Direct potable reuse of reclaimed water, sometimes called 'pipe-to-pipe' or 'flange-to flange,' describes the situation where reclaimed water is piped directly into the potable water treatment facilities or distribution system" [California Potable Reuse Committee, 1996].
- "*Direct potable water reuse* is the immediate addition of reclaimed wastewater to the water distribution system" [National Research Council, 1998]. It is further stated that "…with direct potable reuse, the water is reused with no intervening environmental buffer."
- "Direct potable reuse. 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. Introduction could either be into a service reservoir or directly into a water pipeline" [Metcalf & Eddy, Inc., 2007].
- "'Direct potable reuse' means the use of recycled water for drinking purposes directly after treatment" [California State Senate, 2010]. This definition is from Senate Bill No. 918 (SB 918), which was introduced on February 1, 2010, and amended on March 17, 2010. SB 918 is an act that would amend the Water Code to require CDPH to – among other things – investigate the feasibility of developing uniform water recycling criteria for direct potable reuse and provide a final report to the Legislature by December 31, 2015.

While there is some variation in the above definitions of direct potable reuse, they all conform to the interpretation that direct potable reuse does not include an environmental buffer. An environmental buffer allows time for mixing, dilution, and natural physical, chemical, and biological processes to improve the quality of the recycled water – as well as time to take corrective action in the event that the recycled water does not meet all water quality requirements. Thus, in differentiating between direct potable reuse and IPR from a regulatory standpoint, it must be determined what constitutes an environmental buffer (e.g., required detention time, level of dilution, or a specific measure of water quality improvement). Additional effort is needed to develop a set of definitions that unambiguously address all potable reuse situations. This important issue would have to be resolved by CDPH should it decide to pursue criteria for direct potable reuse.

4. Background and Extent of Direct Potable Reuse

California has primacy to administer the U.S. Environmental Protection Agency's Clean Water Act and Safe Drinking Water Act. However, neither of these acts directly apply to potable reuse. There are no federal regulations in the U.S. that contemplate direct potable reuse (or any recycled water application), and the practice generally has been deemed unacceptable in the past by regulatory agencies in California and nationally-recognized public health professionals in the water and wastewater industries due to a lack of definitive information related to public health protection. A report prepared by the California Potable Reuse Committee in 1996 for the California Department of Health Services (now CDPH) and the California Department of Water Resources stated that "The Committee concludes that the direct potable reuse of reclaimed water is unacceptable and should not be permitted at this time … At present this application is unacceptable even with advanced treatment because of the lack of reliable real-time water quality monitoring methods and lack of time to react to accidental emergencies or system upsets" [California Potable Reuse Committee, 1996]. Further, a 1998 National Research Council report stated that "Direct use of reclaimed wastewater for human consumption, without the added protection provided by storage in the environment, is not currently a viable option for public water supplies" [National Research Council, 1998].

In the last decade, however, there have been significant advances in treatment technology (e.g., improvements in membrane performance, the use of advanced oxidation processes for the reduction of organic compounds, and the increasing use of ultraviolet radiation for disinfection) and analytical monitoring methodology (e.g., development of test methods for trace organic constituents – particularly endocrine disrupting compounds, pharmaceuticals, and ingredients in personal care products – and the ability to measure them at nanogram per liter or lower levels). In addition, recycled water quality data generated at several facilities in California and elsewhere that currently produce recycled water for IPR indicate that product water reliably meets all drinking water standards and California notification levels (notification levels are health-based advisory levels established by CDPH for chemicals in drinking water that lack maximum contaminant levels [MCLs]) for unregulated chemicals. As a result, there is a growing interest by some water utilities, water-related associations, and environmental engineering professionals in California in pursuing an assessment of research needs, regulatory requirements, and other factors that need to be addressed for direct potable reuse to be considered in the future.

Direct potable reuse currently is not practiced anywhere in the U.S. It was implemented on an emergency basis in Chanute, Kansas, for a five-month period in 1956 during an extreme drought circumstance and was evaluated in Denver, Colorado, during a demonstration project from 1985 to 1992. The only known existing direct potable reuse facility in the world is located in Windhoek, Namibia.

4.1 Chanute, Kansas, Emergency Direct Potable Reuse

Chanute, Kansas, is located adjacent to the Neosho River, which serves as its drinking water supply source. During a severe drought from 1952 to 1957, the City of Chanute was plagued by intermittent water shortages. At the time, Chanute (population 12,000) used an average of about 1.4 million gallons per day (mgd) of potable water, with a maximum of about 2 mgd. The Neosho River ceased to flow in the summer of 1956. After considering several possible courses of action to take, city officials decided to recirculate effluent from the city's secondary treatment plant. The wastewater treatment processes were primary sedimentation, secondary treatment via trickling filters, and disinfection using chlorine.

The Neosho River was dammed below the sewage treatment plant outfall, and treated effluent backed up to the drinking water supply intake. The impounding reservoir for the potable water treatment plant provided a 17-day retention time and served as an effective waste stabilization pond. Drinking water treatment consisted of softening with the addition of alum, lime, soda ash, chlorination, recarbonation, sedimentation, rapid sand filtration, and chlorination. In October 1956, the city mixed treated sewage with water stored in the river channel behind the water treatment plant dam. The 17-day retention time in the intake pool substantially reduced concentrations of biochemical oxygen demand, chemical oxygen demand, total and ammonia nitrogen, and detergents. The treated sewage was reused for five months, recirculating it from eight to 15 times.

The treated water had several objectionable characteristics. It had a pale yellow color and an unpleasant musty taste and odor. It was high in chlorides, total solids, and organic matter, and agitation of the water caused frothing due to the high concentration of alkyl benzene sulfonate [Metzler et al., 1958]. Initial public acceptance of the water was good, perhaps because the citizens knew that their raw water supply normally included diluted secondary-treated wastewater from seven upstream communities. Public reaction became more adverse when articles appeared in the local newspapers, at which time bottled water sales flourished. Although the public accepted the use of treated wastewater for potable reuse as a short-term emergency measure, a majority rejected the water for human consumption.

4.2 Denver, Colorado, Direct Potable Reuse Demonstration Study

Although direct potable reuse currently is not practiced anywhere in the U.S., extensive research focusing on direct potable reuse was conducted at Denver, Colorado. In 1968, the U.S. Environmental Protection Agency allowed Denver to divert water from the Blue River on the west side of the Continental Divide, on the condition that the city examine a range of alternatives to satisfy projected future demands of a growing metropolitan area. The Denver Direct Potable Water Reuse Demonstration Project was designed 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.

In 1979, plans were developed for the construction of a demonstration facility to examine the cost and reliability of various treatment processes. A 1.0-mgd demonstration plant (reduced to 0.1 mgd during later stages of treatment) began operation in 1985 and, during the first three years, several process trains were evaluated [Lauer, 1993]. Data from the evaluation period were used to select the optimum treatment sequence, which was used to produce samples for a two-year animal feeding health-effects study. The influent to the potable reuse demonstration facility was unchlorinated secondary effluent from the Denver Metropolitan Wastewater Reclamation District's regional wastewater treatment facility. Two different advanced treatment trains were selected. One included high-pH lime clarification, recarbonation, multimedia filtration, ultraviolet radiation (UV), granular activated carbon adsorption (GAC), reverse osmosis (RO), air stripping, ozonation, and chloramination. The other treatment train was identical to that just described, with the only difference being that ultrafiltration was used instead of RO.

Comprehensive analytical studies defined the product water quality in relation to standards that existed at the time and to Denver's potable supply. The product water was of a higher quality than the Denver drinking water for all chemical, physical, and microbial parameters tested except for nitrogen, and alternative treatment options were demonstrated for nitrogen removal [Lauer and Rogers, 1998]. The final health effects study, which used organic residue concentrates in a two-year *in vivo* chronic/carcinogenicity toxicological study of rats and mice, did not reveal any adverse health effects associated with either water [Lauer, 1993; Condie et al., 1994].

4.3 Windhoek, Namibia, Direct Potable Reuse System

The only known example of direct potable reuse occurs in Windhoek, Namibia, where highly treated recycled water is put directly into the drinking water system. Water resources are limited for this city, which has a population of approximately 250,000. The average rainfall is 14.4 inches while the annual evaporation is 136 inches, and the city relies on three surface reservoirs for 70 percent of its water supply. First implemented in 1968 with an initial flow of 1.3 mgd [Haarhof and Van der Merwe, 1996], the Goreangab water reclamation plant – which receives secondary effluent from the Gammans wastewater treatment plant – has been upgraded through the years to its current capacity of 5.5 mgd. Industrial and potentially toxic wastewater is diverted from the wastewater entering the plant. There have been four distinct treatment process configurations since 1968. The current treatment train was placed in operation in 2002 and includes the following processes:

- Primary sedimentation.
- Activated sludge secondary treatment with nutrient removal.
- Maturation ponds (4 days).
- Powdered activated carbon, acid, polymers (used when required).
- Pre-ozonation.
- Coagulation/flocculation with ferric chloride ($FeCl_3$).
- Dissolved air flotation.
- Rapid sand/anthracite filtration preceded by potassium permanganate ($KMnO_4$) and sodium hydroxide (NaOH) addition.
- Ozonation preceded by hydrogen peroxide (H_2O_2) addition.
- Biological and granular activated carbon.
- Ultrafiltration (0.035-micrometer [μm] pore size).
- Chlorination.
- Stabilization with NaOH.
- Blending prior to distribution.

Blending occurs at two locations. The first blending takes place at the Goreangab water treatment plant, where recycled water is blended with conventionally treated surface water. This mixture is then blended with treated water from other sources prior to pumping to the distribution system. The percentage of recycled water in the drinking water has been relatively low through the years, averaging 4 percent between 1968 and 1991 [Odendaal et al., 1998]. The upgraded plant provides up to 35 percent of the potable water supply during normal periods, but is allowed to supply up to 50 percent of the potable water requirements of Windhoek during certain times of the year when natural water supplies are limited [Lahnsteiner and Lempert, 2005; du Pisani, 2005]. Chlorine is added to maintain a residual in the distribution system. Extensive microbial and chemical constituent monitoring is performed on the product water, with several constituents being monitored continuously using online analytical instrumentation.

In vitro toxicological testing has included the Ames test, urease enzyme activity, and bacterial growth inhibition, while *in vivo* testing included water flea lethality and fish biomonitoring (guppy breathing rhythm). An epidemiological study (1976 to 1983) of cases of diarrheal diseases, jaundice, and deaths found no relationships to drinking water source [Isaacson and Sayed, 1988; Law, 2003; Odendaal et al., 1998]. Due to the limitations of the epidemiological studies that have been performed at Windhoek and its unique environment and demographics, the results of the studies cannot be extrapolated to other populations in industrialized countries [National Research Council, 1998].

In the beginning, there was some initial public opposition to the project, but this has gradually faded, and no public opposition has surfaced in recent years.

5. Health Effects Studies

Epidemiological studies of exposed populations are intended to provide information as to whether the consumption of recycled water is associated with any adverse effects on human health due to microbial pathogens or chemical contaminants. Toxicological studies evaluate chemical hazards to human health using live animals (other than humans), usually mammals such as rats and mice, or testing of lower life forms such as bacteria in cell cultures. Testing chemicals in animals is called *in vivo* testing, while testing chemicals in lower life forms is called *in vitro* testing. Whereas *in vitro* assays with bacterial or mammalian tissue or cell cultures can test effects on single systems, *in vivo* whole animal testing may help to identify the integrated effects of the test material on complex biological systems.

Some experts have stated in the past (when treatment technology and analytical monitoring methodology were not as advanced as they are today) that the use of laboratory animals is essential to the assessment of possible health effects associated with the consumption of recycled water [National Research Council, 1982; State of California, 1987]. More recently, a report published by the National Research Council in 1998 stated that “The requirements for toxicological testing of water derived from an alternative source should be inversely related to how well the chemical composition of the water has been characterized. If very few chemicals or groups of chemical groups of concern are present, and the chemical composition of the water is well understood, the need for toxicological characterization of the water is low and may be neglected altogether. Conversely, if a large fraction of potentially hazardous and toxicologically uncharacterized organic chemicals is present, then toxicological testing will provide an additional assurance of safety” [National Research Council, 1998]. The report states that toxicological testing, if necessary, should be conducted on live animals for a significant period of their lifespan.

Several epidemiological and toxicological health effects studies have been conducted in the last 30 years to evaluate the public health implications of direct potable reuse and IPR. A 1998 National Research Council report on potable reuse states that the data from these studies are sparse and the limited nature of the toxicological and epidemiological techniques used for many of the studies prevents extrapolation of these results to potable reuse projects in general [National Research Council, 1998]. The National Research Council report further states that only one set of epidemiological studies (those conducted in Los Angeles County for the Montebello Forebay groundwater recharge project) has been conducted in a setting that is useful for assessing possible health effects in other locations that use recycled water. These studies used an ecologic approach, which is an appropriate first step, but negative results from such studies do not necessarily prove the safety of recycled water for human consumption. Case-control studies or retrospective cohort studies should be undertaken to provide information on health outcomes and exposure while controlling for other important risk factors [National Research Council, 1998].

Health effects data from some existing and demonstration potable reuse facilities, including the only known direct potable reuse project (Windhoek, Namibia), are presented in Table 2. Most of the health effects studies listed in Table 2 were conducted more than 10 years ago, and the methods used for some of those historical studies should be considered when evaluating the current value of the findings of those studies.

Table 2: Summary of Potable Reuse Health Effects Studies

Study Location	Recycled Water Treatment	Types of Studies	Major Findings
Windhoek, Namibia (Direct potable reuse project) [Isaacson and Sayed, 1998]	Secondary treatment, sand filtration, GAC, chlorine disinfection	Epidemiological Toxicological (*in vitro* and short-term *in vivo*)	No relationship was observed between drinking water source and cases of diarrheal disease. *In vitro* tests included the Ames test, urease enzyme activity, and bacterial growth inhibition. In vivo tests included water flea lethality and fish biomonitoring (guppy breathing rhythm).
Montebello Forebay, Los Angeles County [Frerichs et al., 1983; Nellor et al., 1984; Sloss et al., 1996; Sloss et al., 1999]	Secondary treatment, filtration, chlorination-dechlorination, soil aquifer treatment	Epidemiological Toxicological (*in vitro*)	No relationship was observed between percent recycled water in wells and observed mutagenicity or residues isolated from wells. Epidemiological studies did not demonstrate any higher rates of cancer, mortality, infectious disease, or adverse birth outcomes in the population ingesting recycled water.
Potomac Estuary Experimental Water Treatment Plant, Washington. D.C. [National Research Council, 1984]	Secondary treatment, aeration, flocculation, sedimentation, predisinfection, filtration, GAC, post-disinfection	Toxicological (*in vitro*)	Ames test showed low level of mutagenic activity, with recycled water showing less activity than finished drinking water. Cell transformation test showed a small number of positive samples with no difference between recycled water and finished drinking water.
Denver, Colorado, potable water reuse demonstration plant [Lauer, 1993]	Secondary treatment, lime treatment, recarbonation, filtration selective ion exchange, GAC, ozonation, RO, air stripping, chlorination	Toxicological (*in vivo*)	No treatment-related effects were observed in toxicological tests using organic residue concentrates for *in vivo* studies.

Study Location	Recycled Water Treatment	Types of Studies	Major Findings
San Diego, California, Total Resource Recovery Project [Western Consortium for Public Health, 1996; Western Consortium for Public Health, 1997]	Secondary treatment, coagulant addition, filtration, UV disinfection, RO, air stripping, GAC	Toxicological (*in vitro* and *in vivo*) Neural tube defects study	Ames test showed some mutagenic activity, but recycled water showed less mutagenic activity than drinking water. Micronucleus test showed positive results only at high doses (600x) in both waters. *In vivo* fish biomonitoring (28-day bioaccumulation and swimming tests) showed no positive results. No estimated health risk from chemicals identified based on use of reference doses and cancer potencies
Tampa, Florida, Water Resource Recovery Project (Pilot plant) [Hemmer et al., 1994; Pereira et al., Undated)]	Secondary treatment, filtration, denitrification, lime treatment, recarbonation, filtration, GAC, ozonation	Toxicological (*in vitro* and *in vivo*)	No mutagenic activity was observed in Ames *Salmonella*, micronucleus, and sister chromatid exchange tests. All *in vivo* tests were negative except for some fetal toxicity exhibited in rats, but not mice, for the advanced wastewater treatment sample
Singapore Water Reclamation Study [Khan and Roser, 2007]	Secondary treatment, microfiltration, RO, UV disinfection,	Toxicological (*in vivo*)	Toxicological tests using fish indicated no estrogenic or carcinogenic effects. Toxicological tests using mice did not show any tissue abnormalities or health effects
Essex & Suffolk Water Langford Recycling Scheme, United Kingdom [Walker, 2000]	Secondary treatment, coagulant and polymer addition, sedimentation, nitrification/denitrification in biologically aerated filter, UVdisinfection	Toxicological (*in vivo*)	Toxicological tests using fish indicated no significant estrogenic effects

6. Treatment Technology, Constituents of Concern, and Monitoring Needs

Constituents of concern for direct potable reuse include both microbial pathogens and chemicals that may pose health risks. In addition, other parameters, such as turbidity and pH, are subject to regulatory limits. Municipal wastewater contains a myriad of microbial pathogens (bacteria, parasites, and viruses) and chemical contaminants (e.g., heavy metals, pharmaceutically active compounds, endocrine disrupting compounds, and ingredients in personal care products) that would need to be reduced to extremely low or immeasurable levels in recycled water used for direct potable reuse. Advanced wastewater treatment processes are available that may be suitable to reliably accomplish this task, although assurance that the product water is consistently “safe” for consumption is another matter that depends to a large degree on monitoring and its attendant capabilities.

Due, in part, to the fact that microbial pathogens present acute health effects, the removal, destruction, or inactivation of pathogens is essential prior to distributing recycled water as a potable supply. Traditional microbial monitoring methods are often labor-intensive and time consuming. For example, it can take up to four weeks to type and quantify viruses from water samples. The current state-of-the-art has not been developed to the point where rapid, online monitoring techniques for microbial pathogens and/or indicator organisms are available or have been proven to be reliable, and the development of such techniques is desirable.

Since there would be no environmental buffer in direct potable reuse (and, thus, no additional improvement in water quality that could occur were an environmental buffer present or adequate retention time after treatment to provide time to receive microbial quality data prior to distribution of the water using currently-used monitoring methodology), it would be advantageous, and perhaps required, to have real-time online monitoring such that microbial water quality could be determined almost instantaneously. There also needs to be a means for immediate response to prevent the release of product water into a drinking water supply in the event that it is determined to be of unacceptable microbial quality.

It may be possible to ameliorate concerns relating to the microbial quality of the product water through the use of sufficient multiple treatment barriers that are adequately instrumented to rapidly detect changes in treatment performance, thus reducing or eliminating the need for real-time monitoring of the product water. Criteria for “sufficient” multiple barriers would have to be developed and the effectiveness of the barriers validated against the criteria.

A similar situation exists for chemical constituents of concern. Treatment technology has progressed to the point where recycled water of almost any quality can be produced; however, as with microbial pathogens, it would be desirable (and perhaps required) to have real-time online monitoring for at least some specific chemicals and/or surrogates. However, as with microbial pathogens and indicator organisms, the current state-of-the-art has not been developed to the point where rapid, online monitoring techniques for chemical constituents of concern or surrogates (except for a few surrogates, such as TOC and electrical conductivity) are available or have been proven to be reliable, and the development of such techniques is desirable. In lieu of real-time monitoring, methodology that provides very rapid – but not necessarily immediate – feedback for parameters of interest would be advantageous.

It could be argued that real-time monitoring is not as essential for many chemical constituents as for microbial pathogens because many chemical constituents present chronic health effects that are dependent on extended exposure to health-significant concentrations. Thus, for some chemicals, it may be appropriate to rely on standard analytical drinking water methodologies that do not produce immediate results. For others, however, there may be a need for a more rapid turn-around time for analytic results.

The development and use of new online monitoring methods for specific chemicals, surrogates, or other parameters that could continuously determine treatment effectiveness may reduce the need for real-time monitoring of constituents of public health concern, especially for chemicals that present health concerns resulting from chronic exposure. Perhaps a rigid protocol for preventing improperly-treated recycled water from entering a potable water distribution system that includes multiple treatment barriers adequately instrumented to rapidly detect changes in treatment performance and the use of surrogate monitoring could make up for the loss of time to identify and react to a treatment process failure. There also needs to be a means for immediate response to prevent the release of product water into a drinking water supply in the event that it does not meet all quality requirements.

Additional monitoring requirements for chemical constituents of concern or surrogates may be required by CDPH should direct potable reuse be considered acceptable in the future, based (in part) on the findings of a SWRCB-sponsored panel of experts convened in 2009 to guide future actions relating to constituents of emerging concern (CECs) in recycled water. A panel report describing the current state of knowledge regarding the risks of CECs to public health and the environment is scheduled for completion in 2010 [State Water Resources Control Board, 2009].

7. Multiple Barriers

The multiple barrier concept is based on the principle of establishing a series of barriers to preclude the passage of microbial pathogens and harmful chemical constituents into the water system to the greatest extent practical. CDPH requires that multiple barriers be incorporated in the design and operation of water reclamation facilities that produce recycled water for IPR to augment potable water supplies. Such barriers may include the following:

- Source control programs designed to prevent the entrance of constituents of concern into the wastewater collection system that will inhibit treatment or may preclude use of the water.
- A combination of treatment processes (which may include both conventional and advanced treatment processes) where each process provides a specific level of constituent reduction.
- Constituent monitoring at various points of treatment.
- Design and operational procedures to rapidly detect abnormalities in treatment process performance so that corrective action can be taken.
- Environmental buffers that can provide dilution, natural attenuation of contaminants, and retention time.

The advantage of the multiple barrier approach is that the probability that multiple processes will fail simultaneously is small, and the public would be provided a degree of protection even in the event that one of the barriers fails. An environmental buffer is considered by CDPH to be one of the necessary multiple barriers for IPR projects to provide additional treatment and time to take corrective action in the event that all water quality requirements are not met in the product water. The environmental buffer in an IPR project serves to isolate the public water system from an immediate concern, such as might be caused by the discharge of a toxic waste to the sewerage system or equipment or treatment problems at the wastewater treatment facility. Without this buffer, timely notification of problems (e.g., source water deterioration, treatment process operational failures, and inadequate water quality) becomes even more important. Such notification would need to address problems related to the final product water (drinking water), as well as at various points throughout the treatment process. For direct potable reuse, it may be necessary to compensate for the lack of an environmental buffer as one of the multiple barriers by increased treatment or redundancies in treatment and/or inclusion of real-time monitoring methodology for selected constituents. Another potential means of compensating for the lack of an environmental barrier would be to store the product water for a time period sufficient to receive monitoring results prior to release.

8. Regulatory Authority

The principal state regulatory agencies involved in water recycling in California are CDPH, the SWRCB, and the nine RWQCBs. In 1991, the SWRCB and RWQCBs were brought together with five other state environmental protection agencies under the newly crafted California Environmental Protection Agency (Cal/EPA). Cal/EPA was created in 1991 by Governor's Executive Order. Various boards (including the SWRCB and RWQCBs), departments, and offices were placed within the Cal/EPA "umbrella" to create a cabinet level voice for the protection of human health and the environment and to ensure the coordinated deployment of state resources. CDPH was not included in that reorganization and remains as a separate department under the California Health and Human Services Agency.

8.1 State Water Resources Control Board

The SWRCB is generally responsible for setting statewide water quality policy and considering petitions contesting RWQCB actions. The SWRCB is organized into five divisions encompassing three broad program areas and an administration function that supports not only the SWRCB, but also the nine RWQCBs. The Division of Water Quality is responsible for providing the statewide perspective on a wide range of water quality planning and regulatory functions, including the regulation of activities affecting the state's Porter-Cologne Water Quality Control Act programs. The Porter-Cologne Act establishes a comprehensive program for the protection of water quality and beneficial uses of water. It applies to surface waters, groundwater, and point and non-point sources of pollution.

The SWRCB's Division of Water Rights oversees water rights in the state. The elimination or reduction of current wastewater discharges to watercourses may present water rights issues that would need to be resolved if treated municipal wastewater is diverted for direct potable reuse.

8.1.1 Recycled Water Policy

The purpose of the SWRCB Recycled Water Policy is to provide direction to the RWQCBs, proponents of recycled water projects, and the public regarding the appropriate criteria to be used by the SWRCB and RWQCBs in issuing permits for recycled water projects [State Water Resources Control Board, 2009]. Although it does not directly address direct potable reuse, it describes permitting criteria that are intended to streamline the permitting of the vast majority of recycled water projects. The intent of this streamlined permit process is to expedite the implementation of recycled water projects. By prescribing permitting criteria, it is the SWRCB's intent to maximize consistency in the permitting of recycled water projects in California while also providing the RWQCBs sufficient authority and flexibility to address site-specific conditions. The policy also includes a goal to increase the use of recycled water over 2002 levels by at least 1 million acre-feet per year (afy) by 2020 and by at least 2 million afy by 2030.

CECs represent a challenging problem for regulators to address, owing to limited scientific knowledge about their sources, fates, and effects. The SWRCB's Recycled Water Policy attempts to incorporate the most current science on CECs into regulatory policies for use by various state agencies. The Recycled Water Policy states that regulatory requirements for recycled water "shall be based on the best available peer-reviewed science" and that the SWRCB, in consultation with CDPH, shall convene a "blue-ribbon" advisory panel to guide future actions relating to CECs [State Water Resources Control Board, 2009]. A CEC advisory panel has been established and will provide recommendations to the SWRCB and CDPH. Although the panel has been directed to consider CECs in the context of using recycling water for landscape irrigation and IPR via groundwater recharge, many the panel's findings will also apply to direct potable reuse. Under contract with the SWRCB and using advice from a diverse stakeholder group, the Southern California Coastal Water Research Project convened a "blue ribbon" panel of six experts in May 2009 to address the following questions:

- What are the appropriate constituents to be monitored in recycled water, and what are the applicable monitoring methods and detection limits?
- What toxicological information is available for these constituents?
- Would the constituent list change based on level of treatment? If so, how?
- What are the possible indicators (i.e., surrogates) that represent a suite of CECs?
- What levels of CECs should trigger enhanced monitoring in recycled, ground, or surface waters?

The panel is charged with reviewing the scientific literature and, within one year from its appointment, submitting a report to the SWRCB and CDPH describing the current state of scientific knowledge regarding the risks of CECs to public health and the environment. The panel has since been granted a one-month extension to submit its report. Within six months of receipt of the panel's report, the SWRCB (in coordination with CDPH) shall hold a public hearing to consider recommendations from staff and shall endorse the recommendations, as appropriate, after making any necessary modifications. The panel or a similarly constituted panel shall update the report every five years.

8.2 Regional Water Quality Control Boards

The nine RWQCBs are each semi-autonomous. Regional boundaries are based on – and consistent with – major watersheds. Each RWQCB makes water quality planning and regulatory decisions for its region. These decisions include issuing waste discharge requirements (discharge permits) or recommending Clean Water Act certification for activities affecting water bodies. Discharge of treated wastewater requires a National Pollutant Discharge Elimination System (NPDES) permit administered by the RWQCBs. Most RWQCB decisions can be appealed to the SWRCB.

With passage of the Porter-Cologne Water Quality Control Act in 1969, which is part of the California Water Code, the RWQCBs together became the principal state agencies with primary responsibility for the coordination and control of water quality. The RWQCBs regulate discharges under the Porter-Cologne Act primarily through the issuance of waste discharge requirements [State Water Resources Control Board, 2010]. The Water Code provides several means of enforcement, including cease and desist orders, cleanup and abatement orders, administrative civil liability orders, civil court actions, and criminal prosecution.

The SWRCB and RWQCBs promulgate and enforce narrative and numeric water quality standards to protect water quality. Also, the RWQCBs adopt and the SWRCB approves water quality control plans (Basin Plans). Basin Plans identify (designate) legally-binding beneficial uses of water for water bodies, assign water quality objectives (criteria) to protect those uses, and establish appropriate implementation programs.

Specific regulatory responsibilities affecting water reuse include:

- Approval of pollutant source control programs for wastewater collection systems.
- Issuance and enforcement of water reclamation requirements to producers and users of recycled water.
- Definition of beneficial uses of surface water and groundwater bodies through the establishment of water quality control plans.
- Regulation of operators of wastewater and water reclamation treatment plants.
- Water rights determinations regarding water reclamation.

8.3 California Department of Public Health

CDPH has statutory authority in two areas with respect to direct potable reuse. It regulates public water systems (drinking water purveyors) in accordance with the California Safe Drinking Water Act (Health and Safety Code Section 116270 et seq.) [State of California, 2009]. CDPH also develops and adopts water recycling criteria as required by Section 13521 of the Water Code, which states that "The State Department of Health Services (now CDPH) shall establish uniform statewide recycling criteria for each varying type of use of recycled water where the use involves the protection of public health" [State Water Resources Control Board, 2010].

9. California Department of Public Health Policies and Regulations

The regulations, policies, and guidance that CDPH has developed to carry out its statutory responsibilities with regard to potable reuse are briefly discussed below. CDPH responsibilities for drinking water regulation and recycling criteria are addressed together because the two activities overlap with IPR.

Public Water System (PWS) permits are issued to each producer or purveyor of drinking water serving a specified minimum number of connections as required by the California Health and Safety Code. The permit covers each source of water used by the system. The permit identifies the source site, construction, and contaminant threats. It establishes the treatment, operational, and monitoring requirements for the source. In the case of potable reuse, the use of recycled water as a source must be identified in the PWS permit. There are several regulations, draft regulations, and policies that CDPH uses in its current operations that would have to be considered in the development of any project involving direct potable reuse. Examples include:

- California Drinking Water Regulations.
- Drinking Water Source Assessment and Protection (DWSAP) Program.
- Policy Guidance for Direct Domestic Use of Extremely Impaired Sources (Memo 97-005).
- Water Recycling Criteria.
- California Recharge Reuse Draft Regulation.
- Proposed Framework for Regulating the Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation in California.
- Memorandum of Agreement Between the Department of Health Services and the State Water Resources Control Board on Use of Reclaimed Water.

9.1 California Drinking Water Regulations

Domestic Water Quality and Monitoring Regulations (California Code of Regulations, Section 64400 et seq.) [State of California, 2010] include maximum contaminant levels for chemicals, monitoring requirements, compliance determination procedures, and requirements for public notification in case of failure.

A Consumer Confidence Report is required annually for each PWS (California Code of Regulations, Section 64481) [State of California, 2010]. Each report shall contain information on the source of the water delivered, including:

- The type of water delivered by the water system (e.g., surface water, groundwater, and the commonly used name [if any] and location of the body of water).
- If a source water assessment has been completed, notification that the assessment is available, how to obtain it, the date it was completed or last updated, and a brief summary of the system's vulnerability to potential sources of contamination.

The report is intended to clearly communicate to the public the source of their water, threats to the source, and any water quality problems. If direct potable reuse becomes acceptable, it is likely that CDPH will require that the report identify direct potable reuse as a source in simple, unambiguous terms.

The Surface Water Treatment Rule (SWTR) (California Code of Regulations, Section 64650 et seq.) [State of California, 2010] is a set of regulations intended to control the pathogenic microorganisms found in surface sources by setting treatment requirements in lieu of MCLs. For example, the SWTR gives a credit of 3 logs (99.9 percent) reduction of *Giardia lamblia* cysts and 4 logs (99.99 percent) reduction of viruses through proper filtration and disinfection. Also, treatment must be sufficient to provide a 3-log (99-percent) reduction of *Cryptosporidium*. The regulations establish source sanitary survey, multi-barrier treatment, treatment design, operation, reliability, monitoring, reporting, and failure notification requirements. The regulation requires that the source be an approved surface water (i.e., a surface water or groundwater under the direct influence of surface water that has received permit approval from CDPH in accordance with sections 116525 through 116550 of the Health and Safety Code). Wastewater and recycled water are considered as surface water sources (as opposed to groundwater) because they are not protected from microbial contaminants that occur at the ground surface and, thus, must meet all surface water treatment requirements [Hultquist, 2010]. Since municipal wastewater is presumed to have much higher levels of microbial pathogens than conventional surface water sources, it may be appropriate to consider requiring a higher reduction of pathogens (as determined by the multi-barrier treatment provided) in recycled water used for potable purposes than is required by the SWTR. With regard to any potable reuse project, it is within CDPH's purview to decide at what point recycled water would be determined to be an approved source.

9.2 Drinking Water Source Assessment and Protection (DWSAP) Program

The document entitled "Drinking Water Source Assessment and Protection (DWSAP) Program" [California Department of Health Services, 1999] describes California's DWSAP Program and presents procedures for conducting drinking water source assessments. It was prepared in response to the 1996 reauthorization of the federal Safe Drinking Water Act, which included an amendment called the Source Water Assessment Program requiring states to develop a program to assess sources of drinking water and encouraging states to establish protection programs. Key elements of the program include protection area and zone delineation, inventory of possible contaminating activities, and vulnerability analysis. In response, the California Health and Safety Code was revised to require CDPH to develop and implement a source water assessment program to protect sources of drinking waster (California Health and Safety Code, Section 116762.60) [State of California, 2009].

Drinking water source assessment is the first step in the development of a complete drinking water source protection program. The assessment includes a delineation of the area around a drinking water source through which contaminants might move and reach that drinking water supply. It also includes an inventory of activities that might lead to the release of microbial or chemical contaminants within the delineated area. The assessment identifies potential sources of contamination for drinking water sources and helps determine source treatment and protection activities. This enables a determination to be made as to whether the drinking water source might be vulnerable to contamination. A source water assessment is required by CDPH prior to authorization of the source in a PWS permit. The permit conditions for approval of a domestic water source must address all sources of contamination identified in the DWSAP. Source protection, treatment, and monitoring requirements are imposed to address the threat of contamination. Extremely contaminated sources are routinely approved for use with appropriate conditions. The extent of the required protection, treatment, and monitoring is proportional to the contamination threat. Direct potable reuse would simply be an extension of this approach.

9.3 Policy Guidance for Direct Domestic Use of Extremely Impaired Sources

CDPH developed a policy in 1997 (Policy Memo 97-005, Policy Guidance for Direct Domestic Use of Extremely Impaired Sources) to address the need to consider a variety of contaminated water sources for drinking water use [California Department of Health Services, 1997]. Although CDPH was then faced with a number of groundwater cleanup projects for which the product water was being considered for domestic use, the policy was developed to cover a number of anticipated situations. The policy established criteria for impaired sources that were expected to capture the following: extremely contaminated groundwater; effluent dominated surface water; oilfield produced water; products of toxic site cleanup programs; and water that is predominantly recycled water, treated or untreated wastewater, or agricultural return water. The policy is not being used to evaluate IPR projects using groundwater recharge or surface water augmentation because the principles in the policy have been incorporated into guidance and draft regulations specific to those activities.

Two sections of the policy should be considered when evaluating whether this guidance might apply to direct potable reuse of municipal wastewater:

- Section 5 requires an evaluation of the risks of failure of a proposed treatment system and an assessment of potential health risks associated with a failure of a treatment process. This effort is envisioned to be an evaluation not only of the potential health risks, but also an evaluation of the potential risks/likelihood of treatment failure.
- Section 6 recommends the identification of alternatives to the use of the extremely impaired source and a determination of relative health risk to the community. A comparison of the alternatives to supplying water from a direct potable reuse facility might be reasonable to expect.

A quality control process similar to the Hazard Analysis and Critical Control Points (HACCP) system may be useful to help mitigate potential health risks associated with the failure of a treatment process. HACCP is a system that identifies and monitors specific parameters (microbial, chemical, or physical properties) at various locations in a treatment facility that can adversely affect the safety of a product – in this case, recycled water to be used for direct potable reuse. The HACCP system examines the entire treatment process, determines the critical control points, establishes the critical values that define stable and acceptable operations, and identifies monitoring procedures for the control points. Specific protocols are established to handle situations when the control variables stray from pre-set levels.

9.4 Water Recycling Criteria

To ensure the protection of public health where recycled water is involved, CDPH has been statutorily directed to establish uniform statewide reclamation criteria for the various uses of recycled water (Water Code Section 13521) [State Water Resources Control Board, 2010]. Water recycling criteria have been developed and adopted by CDPH and are included in Title 22, Division 4, Chapter 3 of the California Code of Regulations [State of California, 2010]. CDPH does not have enforcement authority for the Water Recycling Criteria; they are enforced through a permit system administered by the nine RWQCBs under the overall jurisdiction of the SWRCB. The Water Recycling Criteria include comprehensive requirements for nonpotable water reuse applications and general requirements for groundwater recharge of domestic water supply aquifers by surface spreading. The regulations state that recycled water used for groundwater recharge of domestic water supply aquifers by surface spreading “shall be at all times of a quality that fully protects public health" and that CDPH recommendations "will be based on all relevant aspects of each project, including the following factors: treatment provided; effluent quality and quantity; spreading area operations; soil characteristics; hydrogeology; residence time; and distance to withdrawal" [State of California, 2010]. Until more definitive criteria are adopted, proposals to recharge groundwater by either surface spreading or injection are evaluated on a case-by-case basis, although the draft groundwater recharge criteria described below guide CDPH decisions.

9.5 Draft Groundwater Recharge Regulations

Draft groundwater recharge regulations for IPR [California Department of Public Health, 2008] have gone through several iterations and, when formally proposed, finalized, and subsequently adopted, will be included in the Water Recycling Criteria. Selected requirements in the current published version of the draft regulations (dated August 5, 2008) are summarized in Table 3.

Several requirements specified in the draft regulations would also apply to direct potable reuse projects (e.g., industrial pretreatment and source control programs, an operations plan, and a contingency plan), and product water quality requirements would be at least as restrictive as those currently prescribed for IPR and may be more restrictive for some constituents. The existing draft groundwater recharge regulations are being extensively modified to set comprehensive, objective criteria that address both surface spreading and subsurface injection projects involving IPR of the recovered water.

Table 3: Draft California Regulations for Groundwater Recharge into Potable Aquifers

Recycled Water Quality Limits	Treatment Required	Other Selected Requirements
• ≥ 5 log virus inactivation • ≤ 2.2 total coli/100 mL • ≤ 2 nephelometric turbidity units (NTU) • ≤ 0.5 mg/L TOC of wastewater origin • Drinking water MCLs • Action levels for lead and copper • Nitrogen limits vary: depend on method used	**<u>Spreading</u>** • Secondary • Filtration • Disinfection • Soil aquifer treatment **<u>Injection</u>** • Secondary • Filtration • Reverse osmosis • Advanced oxidation process (AOP)*	• Industrial pretreatment and source control program • ≥ 80% dilution for spreading (to start); • ≥50% dilution for spreading applications (to start) that provide reverse osmosis and (AOP)* ≥ 50% dilution for injection (to start) • 6-month retention time underground • Monitor recycled water and monitoring wells for priority toxic pollutants, chemicals with state notification levels specified by CDPH, and unregulated constituents specified by CDPH • Operations plan • Contingency plan

* AOP must reduce N-nitrosodimethylamine (NDMA) and 1,4-dioxane by at least 1.2 logs and 0.5 logs, respectively.

Dilution is not required by the current CDPH draft groundwater recharge regulations if certain conditions are met. If recycled water is to be used for direct potable reuse, it will likely be required to have advanced treatment, and the product water may present aesthetic concerns or operational problems (e.g., be corrosive, have a flat taste, lack minerals, or promote chemical changes when mixed with other treated drinking water). Some potential aesthetic and operational problems would be remedied by mixing the recycled water with diluent water. If CDPH develops regulations for direct potable reuse, it is unclear what requirements, if any, it would impose related to dilution.

9.6 Proposed Framework for Regulating IPR via Surface Water Augmentation

Currently, there are no recycling criteria addressing IPR via surface water augmentation, although draft criteria for such use are currently under development by CDPH. Surface water augmentation has previously been addressed in a document entitled "A Proposed Framework for Regulating the Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation in California" [California Potable Reuse Committee, 1996].

The committee that wrote the 1996 framework concluded that planned IPR of advanced treated recycled water by augmentation of surface water supplies would not adversely affect drinking water quality if the following conditions were met:

- Approved advanced wastewater treatment processes have been applied.
- All relevant water quality standards are achieved.
- Advanced treated recycled water is retained in a storage reservoir for sufficient time before treatment in a water treatment plant.
- Downstream drinking water treatment plant operations will not be negatively impacted.
- There are multiple barriers for the removal of pathogens and toxic chemicals. The report states that source control of discharges into the wastewater collection system, conventional wastewater treatment, membrane treatment, disinfection, reservoir retention, and surface water treatment are effective physical and chemical barriers.

The 1996 report includes the following six criteria considered by the authors to be critical:

- Application of best available technology in advanced wastewater treatment with the treatment plant meeting operating criteria.
- Maintenance of appropriate retention times based on reservoir dynamics.
- Maintenance of advanced wastewater treatment plant operational reliability to consistently meet primary microbiological, chemical, and physical drinking water standards.
- Surface water augmentation projects using advanced treated reclaimed water must comply with applicable State of California criteria for groundwater recharge for direct injection with reclaimed water.
- Maintenance of reservoir water quality.
- Provision for an effective source control program.

The second criterion calls for a reservoir retention time. A required retention time that would hold the treated water for a time period determined to be adequate to provide some level of additional treatment via an environmental buffer has not yet been specified by CDPH. Thus, discharges of recycled water into a raw water reservoir for IPR will be influenced by a science-based regulatory decision on the minimum retention time determined by CDPH to be necessary to provide an adequate environmental buffer. This decision is complicated by the realities of reservoir hydrodynamics, particularly short-circuiting during reservoir turnover. The City of San Diego is conducting studies at the present time that will provide information to be considered by CDPH in these deliberations. For direct potable reuse to be considered as an acceptable means to supplement drinking water supplies, there will likely be similar concerns that will need to be addressed.

9.7 Memorandum of Agreement between CDPH and the SWRCB

A 1996 Memorandum of Agreement (MOA) between CDPH (then California Department of Health Services) and the SWRCB on behalf of itself and the nine RWQCBs set forth principles, procedures, and agreements to which these agencies committed themselves relative to the use of recycled water in California. The MOA, entitled "Memorandum of Agreement Between the Department of Health Services and the State Water Resources Control Board on Use of Reclaimed Water," is intended to ensure that the respective authority of these agencies relative to the use of recycled water will be exercised in a coordinated and cohesive manner designed to eliminate overlap of activities, duplication of effort, gaps in regulation, and inconsistency of action. It establishes basic principles relative to the activities of CDPH, the SWRCB, and the RWQCBs, clarifies primary areas of responsibility and authority between the agencies, and provides for methods and mechanisms necessary to ensure ongoing, continuous future coordination of activities relative to the use of recycled water in the state [California Department of Health Services, 1996].

The MOA provides general background information that succinctly summarizes sections of the Water Code applicable to water recycling, including the following: basic authorities and responsibilities of the agencies; water reclamation requirements and reports; regulatory enforcement; cross connection control; source control; potable water supply source control; operator certification; and water rights. Under "General Principles," the MOA includes stipulations that each agency shall consult with the other agency before adopting new policies or procedures and that, where a public water system is involved in supplying or distributing recycled water, CDPH will use its enforcement authority over public water systems to assist the RWQCBs in their enforcement efforts.

The MOA also includes several provisions and commitments, including the following:

- CDPH will review and respond to water reclamation proposals and requirements within 30 days of receiving such referrals from the RWQCB.
- The RWQCBs will defer to CDPH with respect to any questions involving the interpretation of any criteria in the Water Recycling Criteria.

- In recognition of budget and staff limitations, the agencies may be unable to fulfill all of the tasks outlined in the MOA and agree to commit to setting priorities that ensure public health protection.

To resolve any concerns, issues, or disputes arising between the RWQCBs and CDPH, the MOA states that the Executive Director of the SWRCB will attempt to resolve the matters to the satisfaction of both parties.

10. Regulation of Direct Potable Reuse

As discussed above, the SWRCB, RWQCBs, and CDPH are the principal agencies that have statutory authority, regulations, policies, and interagency agreements that address current water recycling applications. They also are the state agencies that would be most involved in direct potable reuse. Currently, the RWQCBs have the authority and responsibility to prescribe water reclamation requirements and issue water recycling permits for water that is used or proposed to be used as recycled water. For direct potable reuse, a RWQCB-administered NDPES permit would probably be needed as a contingency in the event that the product water does not meet required water quality standards. CDPH has the authority and responsibility to prescribe drinking water requirements and issue water supply permits.

At some point in the treatment process from sewage to drinking water, the water transitions from RWQCB to CDPH jurisdiction. Presumably, the process for direct potable reuse projects where recycled water is introduced directly into a potable water distribution system would be similar in nature to the current process for IPR projects. This point would determine the beneficial use of the recycled water and perhaps the official approved source of drinking water and would be based on statutory authority, regulations, and agreements between the regulatory agencies. CDPH will probably want the final advanced treatment processes regulated under the California Safe Drinking Water Act by a PWS to ensure compliance with all drinking water regulations. It may be possible for CDPH, under its existing statutory authority, to proceed with regulation development for treatment requirements applicable to recycled water used for potable reuse.

There is an issue pertaining to treatment plant operator certification. Currently, water recycling plants are required to have wastewater treatment plant operators certified by the SWRCB, while water treatment plants are required to have water treatment plant operators certified by CDPH. The type of operator certification becomes an issue where recycled water is introduced directly into a potable water distribution system because, under this scenario, the water recycling plant is also a water treatment plant if the recycled water is introduced directly into a potable water distribution system. Some form of special certification may be needed to address the issues with more advanced types of treatment that require separate and distinct knowledge different from that required for conventional wastewater or water treatment operators. Alternatively, the SWRCB and CDPH may work out an agreement (under the MOA) regarding the use of existing certification programs to cover any special operator situations regarding direct potable reuse.

Rapid communication among all regulatory and operating agencies is necessary to prevent a failure or upset at some point from causing difficulties or unsafe drinking water downstream. An effective communication management system must make the boundary between regulatory jurisdictions transparent and foster a partnership between all operating agencies with responsibility for the water at some point.

The current water recycling regulatory structure within the state focuses on nonpotable uses of recycled water and IPR, and the MOA between CDPH and the SWRCB/RWQCBs may need to be modified to deal with the issues raised by direct potable reuse.

11. Approaches for Regulating Direct Potable Reuse in California

California has regulatory programs for permitting water reuse and domestic water systems. The programs cooperate to approve IPR by groundwater recharge, and a similar approach is being developed to provide for the approval of IPR by surface water augmentation. Both of these forms of IPR will ultimately require regulations as required by Section 13521 of the California Water Code, but they can be approved now by regulatory agencies with existing statutes and regulatory agency procedures, using draft regulations as guidance. It might be possible that a similar approach could be developed for direct potable reuse.

Other approaches that could be investigated include the following:

- The designated beneficial use of the recycled water would be drinking water. No CDPH involvement under the California Health and Safety Code would be needed until the water enters the public water system's distribution system. CDPH would be involved in consultation on the RWQCB permit and the result may be CDPH recommendations with the same controls that would otherwise appear in a CDPH permit. This approach would probably require statutes to alter CDPH authority over drinking water sources and would certainly require changes to drinking water regulations. The U.S. Environmental Protection Agency would have to reconsider designating CDPH as the primacy agency for drinking water and would either require SWRCB/RWQCB adoption of relevant drinking water regulations (requiring new statutory authority) or directly regulate the public water systems using direct potable reuse. This scenario would require radical changes in regulatory authority and, on the face of it, would be an extremely unlikely approach to be considered by the regulatory agencies.
- CDPH would regulate all aspects of the source as it does with other water sources – sources that are often subject to significant contamination from a variety of activities or contaminant releases into the watershed. The regulatory activities would require that CDPH impose a sufficient source water protection program throughout the sewershed. This program would require CDPH statutory authority that would duplicate existing authority of the SWRCB/RWQCBs. It would also require the drinking water regulatory program to develop capabilities that duplicate those of the RWQCBs. The regulatory complexities and duplication of effort among the regulatory agencies would seem to indicate that pursuing this approach would not be fruitful.

12. Key Issues Related to Direct Potable Reuse in California

There are many issues related to direct potable reuse that need to be resolved before adequate regulations can be crafted. Some of the issues are interrelated (e.g., multiple barriers, retention time, monitoring), and means to resolve any specific issue should consider the positive or negative effect it may have on the resolution of other issues. Key issues that should be addressed include the following:

1. **Definition of direct potable reuse.** There needs to be a clear distinction between what constitutes direct potable reuse versus IPR. Although direct potable reuse is commonly defined as the introduction of recycled water directly into a potable water distribution system downstream of a water treatment plant, there are other definitions that identify other schemes that may also be considered as direct potable reuse. For example, in a 1996 document prepared by the California Potable Reuse Committee for the California Department of Health Services and Department of Water Resources entitled "A Proposed Framework for Regulating the Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation in California," it is stated that "Direct potable reuse of reclaimed water, sometimes called 'pipe-to-pipe' or 'flange-to flange,' describes the situation where reclaimed water is piped directly into the potable water treatment facilities or distribution system." Thus, introducing recycled water to the inlet of a water treatment plant was also considered to be direct potable reuse by the committee that wrote that report. A standard, inclusive definition of direct potable reuse is needed if the regulatory agencies are to approve direct potable reuse, as different schemes would be subject to differing regulatory requirements.
    - Another example of a definition for direct potable reuse appears in Senate Bill 918 (SB 918), which is an act to amend the Water Code that would – among other things – require CDPH to investigate the feasibility of developing uniform water recycling criteria for direct potable reuse. SB 918 was introduced on February 1, 2010, and amended on March 17, 2010. It defines direct potable reuse as "the use of recycled water for drinking purposes directly after treatment."
    - Storing recycled water for a time period sufficient to receive monitoring results prior to release to a water treatment plant or directly into a potable water distribution system may also be considered as a form of direct potable reuse.

2. **Compensation for loss of an environmental buffer.** CDPH embraces the concept of an environmental buffer for IPR projects as one of the multiple barriers that provides some degree of additional recycled water quality improvement and provides time to take corrective action in the event that monitoring indicates that the product water does not meet all required constituent limits. Means to compensate for the loss of an environmental buffer will likely be required.
    - Such means could include additional multiple barriers for microbial and chemical constituents of concern, improvements in currently-used treatment processes, incorporation of new treatment processes into the treatment train, enhanced monitoring methodology, and/or short-term storage of product water that would provide time for monitoring results to be determined prior to use as a potable supply.
    - CDPH has endorsed the formation of independent advisory panels to assist several utilities engaged in IPR in solving technical and regulatory hurdles and, in many instances, has embraced the findings and recommendations of those panels as they

relate to regulatory issues. A panel of experts could be convened by the State of California to investigate and provide recommendations on means to compensate for the loss of an environmental buffer. Knowledge gaps identified by the panel could be the subject of research to obtain the required information. CDPH should be consulted on the charge to this panel (and any other panel formed to address direct potable reuse) to make certain its concerns are addressed and that approaches presented could work in a regulatory context.

3. **Multiple barriers.** The multiple barrier approach undoubtedly would be required to ensure that all regulated and unregulated constituents of concern are reduced to acceptable levels in the product water. The number, type, and reliability of treatment processes necessary to ensure that constituents of concern are reduced to acceptable levels in the product water would need to be determined. While several treatment processes have been demonstrated to reduce the concentrations of these constituents to acceptable levels, the removal of unknown constituents that may be of health concern is not as clearly defined. It may be necessary to provide more robust multiple treatment barriers than those currently used at existing IPR projects to gain regulatory approval of a direct potable reuse project.

    - A panel (or panels) of experts could be convened to investigate and provide recommendations on treatment processes needed to assure that public health protection is not compromised. Knowledge gaps identified by the panel(s) could be the subject of research to obtain the required information.

4. **Dilution.** The current CDPH draft groundwater recharge regulations for IPR require dilution by specifying maximum recycled water contributions. The dilution requirement may be waived over time upon demonstration that TOC in the recycled water does not exceed 0.5 mg/L and that all water quality requirements can reliably be met. It is not known whether CDPH would impose dilution requirements for direct potable reuse projects.

    - If dilution were to be required, a regulatory decision would have to be made as to whether the recycled water will need to be mixed with other water (either raw water if the recycled water is introduced into a raw water supply immediately upstream or at the intake of a water treatment plant, or with potable water if recycled water is introduced directly into a potable water distribution system downstream of a water treatment plant) or whether the recycled water contribution can be determined based on the total volumes of recycled water and diluent water introduced into a potable water distribution system over a specific time period (as is allowed where dilution is required in the current CDPH draft groundwater recharge regulations for IPR).

5. **Constituents of concern and monitoring.** There is a need to identify constituents of concern that should be monitored for either directly or indirectly via the use of surrogates. Real-time online monitoring is desirable, but may not be achievable for many constituents/parameters with existing technology. CDPH will have to determine whether existing treatment process efficiencies for constituent reduction/removal and monitoring methodologies are adequate to eliminate the need for an environmental buffer and retention time after treatment of the recycled water. Improvement in treatment process removal

efficiencies and/or monitoring methods may be necessary to enable the consideration of direct potable reuse in California.

- This issue is related to the issue of multiple barriers. Multiple barriers for constituent removal and monitoring are complimentary ways to pursue the same objective (i.e., to reduce the probability of failure and to reduce the likely consequences of any failure that may occur).
- The “blue ribbon” panel convened by the Southern California Coastal Water Research Project under contract with the SWRCB is charged with, among other things, identifying appropriate constituents to be monitored in recycled water along with applicable monitoring methods. The panel’s report, due later this year, should be helpful in identifying constituents to be monitored and the related monitoring methodology. Analytical methods should be suited for drinking water and not wastewater, as drinking water methods are usually more sensitive and have lower detection limits.
- In lieu of real-time online monitoring, methodology that provides very rapid – but not necessarily immediate – feedback for parameters of interest may be satisfactory for chemical constituents of concern that present chronic health effects resulting from extended exposure to health-significant concentrations. The method(s) used should be accurate, reliable, and capable of being integrated into supervisory control and data acquisition (SCADA) systems at water reclamation facilities.
- Implementation of a quality control process similar to the HACCP system would be useful in monitoring water quality at various points in the treatment process. The HACCP system examines the entire treatment process, determines the critical control points at various locations in the treatment system, establishes the critical values that define stable and acceptable operations, and identifies monitoring procedures for the control points. Specific protocols are established to handle situations when the control variables stray from pre-set levels. HACCP or Water Safety Plans (as developed by the World Health Organization based on HACCP) have been widely adopted as a mechanism for regulating water treatment operations.

6. **Assessment of health risks.** The CDPH Policy Memo 97-005 (Policy Guidance for Direct Domestic Use of Extremely Impaired Sources) requires an evaluation of the risks of failure of a proposed treatment system and an assessment of potential health risks with a failure. Policy Memo 97-005 states that the health risk assessment must take into account the human health risks associated with exposure to insufficiently treated water considering the risks of disease from microbial organisms and the risks of acute and chronic effects from chemical contaminants. Clarification is needed from CDPH as to what such a health risk assessment would entail.

    - Neither the CDPH draft groundwater recharge regulations nor current drinking water standards in California specifically require that epidemiological or toxicological health effects studies be performed to demonstrate that the water is safe.
    - Although some experts have stated in the past that the use of laboratory animals is essential to the assessment of possible health effects associated with the consumption

of recycled water, it appears reasonable to presume that the need to conduct toxicological studies is dependent on the treatment provided (both individual processes and multiple barriers) and the characterization of the chemical water quality.

- CDPH has not required health effects studies for existing IPR projects.

7. **Independent Advisory Panels.** CDPH now requires a scientific peer review of certain IPR projects involving groundwater recharge by independent advisory panels. While it is not known if CDPH would require similar panels of experts for direct potable reuse projects, such a requirement would appear to be likely.

8. **Applicability of existing CDPH regulations.** CDPH's permit procedures and compliance with source water assessment, surface water regulations, drinking water standards, and possibly Policy Memo 97-005 (Policy Guidance for Direct Domestic Use of Extremely Impaired Sources) do not specifically address direct potable reuse. Their applicability to direct potable reuse projects needs to be evaluated.

    - Identification of how existing CDPH drinking water regulations, permit procedures, and policies are addressed for IPR via groundwater recharge and surface water augmentation may be helpful in understanding how they may be considered for direct potable reuse. CDPH began to develop surface water augmentation regulations because public water systems approached CDPH with proposals to use surface water augmentation as a means of IPR.

    - Alternatively, a detailed evaluation that identifies how existing drinking water statutes, regulations, guidance, policies, and permitting process might be used to evaluate direct potable reuse proposals could be submitted to CDPH as an early step in considering direct potable reuse as a possible augmentation of drinking water supplies. Such an evaluation could also identify needs for additional regulatory oversight by CDPH, the SWRCB, and the RWQCBs.

9. **Regulatory responsibility.** The SWRCB, RWQCBs, and CDPH may need to consider clarification of the point at which the water makes the transition from Water Code to Health and Safety Code authority. This transition point defines the beneficial use of the recycled water.

    - The SWRCB, RWQCBs, and CDPH are the principal agencies that have statutory authority, regulations, policies, and interagency agreements that address current water recycling application. They also are the state agencies that are likely to be most involved in direct potable reuse.

    - Currently, the RWQCBs have the authority and responsibility to prescribe water reclamation requirements and issue water recycling permits for water that is used or proposed to be used as recycled water. Similarly, CDPH has the authority and responsibility to prescribe drinking water requirements and issue water supply permits. This arrangement is working for IPR projects.

    - At some point in the treatment process for direct potable reuse projects where recycled water is introduced directly into a potable water distribution system, the RWQCB's authority will have to be replaced by CDPH authority (or, at least, the relationship between the two will have to be defined). This decision would be based on statutory authority, regulations, and agreements between the regulatory agencies. Changes to the CDPH/SWRCB MOA between the agencies may be appropriate.

- An example of the conundrum associated with regulatory responsibility pertains to treatment plant operator certification. Currently, water recycling plants are required to have wastewater treatment plant operators certified by the SWRCB, while water treatment plants are required to have water treatment plant operators certified by CDPH. The type of operator certification becomes an issue where recycled water is introduced directly into a potable water distribution system because, under this scenario, the water recycling plant is also a water treatment plant if the recycled water is introduced directly into a potable water distribution system. Some form of special certification may be needed to address the issues with more advanced types of treatment that require separate and distinct knowledge different from that required for conventional wastewater or water treatment operators. However, a special certification program is unlikely since it would require authorization in law, fee authority in law (a new tax), new regulations, and the creation of new positions to run the certification program. It is more likely that the SWRCB and CDPH would work out an agreement (under the MOA) regarding the use of existing certifications programs to cover any special operator situations regarding direct potable reuse.

10. **Development of a communication management system among agencies.** A communication system must be developed to enable all operating and regulatory agencies involved in a direct potable reuse project to work together to avoid the distribution of unsafe drinking water.

    - This issue is important because it involves complexities beyond those that have been considered for IPR projects. The water reuse and drinking water industries could jointly develop a communication management system that would ensure the timely sharing of information and rapid communication of problems. The system could be incorporated into RWQCB and CDPH permits. At some point, local health authorities and environmental health agencies would likely need to be involved.

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