State Water Board DPR Expert Panel

# Summary of Expert Panel Report on Direct Potable Reuse in California


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Water Boards NWRI

## Expert Panel Members

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## Forms of Potable Reuse

**Indirect potable reuse (IPR):**

Augmentation of a drinking water source **(surface water or groundwater)** with reclaimed water followed by an **environmental buffer** that precedes normal drinking water treatment

**Direct potable reuse (DPR):**

Introduction of reclaimed water **directly into a potable water supply** distribution system downstream of a water treatment plant or **into the raw water supply** immediately upstream of a water treatment plant (California Water Code)

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## Topics of Panel Report

- Public health surveillance tools/methods to quantify/mitigate risks (**Chap 3**)
- Analytical approaches for measuring chemical water quality (**Chap 4**)
- Application of bioanalytical tools to water analyses (**Chap 5**)
- Traditional/molecular methods for assessing microbial water quality (**Chap 6**)
- Antibiotic resistant bacteria and antibiotic resistance genes (**Chap 7**)
- Performance of DPR systems (**Chap 8**)
- Potable reuse regulatory feasibility analysis to compare an example DPR system against an existing Calif. potable water supply that is protective of public health (**Chap 9**)
- Management controls **(Chap 10)**

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## Findings Covered in Presentation

- Pathogen Log Reduction Approach
- Public health surveillance tools
- Short-duration releases of chemical contaminants
- Routine application of bioanalytical tools
- Antibiotic resistant bacteria and antibiotic resistance genes
- Performance of DPR systems and Potable reuse regulatory feasibility analysis
- California-Specific Research Recommendations (included within subject slides)

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## Summary of Panel Key Findings

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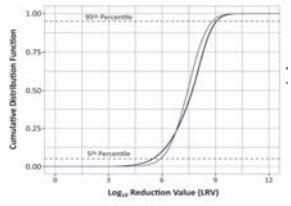
Findings

## Review Performance Criteria for Pathogens

- State LRV assumptions are acceptable basis to evaluate DPR feasibility
- Probabilistic is a robust approach and consistent with the SWB approach
- The probabilistic approach recommended for evaluating DPR feasibility and for future use to measure (baseline) overall plant performance
- Approach used to assign unit process LRV credits is feasible for DPR

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Recommendations to State Water Board

## Public Health Surveillance Tools and Methods

- **Inform local public health partners** when a DPR project is being considered
- **Identify points of contact** and review available surveillance data sources
- **Establish processes for regular engagement**, information sharing, and notification
  - Emphasis on tracking, reporting, and communicating notifiable acute (primarily) waterborne diseases
- Work with DPR project sponsors and local health agencies to **consider the feasibility** of enhanced public health surveillance for communities with DPR systems
  - **Power analysis -** not feasible for well operated systems; gross failure maybe

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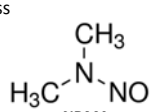
## Chemical Water Quality Monitoring

- Short-duration releases of chemical contaminants of commercial or industrial origin
  - Solvents and other chemicals commonly used in relatively large quantities in commercial or industrial activities (e.g, Acetone, MEK, methanol)
  - Highly toxic contaminants used in small amounts or that are present as trace impurities or byproducts of another process
- Indicator chemicals and surrogate parameters

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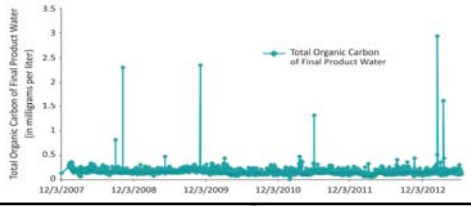
## Monitoring Results Relevant to DPR

**Groundwater Replenishment System (GWRS) at Orange County Water District**

- Despite an exemplary industrial source control program and few industrial dischargers (<5% of stream), GWRS observed at least 6 TOC spikes between 2007–2012 (Patel, 2013)

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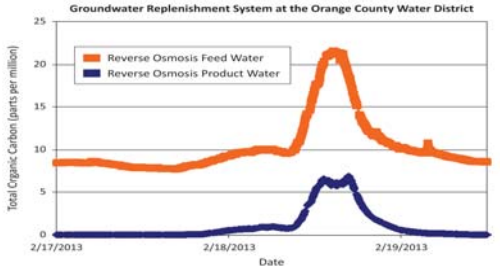
## Results of Online TOC Monitoring Before and After RO at GWRS (Dadakis and Dunivin, 2013)

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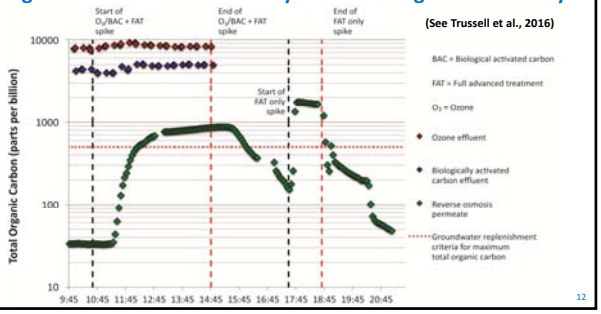
## Spiking of Acetone and Formaldehyde at San Diego Demo Facility




(See Trussell et al., 2016)

BAC = Biological activated carbon

FAT = Full advanced treatment

$O_3$ = Ozone

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## Monitoring Results Relevant to DPR

- GWRS observed conditions of >5 mg/L of acetone present for over 4 hours after RO treatment
- The peak concentrations of acetone likely were attenuated by subsequent biotransformation and mixing in the aquifer
  - CONCERN: If this pulse occurred in a DPR system using the same treatment processes, little further attenuation would be likely
- Without the use of a high-frequency TOC analyzer capable of detecting acetone, the pulse would not be detected at the AWTF in time to avoid introducing water with elevated acetone concentrations to a DWTF or drinking water distribution system

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**Key Findings**

## Chemical Monitoring - TOC Surrogate

- In Calif., most AWTFs currently under consideration for DPR include RO
  - Uncharged, low molecular weight compounds tend to be poorly rejected by RO
    - Examples: NDMA, chloroform, and low molecular weight aldehydes
  - Under normal operating conditions, the concentrations of low molecular weight, neutral compounds in product water generally are below the low TOC method detection limits observed in RO permeate (<0.1 mg/L)
  - **Chemical monitoring plans for DPR systems need to include high-frequency monitoring of TOC or other surrogate parameters capable of detecting pulses of compounds that are poorly removed in RO and subsequent treatment with advanced oxidation**

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**Key Finding & Research**

## Chemical Monitoring – Averaging of Potential Peaks

- AWTFs sometimes employ an oxidant (e.g., ozone, chlorine, chloramines) prior to or after treatment with RO
  - This practice can result in the formation of toxic byproducts, some of which are low molecular weight compounds that are not removed well during RO or might remain after subsequent treatment with advanced oxidation
- Encourage short-term research on identifying suitable treatment options for final treatment processes that can provide some "averaging" with respect to potential chemical peaks for chemicals that have potential to persist through AWTF systems

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## Key Findings

### Chemical Monitoring – Targeted Monitoring

- Inform targeted monitoring for **source control and final water quality**
  - Establish an internal process to monitor the literature and
  - Establish an external peer review process to address the results of the internal efforts to maintain a high level of awareness of these issues

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Findings

### Application of Bioanalytical Tools to Water Analyses

- Bioassays **have potential role** in identifying yet-to-be-discovered contaminants
- Bioassays are **not recommended as part of routine monitoring** programs for DPR projects **at this time**
- Bioassay-directed fractionation is useful for identifying compounds in recycled water that merit further evaluation
  - **Research efforts employing bioassays and non-target screening analysis simultaneously are encouraged** to be used to discover new contaminants of concern

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Findings

### Antibiotic Resistant Bacteria and Genes

- AR is a valid and serious worldwide public health concern & are found in wastewater and other environments like soils and source waters not necessarily impacted by wastewater
- **Risk levels** associated with ARB/ARG in water have **not been determined**
- Concentrations of ARB/ARG in waters subject to DPR treatment processes **would likely be lower than that from current water sources** entering DWTFs
- A combination of secondary wastewater treatment and advanced water treatment processes (i.e., a sequence of treatment train processes like MF/UF, RO, UV/AOP) leading to **(DPR) finished potable water likely will reduce ARB/ARG concentrations in recycled water to levels well below those found in conventional treated drinking water.**

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## Performance of DPR Systems & Feasibility Analysis

- **Quantifying treatment facility reliability**
  - Performance and mechanical
- Enhanced source control
- **DPR alternative treatment systems**
- **Performance analysis (approach concepts)**
- Operation and maintenance

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## Underlying Reliability Assumptions

- **Reliability:** Ability to verifiably deliver water quality that consistently exceeds public health protection expected of conventional drinking water supplies
  - **Redundancy**: Addition of measures beyond minimum requirements to ensure treatment goals are met reliably and performance targets are achieved or exceeded consistently
    - Independent parallel operations of one or more similar treatment trains, permitting continuous operation
  - **Robustness:** Ability to address broad variety of contaminants and resist catastrophic failures
    - Diverse group of barriers to control a variety of contaminants
  - **Resilience:** Capacity to successfully adapt/respond to failure

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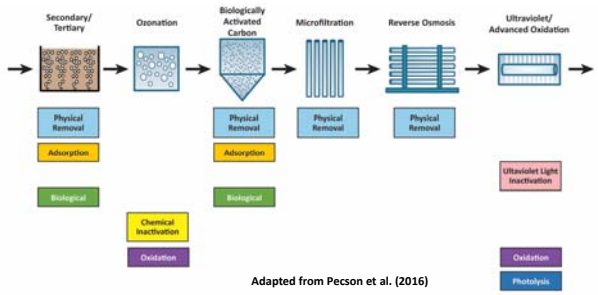
## Schematic of Concept of Robustness




Adapted from Pecson et al. (2016)

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## Evaluating System Reliability- Source to Tap

Application of **"multiple-barrier"** concept (core design principle in which redundancy, robustness, and resilience can be demonstrated)

- Source control
- Conventional wastewater treatment
- Advanced water treatment
- Management of environmental (engineered) buffer
- Drinking water treatment, including management of drinking water distribution system

**The expectation is that a multi-barrier system can maintain treatment goals even if a single unit treatment process fails**

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## Potable Reuse Regulatory Feasibility Analysis

**Comparative approach: Relative comparison of alternative supplies**

- Baseline – Sacramento-San Joaquin River (Delta)
- Baseline – IPR alternatives (GWR and SWA)
- "Source water supply" – Reduced environmental buffer – **The Gap**
- DPR alternatives (several)- one evaluated

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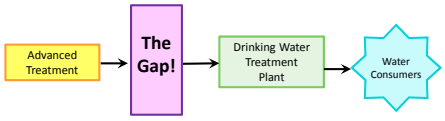
## Potable Reuse with Reduced Environmental Buffer

**Reduced environmental buffer!**




**Maintain functionality of environmental buffer (the "Gap")**

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## Maintaining the "Gap's" Functionality

**Means to maintain positive attributes of the environmental buffer:**

- More robust treatment barriers
- Additional treatment barriers (redundancy)
- Enhanced monitoring for chemicals, pathogens, or surrogates
- High frequency (near real-time) monitoring capability
- Storage of product water to provide time (engineered storage buffer)
- Alternative water supply source
- Means to quickly respond to off-spec water (time to respond)

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**Findings & Recommendations**

## Reduced Environmental Buffer

- Regulatory **"Gap"** between IPR projects with smaller environmental buffers and DPR projects with no environmental buffers
- Gap covers IPR-SWA projects with **hydraulic retention times of ≥2 months and <4 months**
- **Demonstrate – through hydrodynamic and public health risk modeling –** public health protection equivalent to that achieved by full compliance with criteria
- **Establish a consistent framework** for preparation and review of engineering reports
- **Conduct peer review of several Gap project proposals**
- Encourage State Water Board to consider potential benefits of environmental buffers, irrespective of size

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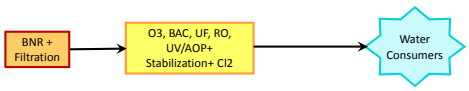
**Direct Potable Reuse**

## Advanced Treated Water as Approved Finished Drinking Water

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## Key Assumptions of DPR Reliability Analysis

**Tolerable Risk Goal**

- Safe Drinking Water Act: $10^{-4}$ or "1 in 10,000" people per year annual risk of infection
- Reference pathogen: *Cryptosporidium*

**Probabilistic Approach**

- Utilizes Unit process (treatment) performance (probability distribution functions) and mechanical reliability (production of off-spec water)
- Combines multiple independent treatment barriers to generate an overall facility PDF (e.g., required LRVs)
- Compare distribution of LRV criteria for *Cryptosporidium* (SDWA Goal) relative to DPR system LRVs performance

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## Unit Performance and Mechanical Reliability Approach

- Characterize treatment facility reliability with respect to:
  - Variability of treatment process effectiveness under normal operation (San Diego 1 yr data)
  - Probability of observed mechanical failures (off-spec water) (3 CA projects, >8 yrs data)
  - Impacts of projected mechanical failures on DPR system performance
- Independence of unit performance
- Unit performance distributions for ozonation, MF, RO, and UV/AOP
- No performance credits given for secondary wastewater treatment and final disinfection
- Generated ATWF cumulative performance distribution and adjusted for mechanical reliability

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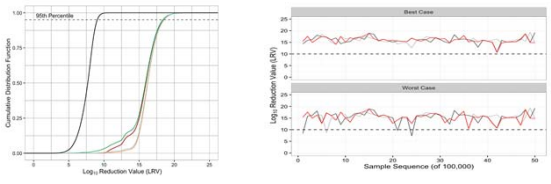
## Comparison of DPR Facility LRV performance vs. *Cryptosporidium* Tolerable Risk

- Unit performance distributions for ozonation, MF, RO, and UV/AOP
- No performance credits given for secondary wastewater treatment and final disinfection
- Generated ATWF cumulative performance distribution and adjusted for mechanical reliability (illustrated in time series)



## Overall Expert Panel Finding

Feasible to develop uniform water recycling criteria for DPR that would incorporate a level of public health protection as good as or better than what is currently provided in Calif. by conventional drinking water supplies, IPR systems using groundwater replenishment, and proposed IPR projects using surface water augmentation

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## Summary of Overall Feasibility Findings for Developing Uniform DPR Criteria

**Regulations specifying DPR practices need to provide the following features in addition to the requirements already specified in IPR regulations for Calif.**

- Implement rigorous response protocols (such as a formal Hazard Analysis Critical Control Point system)
- The State Water Board should not codify a specific set of treatment processes as part of developing DPR criteria, as it could stifle technological innovation
- Project sponsors must show technical, managerial, and financial (TMF) capacity
- Consider an approach to stage the introduction of recycled water from a DPR system into a drinking water supply
- Establish a formal internal and external review process of DPR projects/operations (on a 5-year cycle )

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## California Research Recommendations – DPR Performance

- **Adopt the use of probabilistic QMRA to confirm the necessary LRVs** of viruses, *Crypto,* and *Giardia* needed to maintain a risk of infection equal to or less than $10^{-4}$ ppy
- Include **monitoring requirements in regulatory permits** to measure **pathogens in the raw wastewater** feeding a DPR system to provide more complete information on concentrations and their variability
- **Investigate the feasibility of collecting pathogen concentration data** for raw wastewater associated with **community outbreaks** of disease and collect such data where possible
- NOTE: CA research supported directly by the State of California and **could be done either before and/or concurrently** with the development of uniform water recycling criteria for DPR

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## Thank you for listening!

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