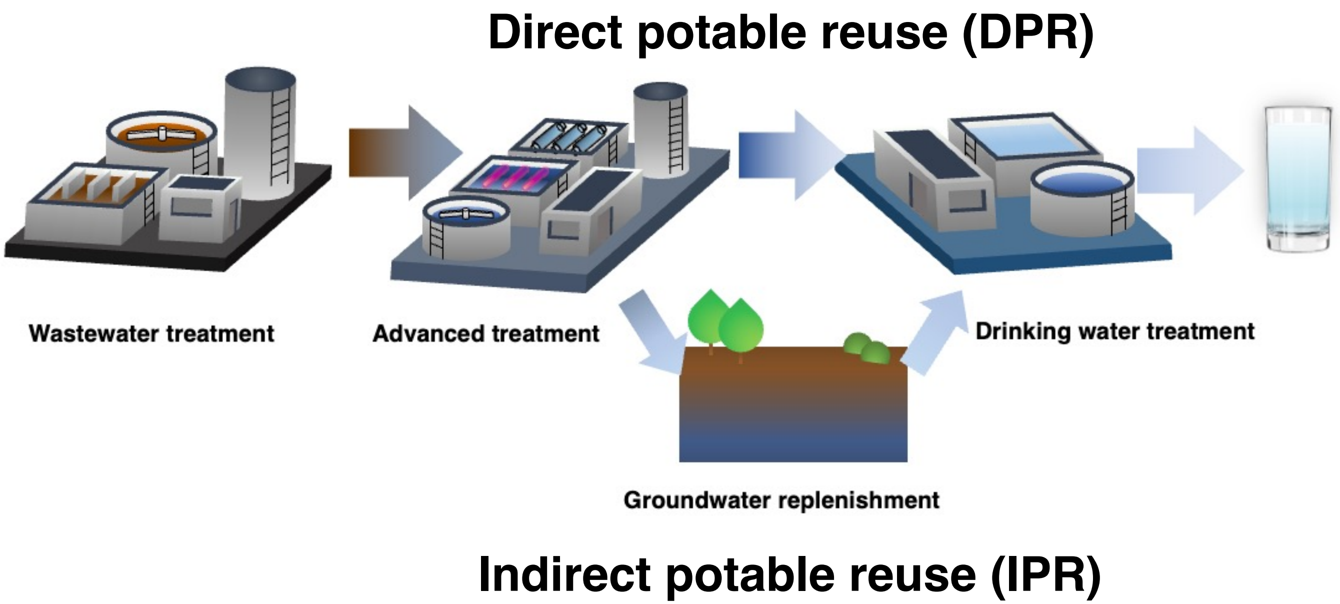
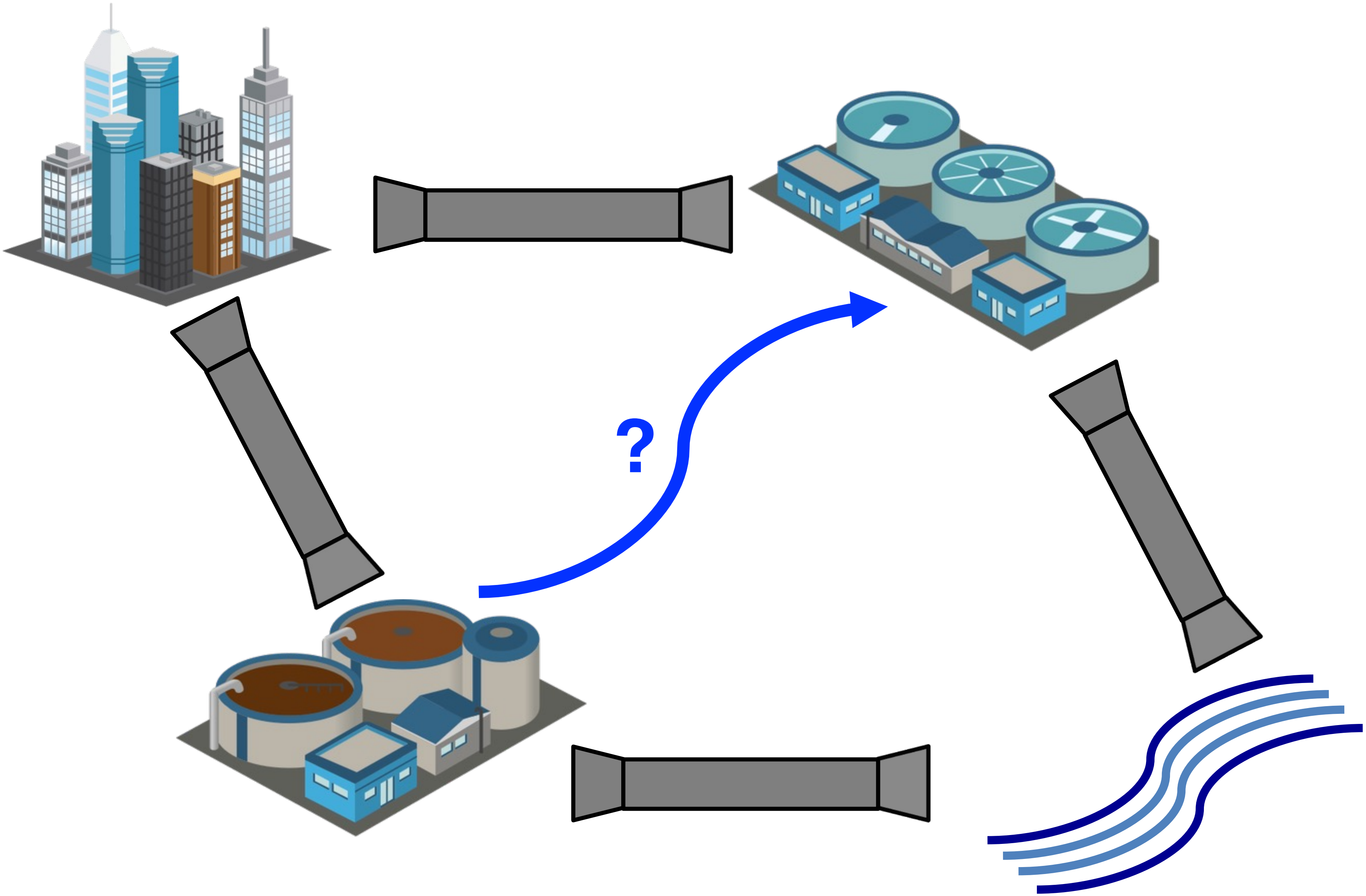
Southern California Water Dialogue

Water Reuse Treatment Technology



Daniel McCurry
Dept. of Civil and Environmental Engineering
University of Southern California
2024-05-29

Potable reuse: treatment challenges

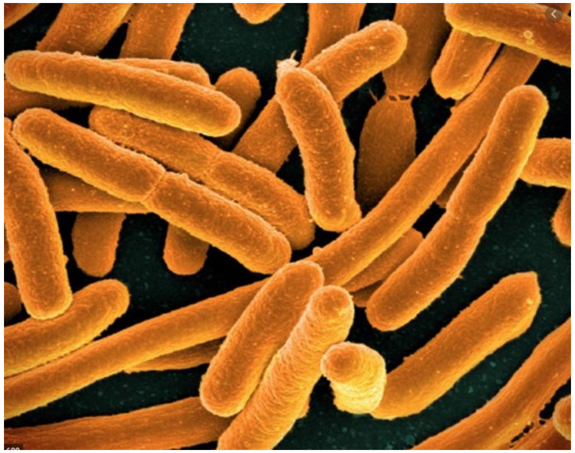


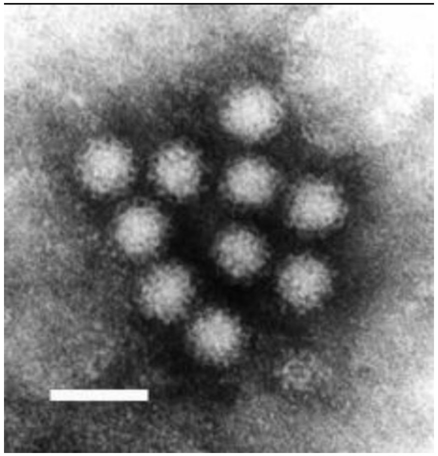
Treatment technology and configurations

But first: treatment for what?

1) Pathogens

    In CA (**IPR**):
        10-log removal of Giardia
        10-log removal of Cryptosporidium
        12-log removal of enteric viruses



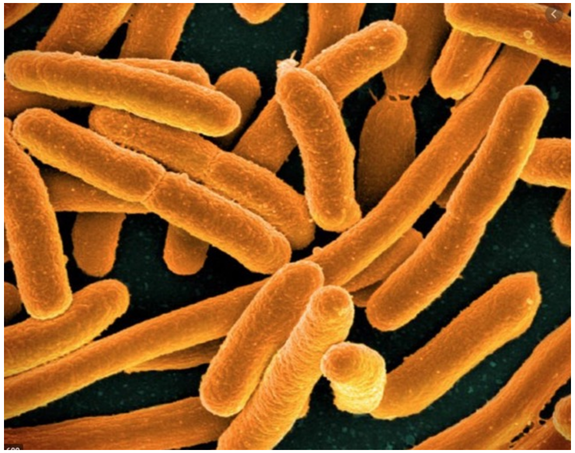


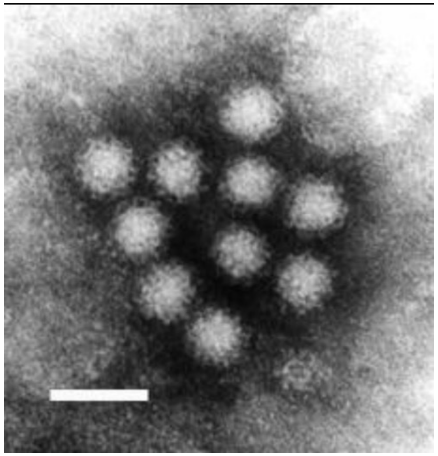
Treatment technology and configurations

Aside: *what is a log removal?*

$$Removal(\%) = \left(1 - \frac{N}{N_0}\right) \times 100\%$$

(1 minus who's left)





Treatment technology and configurations

Aside: *what is a log removal?*

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$$Log\ removal = -log_{10}\left(\frac{N}{N_0}\right)$$

Treatment technology and configurations

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e.g., For 99% removal, $N/N_0 = 0.01$, so:

$$\boldsymbol{Log\ removal} = -log_{10}\left(\frac{0.01}{1}\right) = -log_{10}(10^{-2}) = \mathbf{2}$$

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So 99% removal = '2-log' removal, 99.9% = 3-log, etc

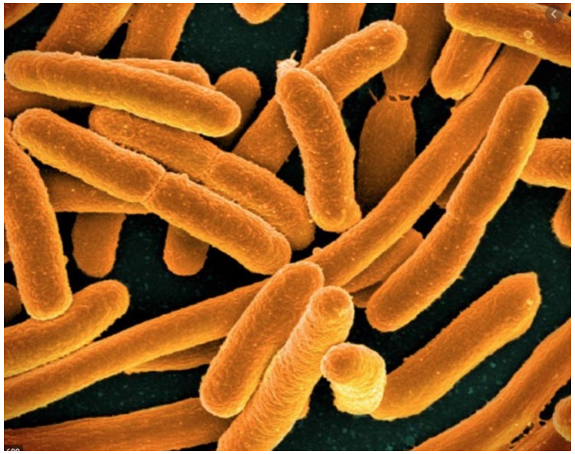
Treatment technology and configurations

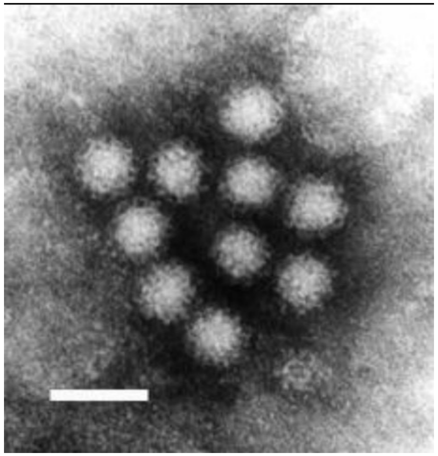
But first: treatment for what?

1) Pathogens

   In CA (**DPR**):

   14-log ~~10-log~~ removal of Giardia
   15-log ~~10-log~~ removal of Cryptosporidium
   20-log ~~12-log~~ removal of enteric viruses



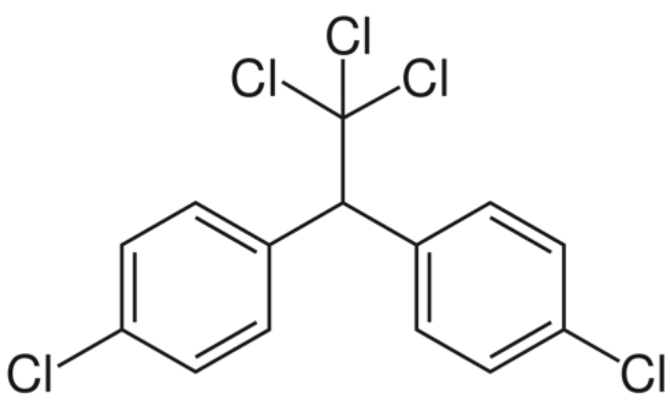


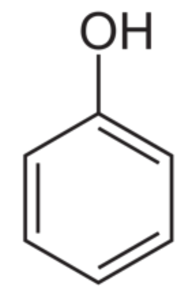
Treatment technology and configurations

But first: treatment for what?

1) Pathogens

2) Chemicals: Much higher concentrations of synthetic chemicals in wastewater than natural water sources





Treatment technology and configurations

But first: treatment for what?

1) Pathogens

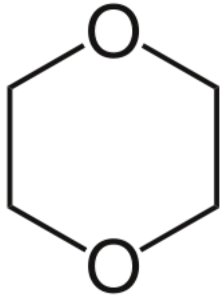
2) Chemicals: Much higher concentrations of synthetic chemicals in wastewater than natural water sources

In CA (**IPR**):

Must demonstrate 0.5-log removal of 1,4-dioxane

Why?

Common WW contaminant
Not well-removed by reverse osmosis



Treatment technology and configurations

But first: treatment for what?

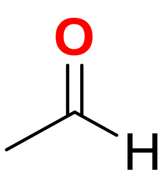
1) Pathogens

2) Chemicals: Much higher concentrations of synthetic chemicals in wastewater than natural water sources

In CA (**DPR**):

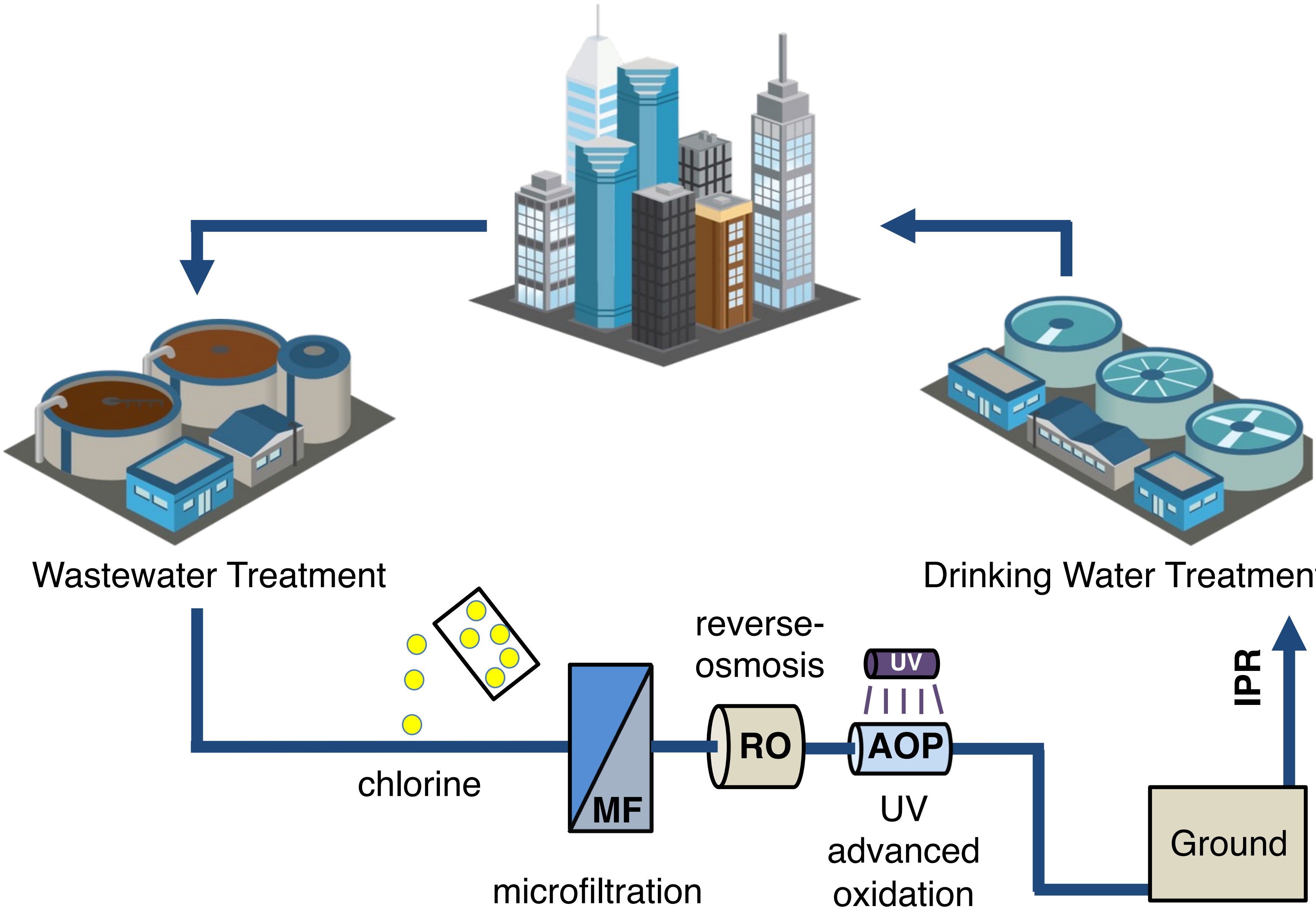
Must also demonstrate 1-log (90%) removal of formaldehyde

Why?



Toxic ozone byproduct
Not well-removed by reverse osmosis

IPR: “Full Advanced Treatment”

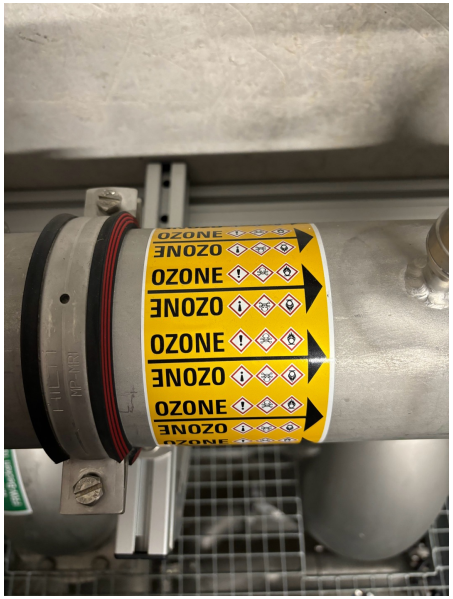


IPR: "Full Advanced Treatment"

First step: **disinfection**

First of several steps to kill/remove pathogens
Other reason: preventing membrane fouling

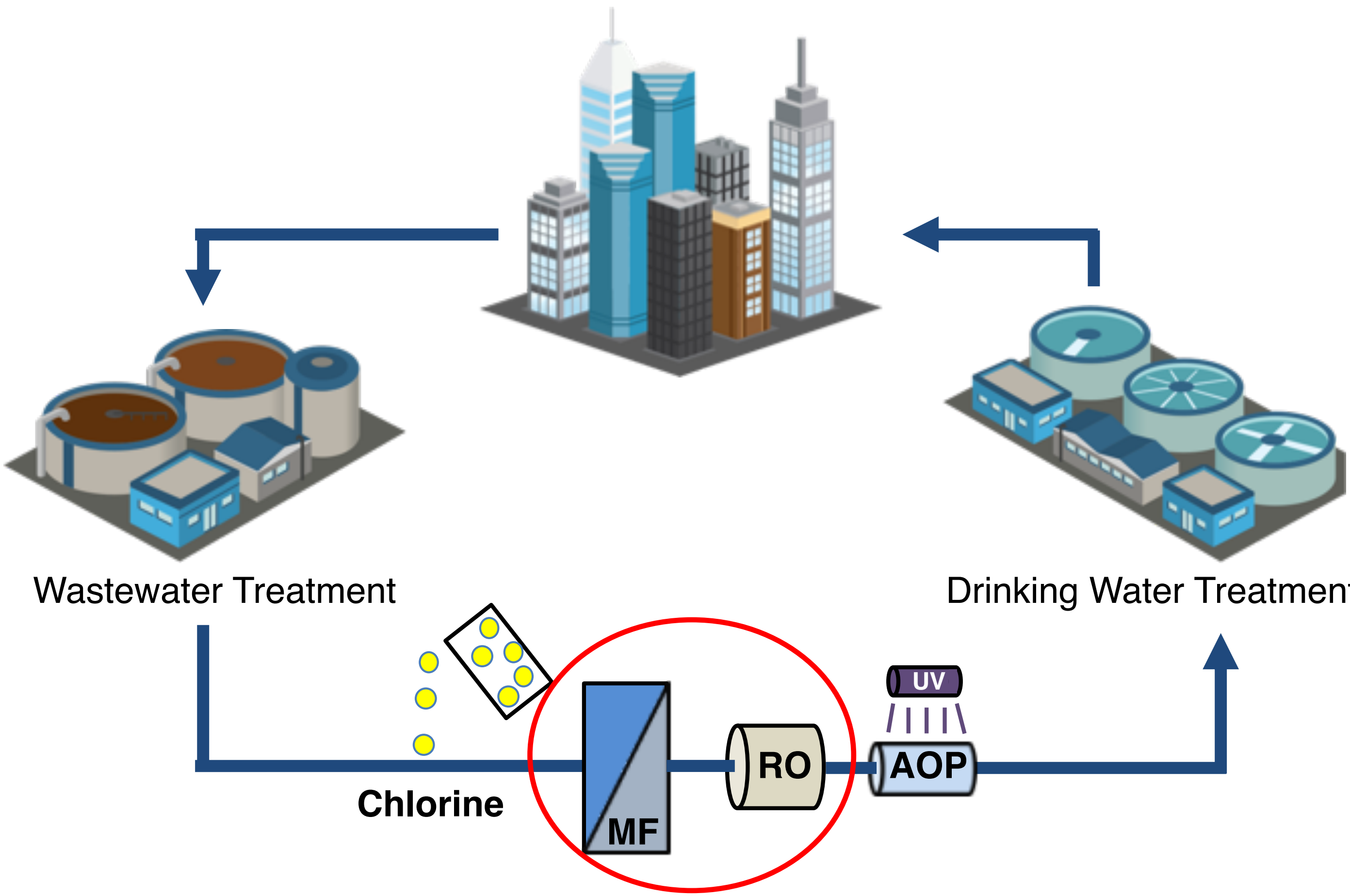
Disinfectants: Generally chlorine (bleach) or ozone



IPR: “Full Advanced Treatment”

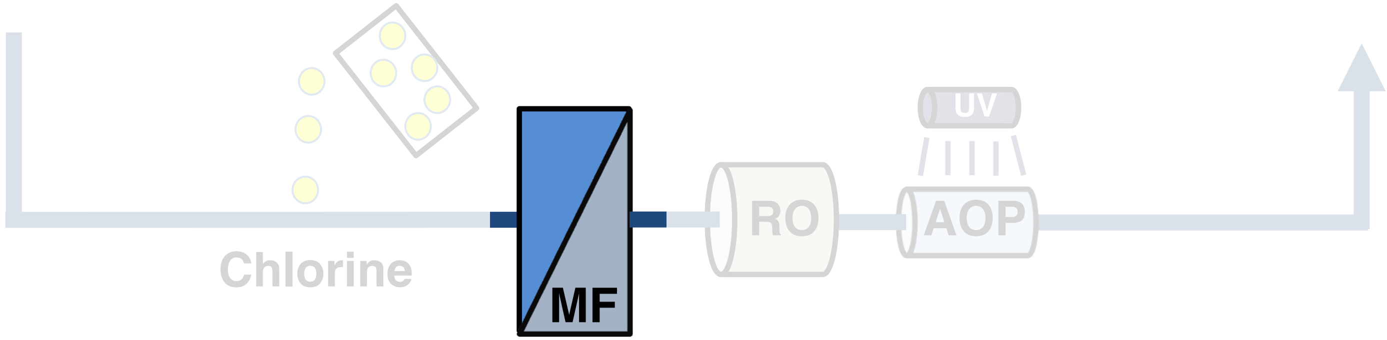
After disinfection: **membrane separation**

Usually *microfiltration* (**MF**) then *reverse osmosis* (**RO**)



IPR: “Full Advanced Treatment”

Microfiltration: removes particles > ~1μm



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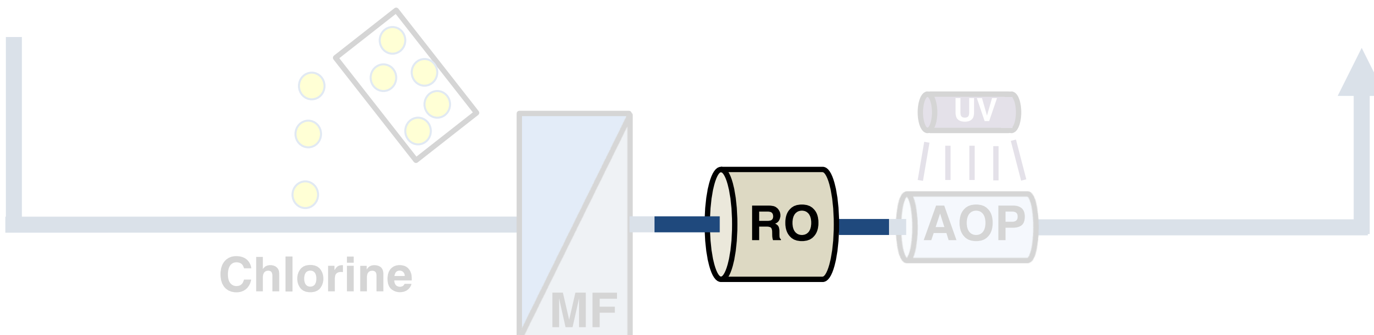

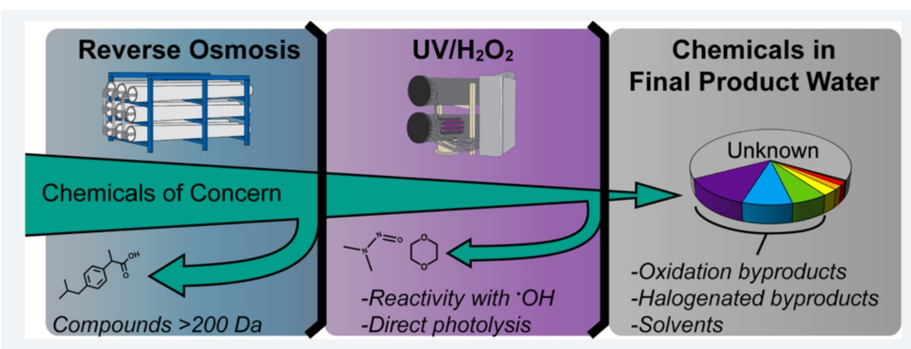

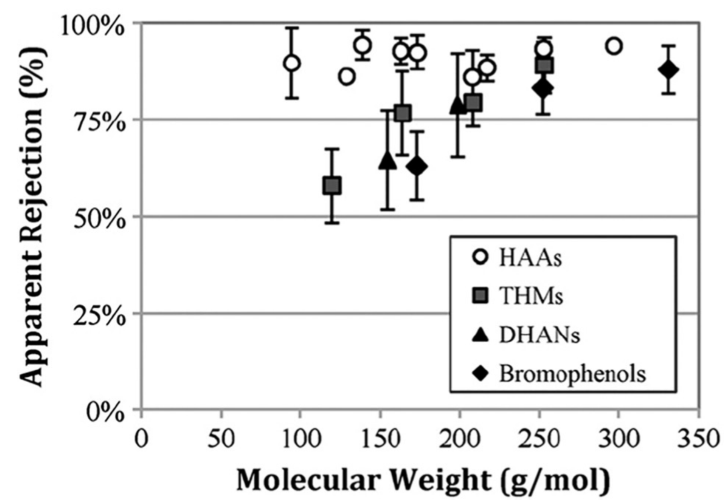

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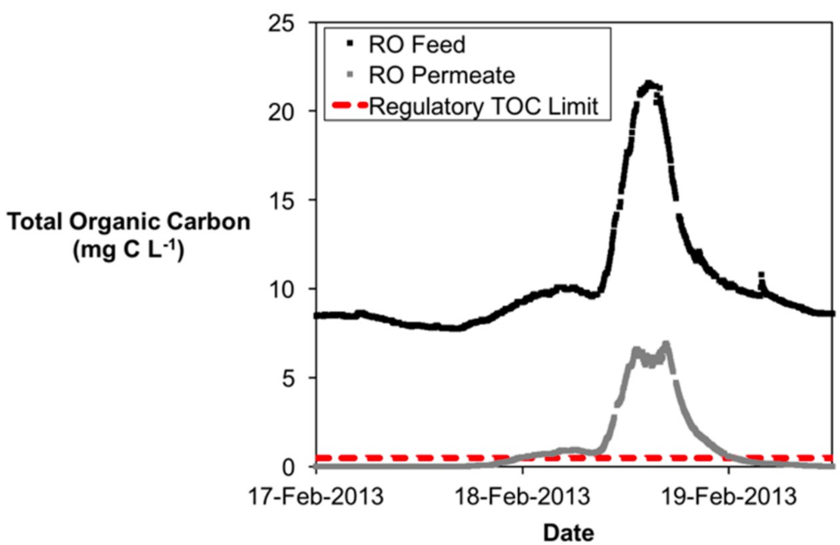
Microfiltration: removes particles > ~1μm

Reverse-osmosis: removes almost everything besides water

but not everything



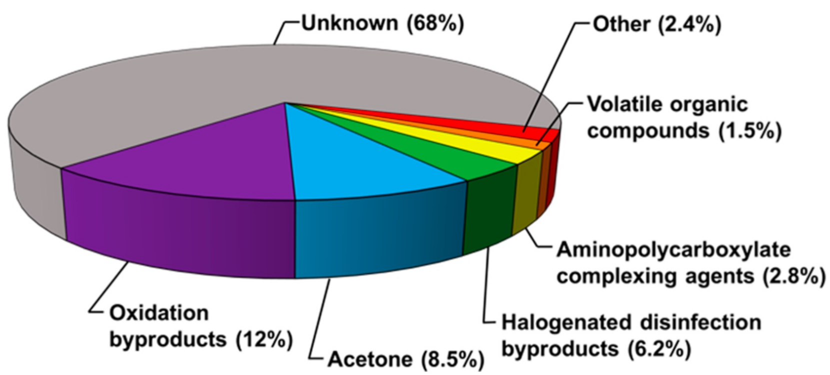


Figure 6. Approximate contributions of select chemical contaminants to the DOC (assuming 100 μg C/L) post-RO treatment in potable water reuse. Data averaged and compiled from three different treatment facilities in refs 31, 49, and 54.

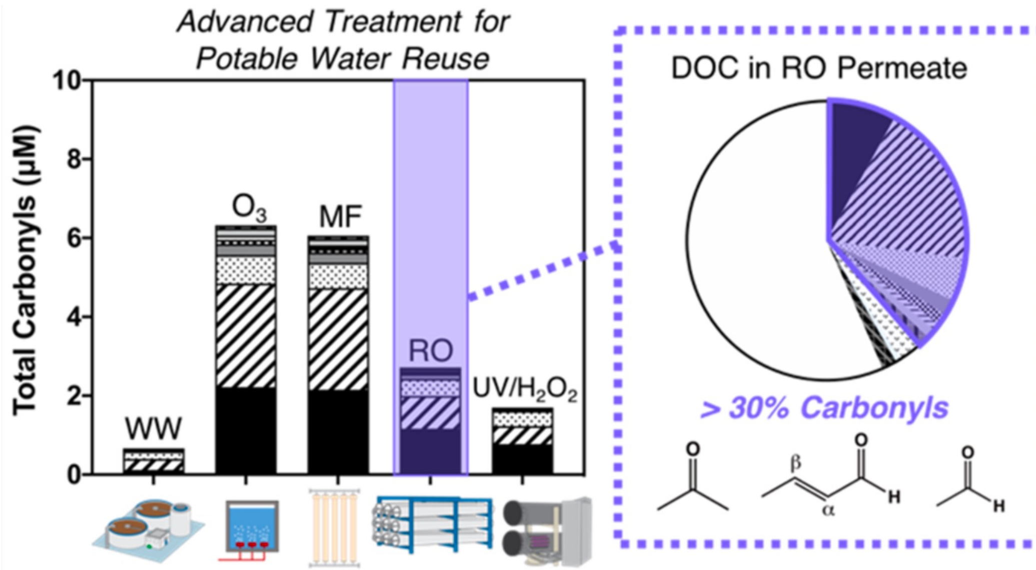
IPR: “Full Advanced Treatment”

Microfiltration: removes particles > ~1μm

Reverse-osmosis: removes almost everything besides water

but not everything

90% formaldehyde removal in draft CA DPR regs



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Article

Formation and Fate of Carbonyls in Potable Water Reuse Systems

Emily L. Marron, Carsten Prasse, Jean Van Buren, and David L. Sedlak*

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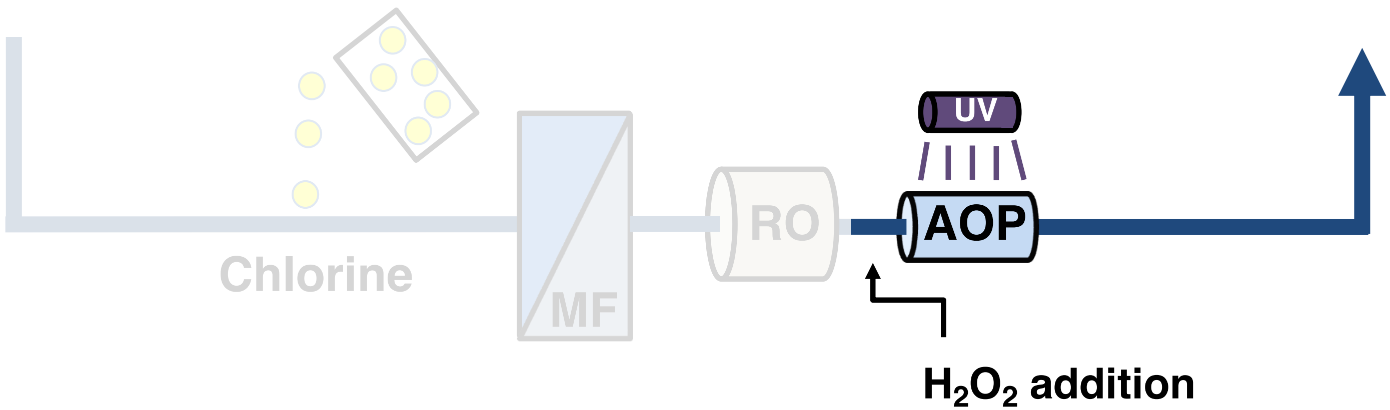
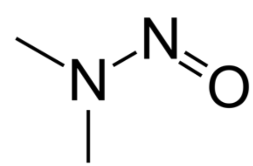
IPR: “Full Advanced Treatment”

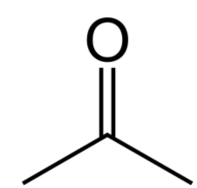
After membrane, advanced oxidation process (**AOP**) to **oxidize small compounds that pass RO**

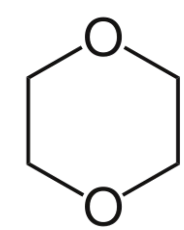


$$H_2O_2 \xrightarrow{UV} 2 \cdot OH$$

Examples of what passes RO:
NDMA, acetone, 1,4-dioxane







Next step: advanced oxidation process

High hydroxyl radical reaction rate constants ($k_{\bullet OH}$) ensure removal of **most chemicals** during UV/AOP

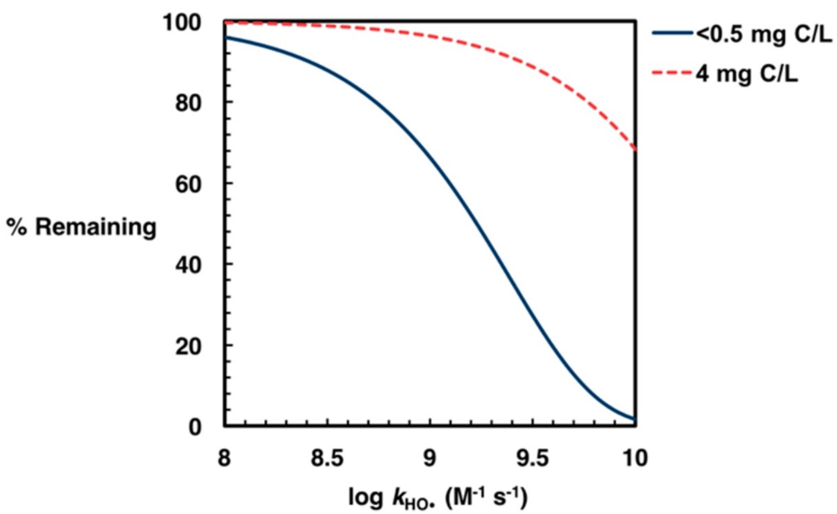
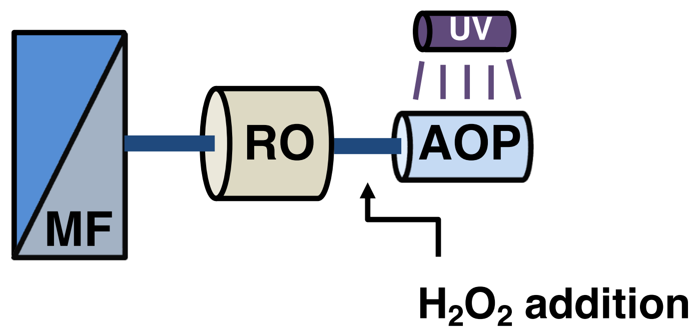
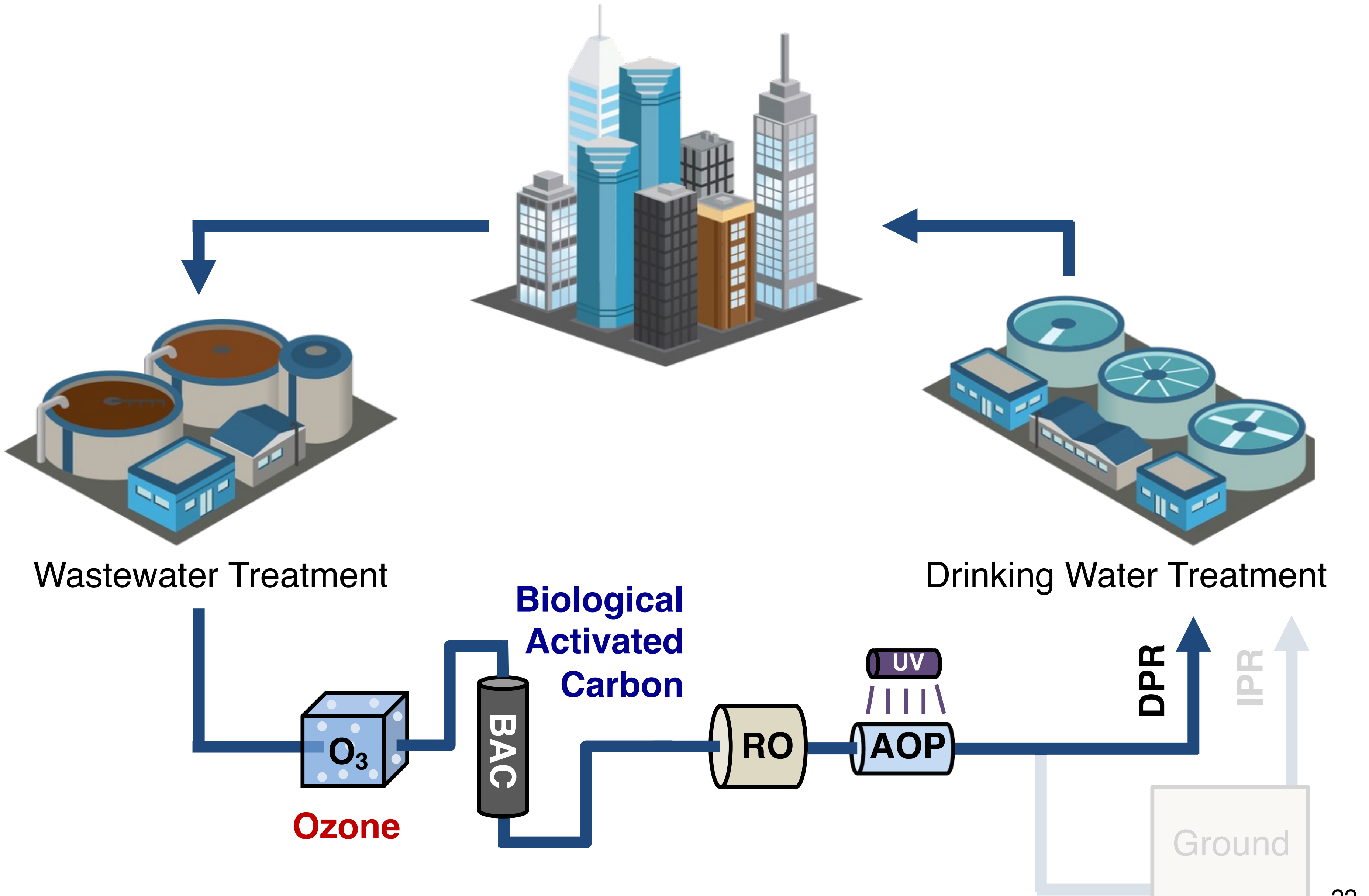


Figure 4. Reactivity of compounds in UV/H_2O_2 as a function of the log of the second-order rate constants of their reaction with ·OH (log $k_{HO\cdot}$) assuming $[\cdot OH]_{ss} = 4 \times 10^{-10}$ M (calculated based on 0.5-log removal of 1,4-dioxane, $k_{HO\cdot} = 2.8 \times 10^{9}$ M^{-1} s^{-1}). The dashed line represents reactivity with a DOC concentration of 4 mg C/L under similar operating conditions.

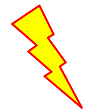


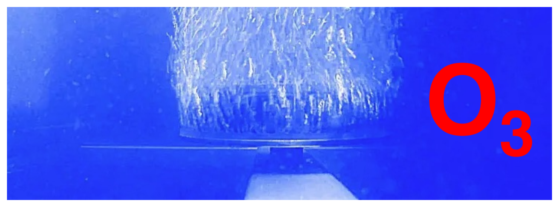
$$H_2O_2 \xrightarrow{UV} 2 \cdot OH$$

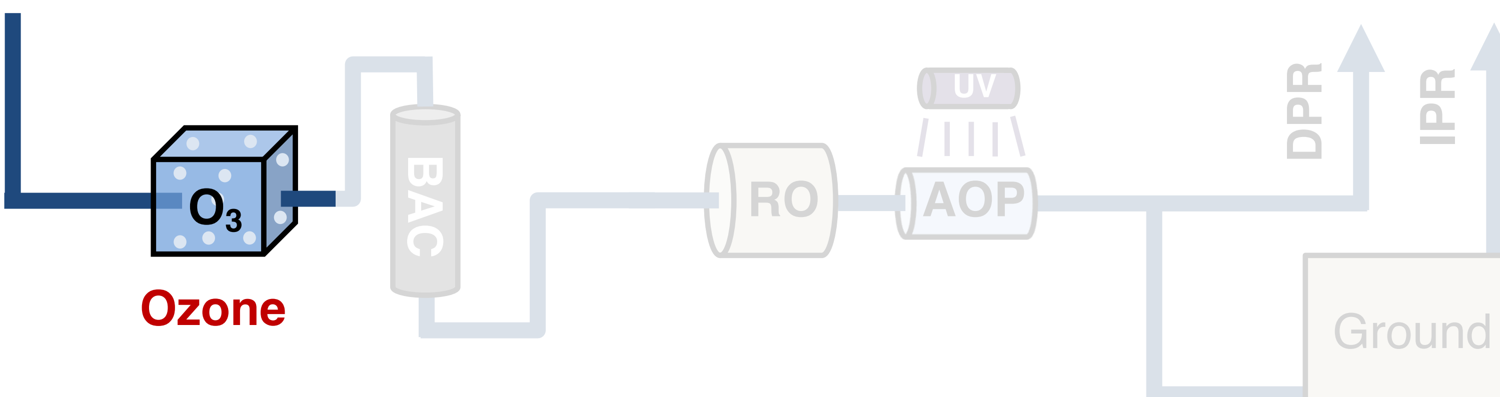
DPR: Adding two treatment steps



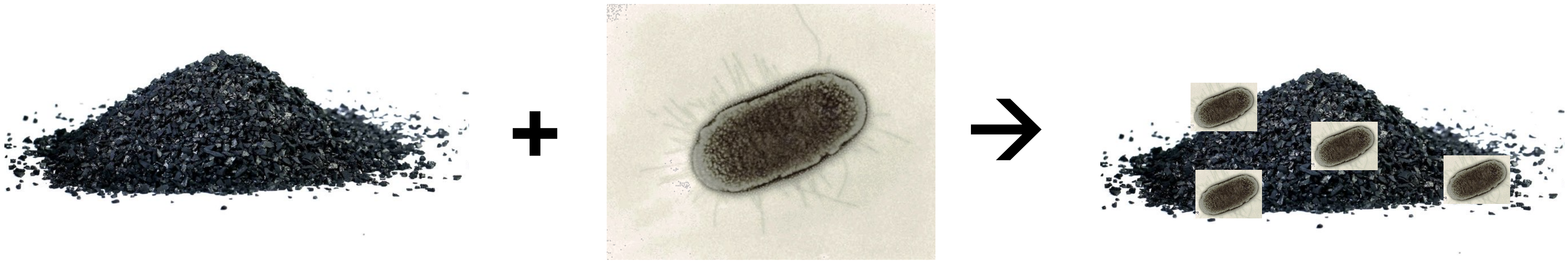
Ozone: disinfectant and oxidant

$3\,O_2 +$  $\rightarrow 2\,O_3$



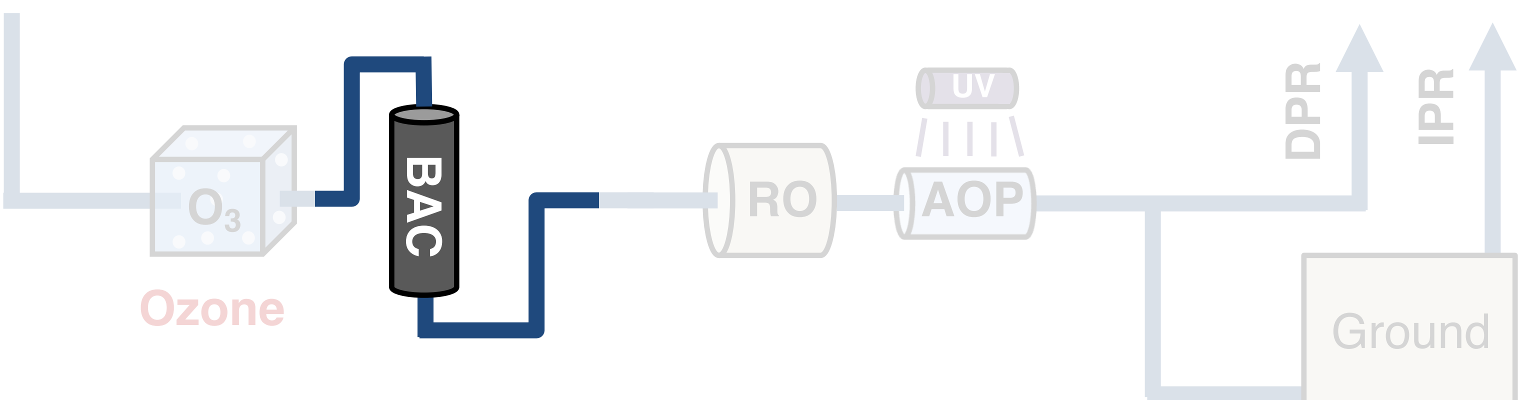


BAC: Post-ozone cleanup step



Removes biodegradable chemicals

Works in tandem with O_3: ozone breaks down large chemicals into 'bite-sized' pieces



Final thought: DPR in CA vs. other states