Advanced Oxidation Processes (AOP) in water treatment

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Content

- Challenges and problems (DW, Muni Wastewater reuse)
- Ozone and AOPs
- Results from selected studies
- Conclusions

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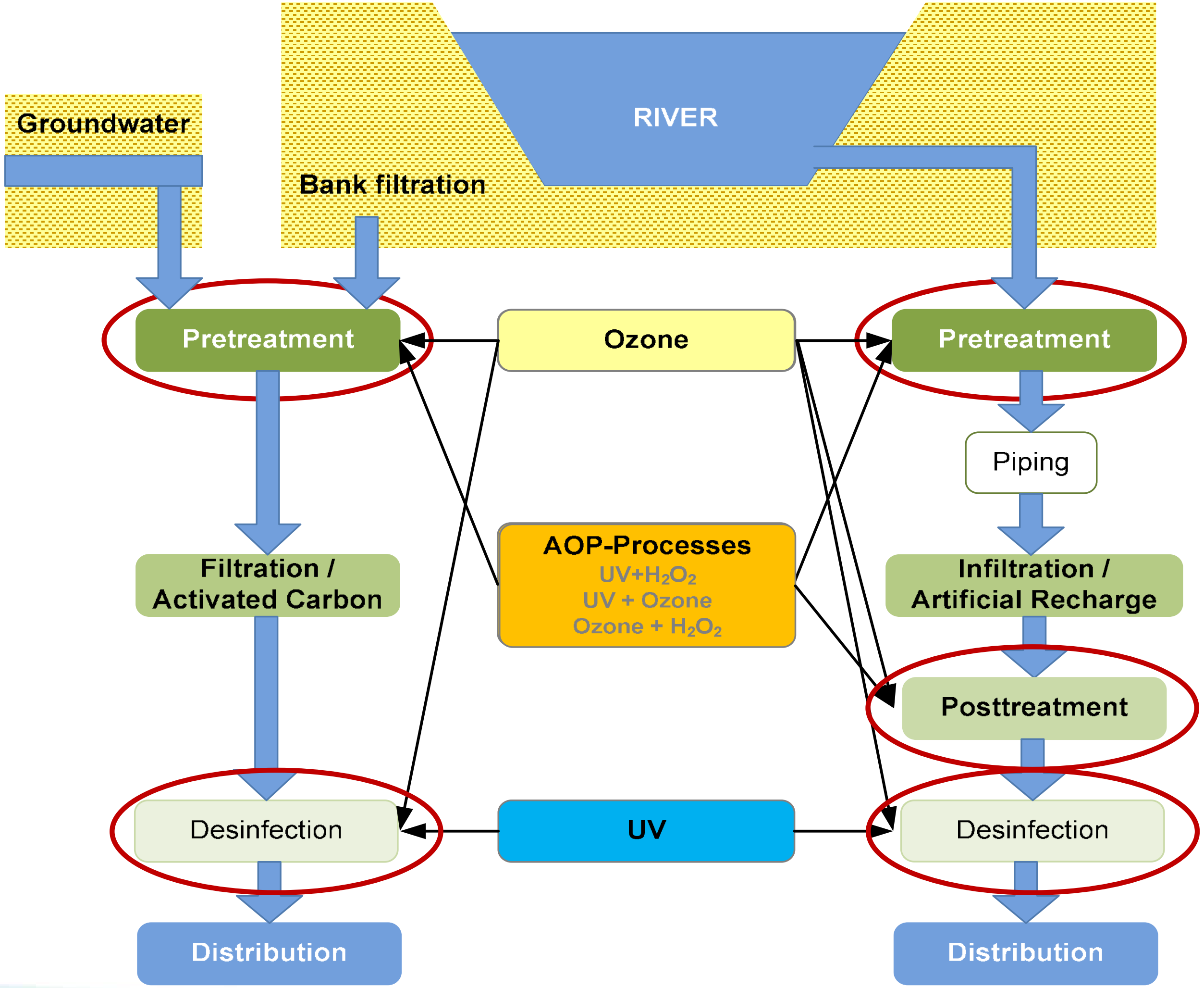
Treatment trains in DW applications

Integration of AOPs

- More stringent treatment goals
- Various Contaminants:
  - -Taste and odor
  - - *Pesticides;*
  - - *Industrial Chemicals;*
  - - *Pharmaceuticals*
- Conventional treatment steps can‘t remove all of them effectively
- Need for Advanced Treatment



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Waste Water Reuse – Challenges

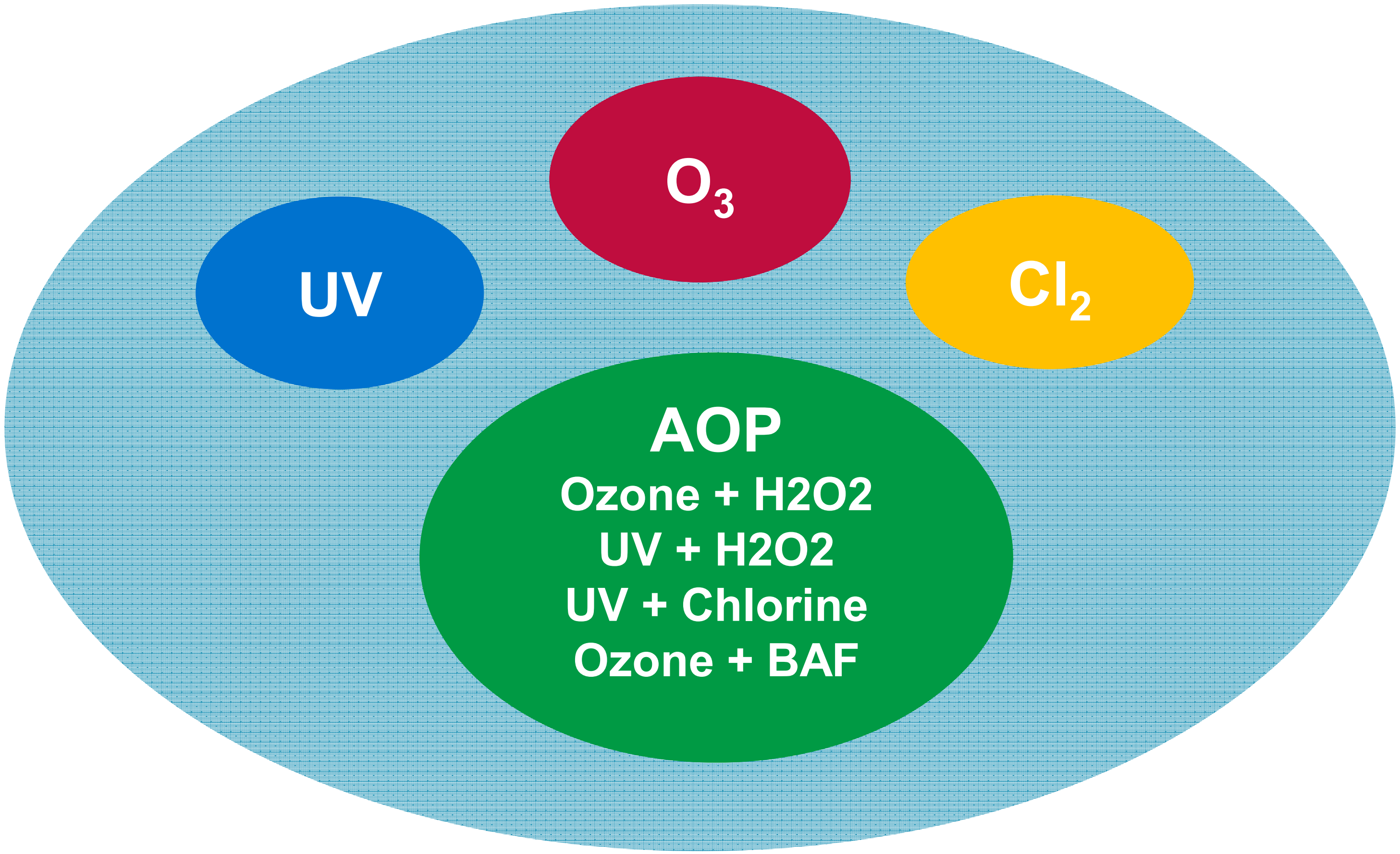
Figure 4: Lake Hume during drought in 2007, Victoria

Reuse Applications:

Non-Potable
Indirect and direct potable

Treatment goals:
Disinfection
Micro Pollutants (CECs) ⟵ Focus
By-products
TOC

Oxidation Players & Synergistic Effects



Part of advanced treatment trains
-> important role
-> contribute directly to specific treatment goals
-> support by synergistic effects

Role of Ozone and Advanced Oxidation

UV

1. log-credits for disinfection
2. Single contaminants (photo-active)

Ozone

1. log-credits for disinfection
2. Single contaminants (ozone-active)

H_2O_2

Needed for OH• formation

↓

3. Contaminants (radical-active)

Chlorine

1. **log-credits for disinfection**
2. **Disinfection credit for effluents**

↓

3. **Contaminats (radical formation with UV)**

A. UV + H_2O_2

B. Ozone + H_2O_2

C. Ozone + H_2O_2 + UV

D. UV + Chlorine

E. Ozone in wastewater generates a significant amount of radicals

Aspects to consider: matrix effects, energy consumption, by-product formation, synergistic effects within treatment trains

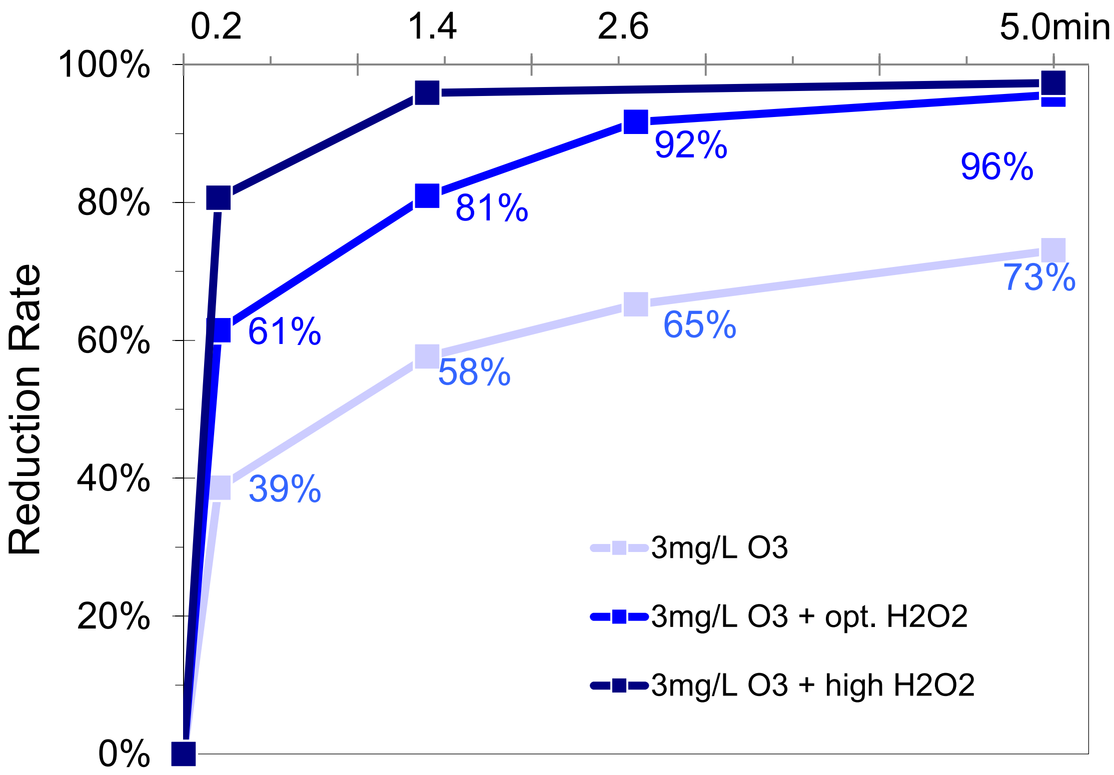
Case study Taste and Odor removal in DW

AOPs used:

Ozone
Ozone + H_2O_2
UV/H_2O_2

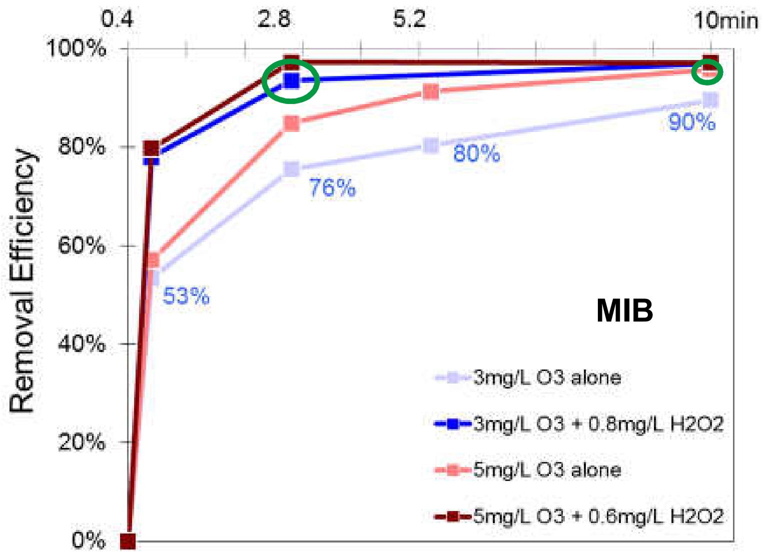
- Study WTP Singapore
  (Reduction of Taste & Odor compounds and other relevant CECs)

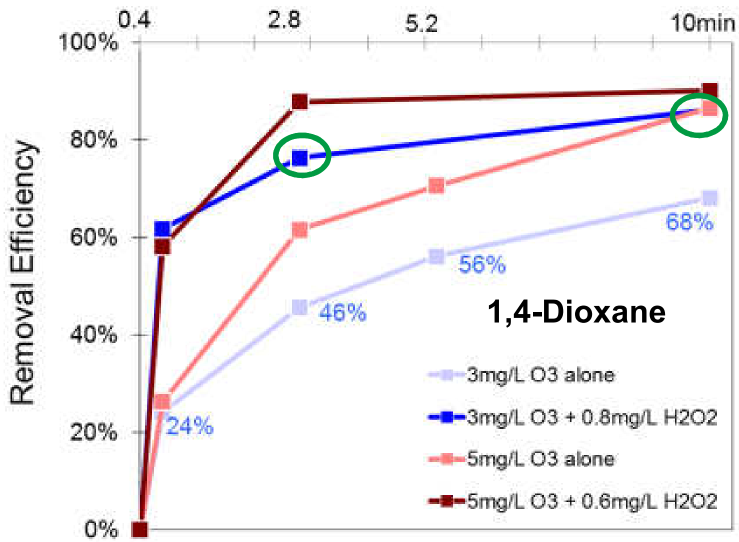
Removal rates for MIB using ozone w/wo H2O2



Source: Pilotstudy Singapore

Comparison of MIB and 1,4 Dioxan removal





MIB removal rate:

3 mg/L O_3 + 0.8 mg/L H_2O_2 in short reaction time

≈ 5 mg/L O_3 in long reaction time

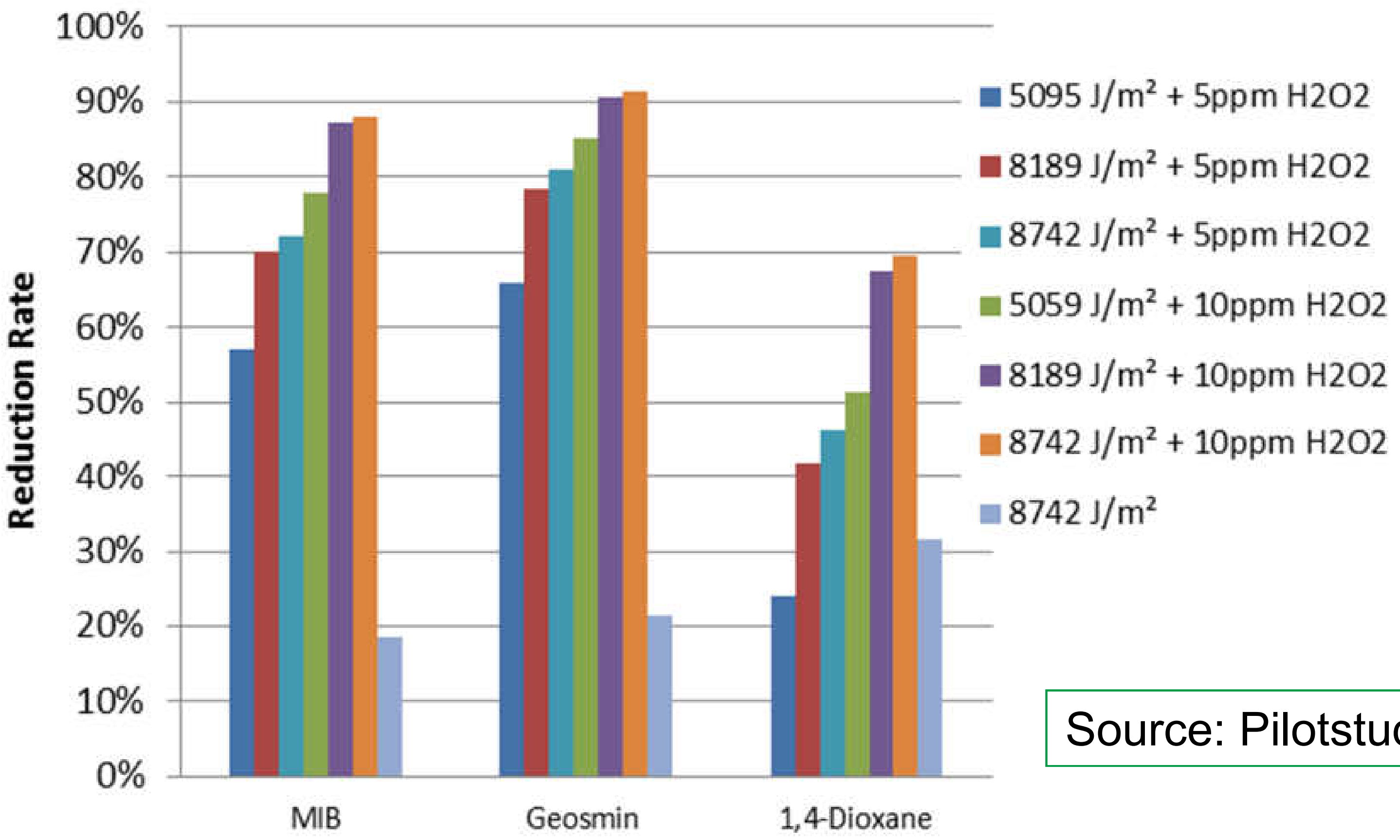
1,4-Dioxane removal rate:

3 mg/L O_3 + 0.8 mg/L H_2O_2 in short reaction time

≈ 5 mg/L O_3 in long reaction time

Source: Pilotstudy Singapore

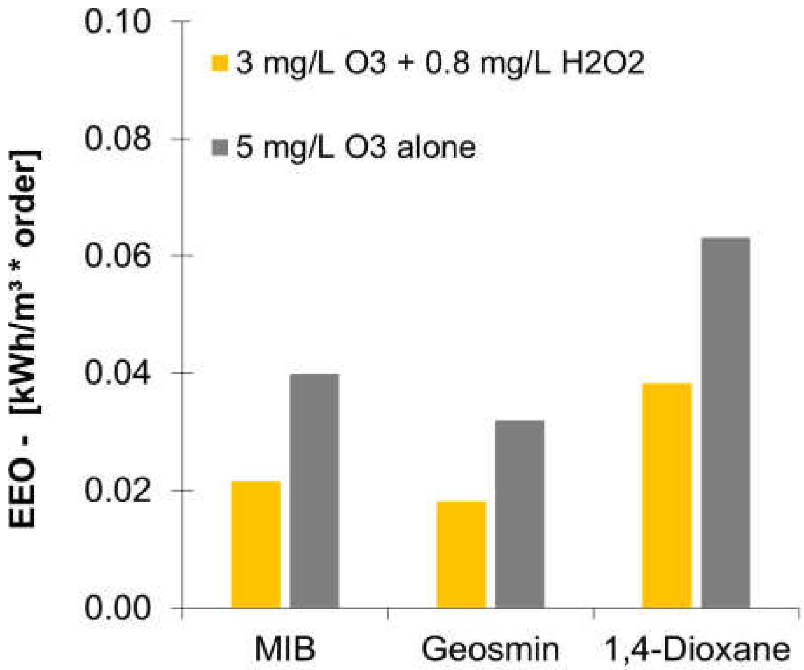
Test Results UV and UV based AOP

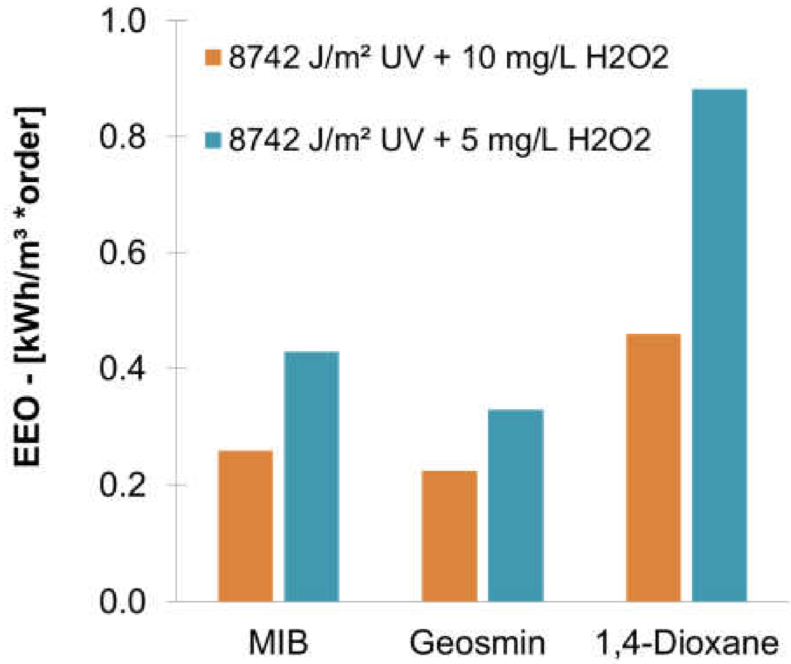


Source: Pilotstudy Singapore

For the contaminant removal, UV AOP is necessary than UV alone.
To remove the same removal rate, higher H_2O_2 concentration will significantly reduce the required UV Dose.

EEOs of AOPs

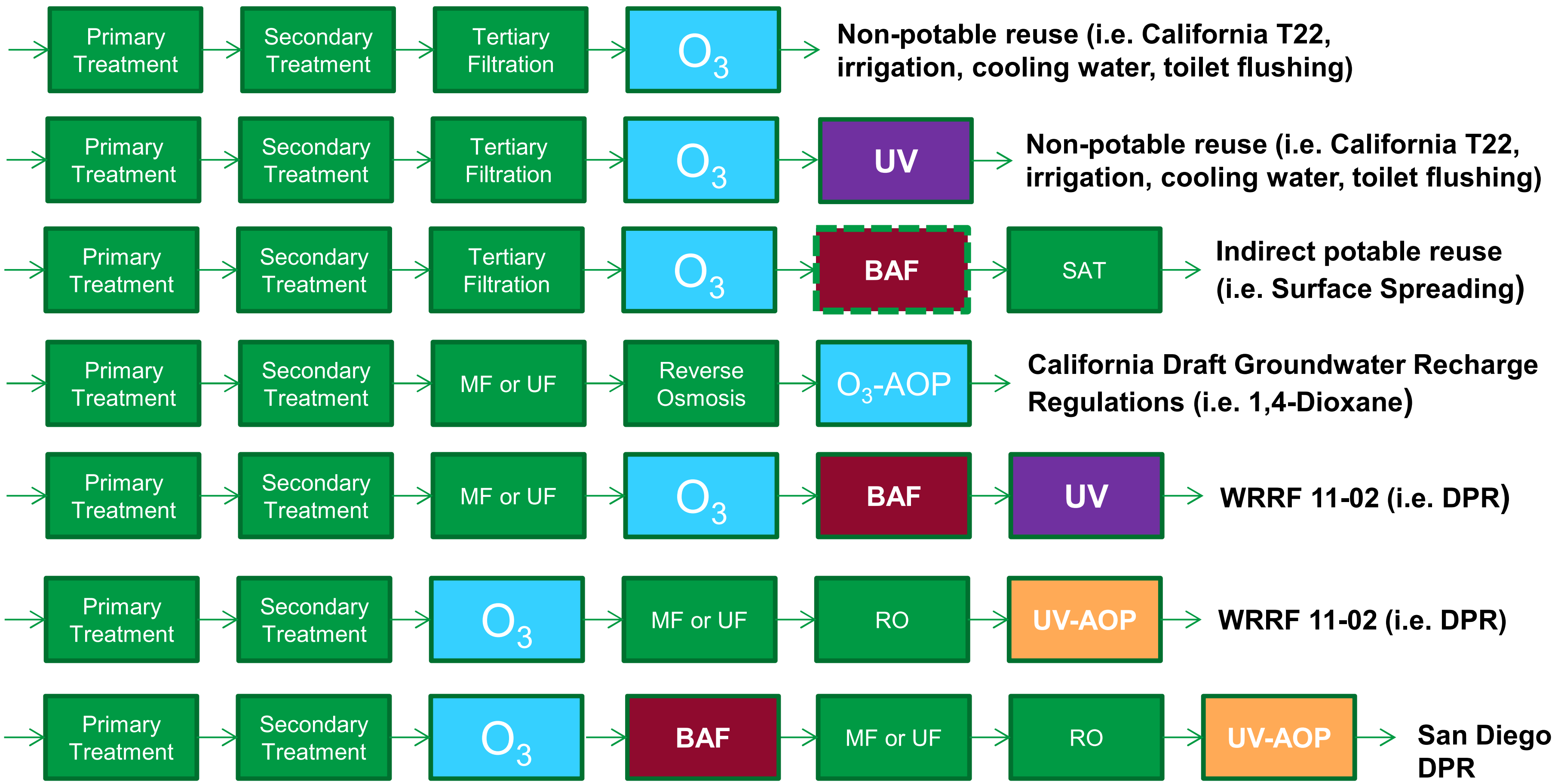




In this case, Ozone and Ozone based AOP with relative low energy consumption and low hydrogen peroxide utilization are superior to UV based AOP in the degradation of the selected compounds.

Source: Pilotstudy Singapore

Different ways to integrate in Water Reuse –
Treatment Train Options – Reuse Applications



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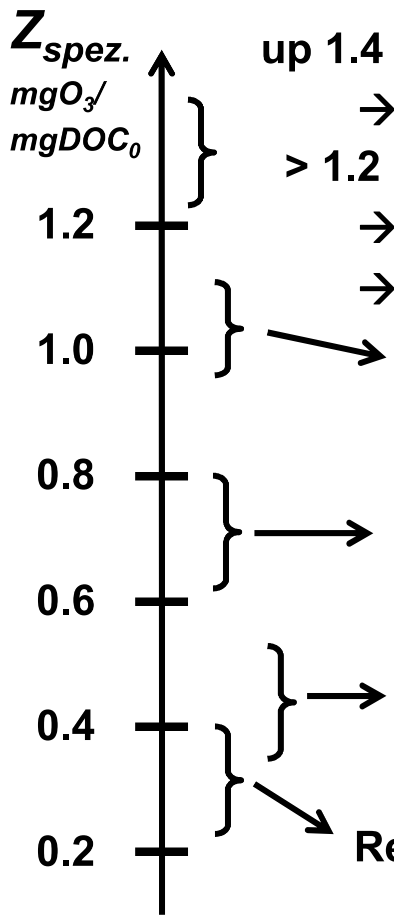
Effects on Micro Pollutant Oxidation

Ozone
Ozone/H_2O_2
UV/H_2O_2
UV/Chlorine

Micro Pollutant removal by ozone treatment

✓Effects from different specific ozone dosages (12mg DOC/L)



up 1.4 → slight DOC-Elimination

→ 60 % decrease of UV-T(254nm)

> 1.2 → max. 60 % removal of Iopromid, Iopamidol

→ 30-40% removal of Iohexol, Diatrizoat, AOI

→ Removal of the metabolites AMDOPH, AMPH

90 % Removal of Clofibrinsäure, Ketoprofen

Removal of Bezafibrat, Ibuprofen, Indomethacin

→ Removal of: Carbamazepin, Phenazon, Propyphenazon, Diclofenac, Naproxen, AAA, FAA

→ Disinfection effect

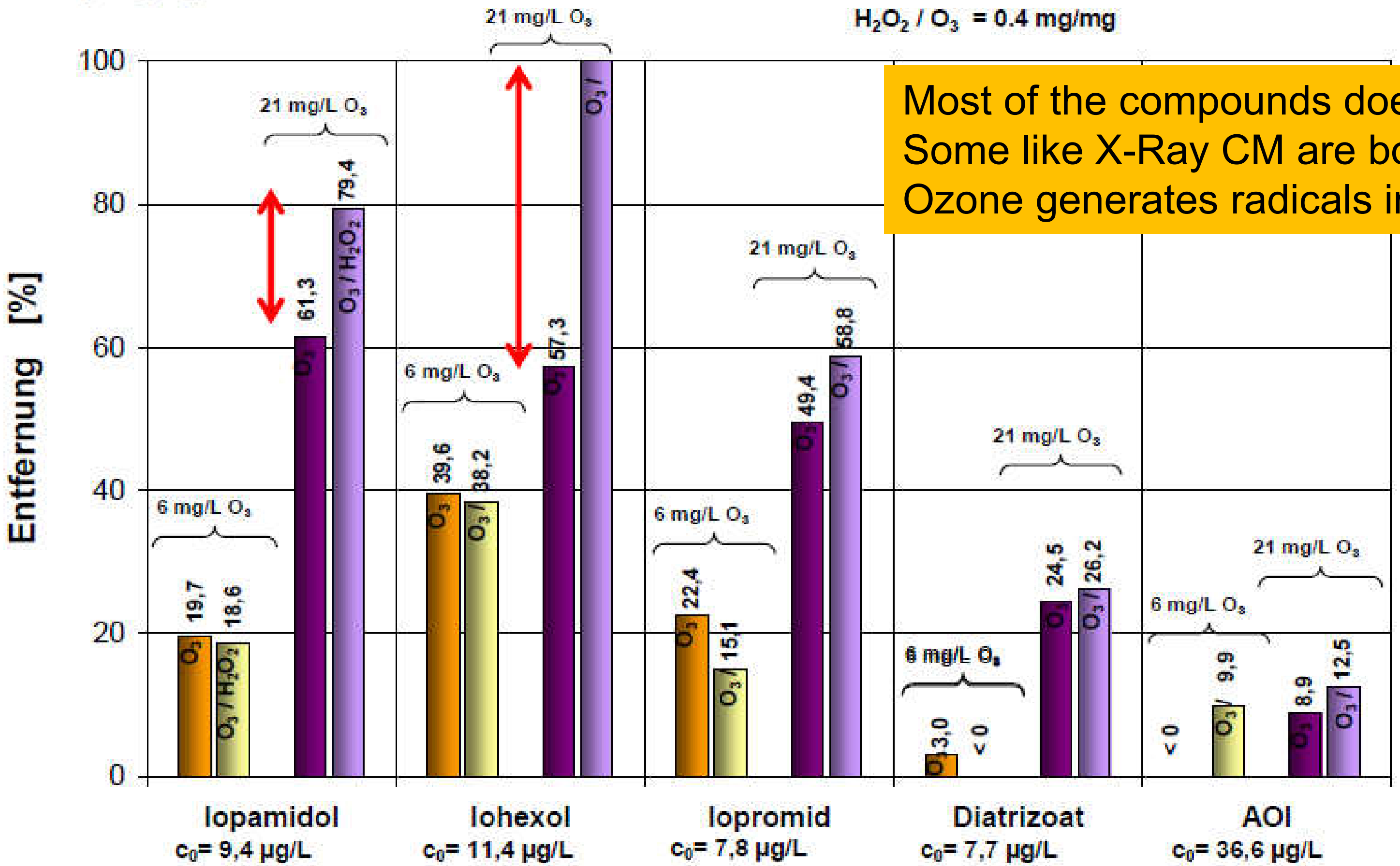
Removal of : Estrogens, Estron, Ethinylestradiol

source: C. Bahr, TU Berlin, PILOTOX

Micro pollutant removal by Ozone/H2O2

2. Versuchsergebnisse → O_3 / H_2O_2 — Technische Universität Berlin · Fachgebiet Wasserreinhaltung

➤ O_3/H_2O_2: RKM



Most of the compounds does not require H2O2
Some like X-Ray CM are boosted by H2O2
Ozone generates radicals in wastewater

Prof. Dr.-Ing. M. Jekel · Dr. M. Ernst · C. Bahr — 01.07.2005

source: C. Bahr, TU Berlin, PILOTOX

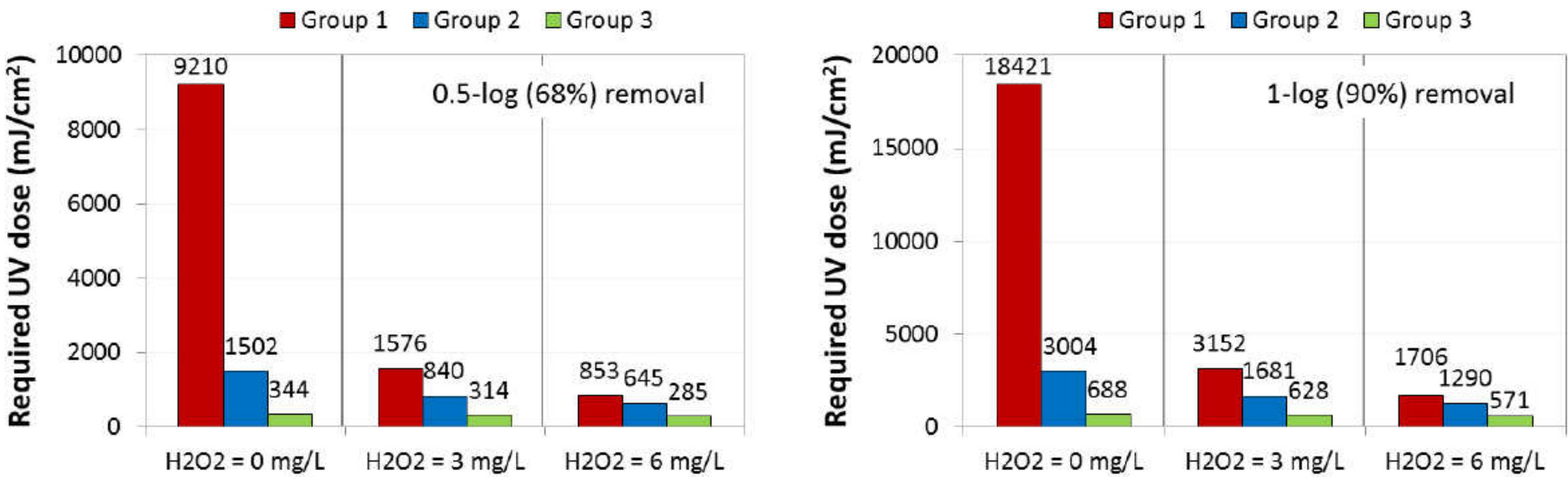
Micro Pollutant removal by UV/H2O2

UV doses required for objective removal

24/19

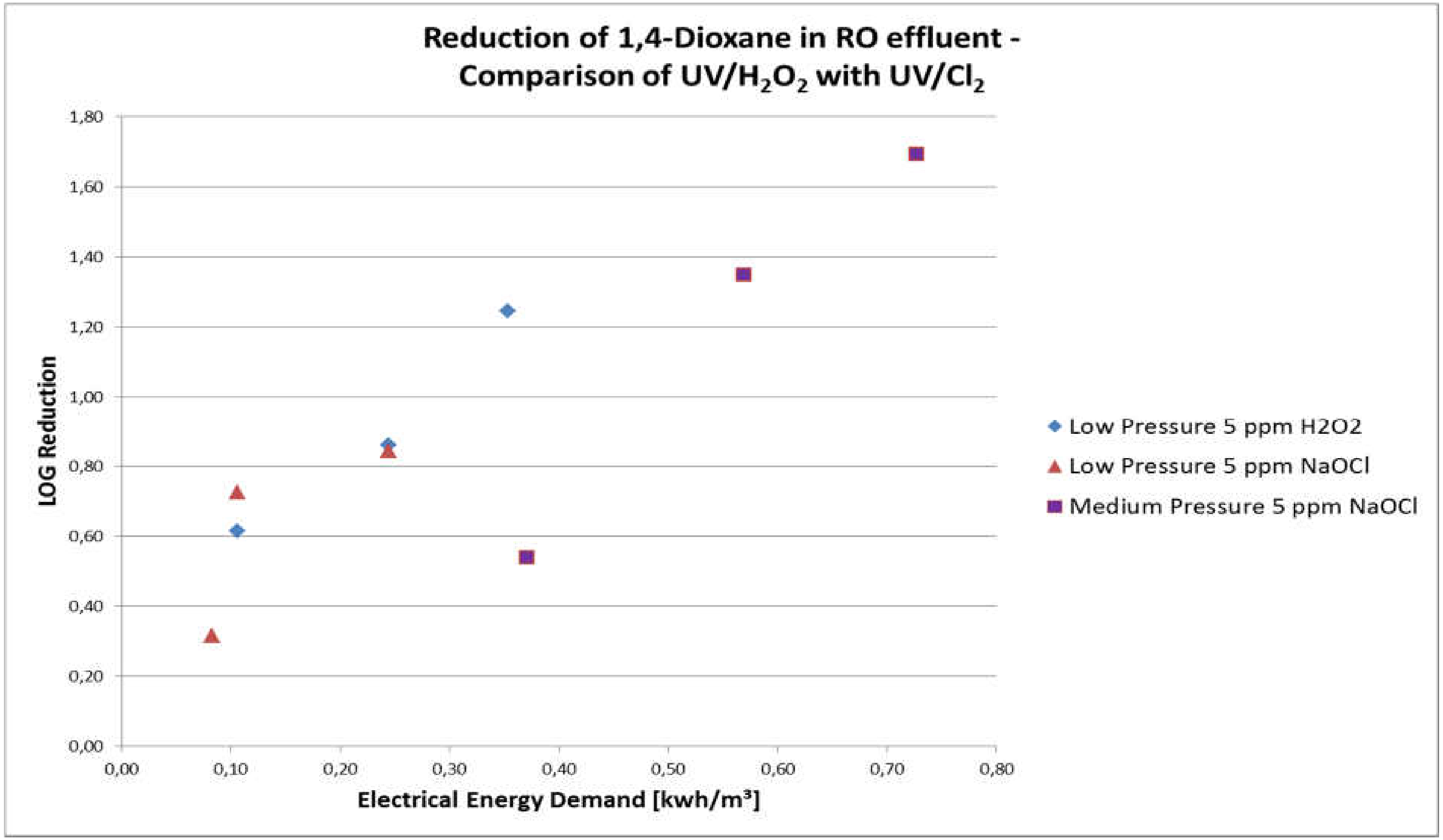
UV dose: 1700 – 3200 mJ/cm2
(40mJ/cm2 standard disinfection)

- To achieve 0.5-log (68%) and 1-log (90%) removal for TOrCs by LP-UV photolysis and LP-UV/H_2O_2 oxidation



Source: Hye-Weon Yu, 29th Water Reuse Symposium 2014
„Online sensor monitoring for detection of trace organic contamonats during UV/H2O2 process"

Micro Pollutant removal by UV/Chlorine



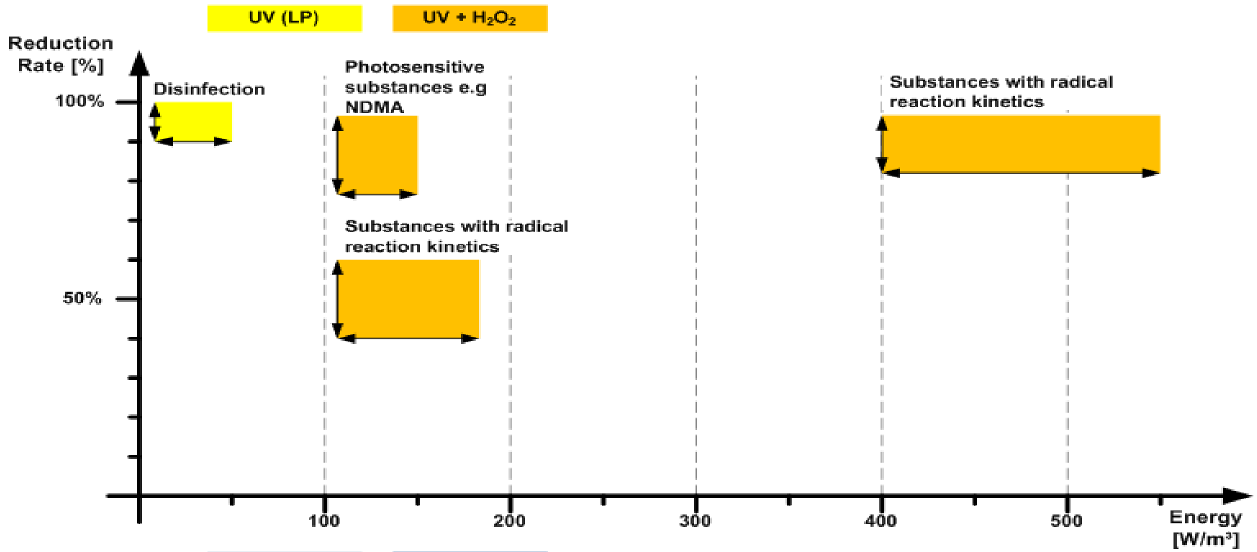
H2O2 and NaOCl forms radicals by UV irridiation
Similar energy consumption & log reduction

Source: pilot study Terminal Island

AOP tools – Reduction rate in relation to energy efficiency in drinking water

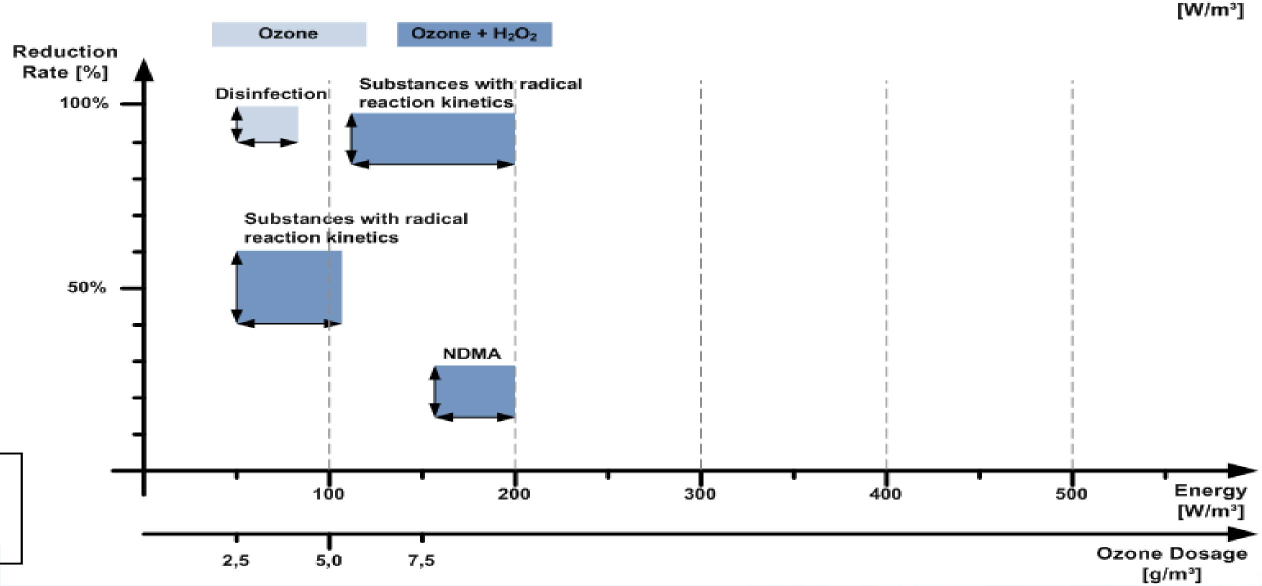
UV: most energy efficiency for disinfection

UV/(H_2O_2): most energy efficiency to remove photo-sensitive substances



Ozone: less energy efficiency for disinfection

Ozone/H_2O_2: most energy efficiency for radical-active substances



Analysis of existing Literature

Conclusions

- Start with detailed case description (treatment conditions and goals)
  Understand when AOP is needed
  Oxidation of Micro pollutant (reaction kinetics)
  Additional treatment effects (e.g. disinfection)
  Synergistic effects with other treatment steps in advanced treatment trains
  By-product formation

- Ozone by itself is powerful
  - gets advanced by combination: Ozone/H_2O_2

- AOPs (e.g. Ozone/H_2O_2; UV/H_2O_2; UV/Chlorine) are selected depending on onsite conditions and treatment goals

- More "complex" decision matrix will lead to the best available solution in a specific case (on-site conditions, energy and chemical consumption, treatment goals, synergistic effects within treatment train)

Conclusions

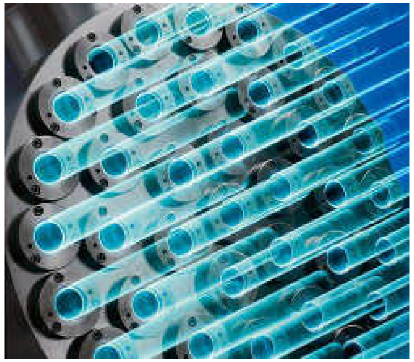
- **AOPs are an efficient barrier against unwanted compounds in DW like:**
  - **Taste & Odor (MIB, Geosmin)**
  - **Pesticides (Metaldehyde, Atrazin)**
  - **Industrial Chemicals (1,4 Dioxan)**
  - **Pharmaceuticals**

- **The different AOP tools UV, H_2O_2 and Ozone have specific treatment effects:**
  - ***ozone active***
  - ***UV active***
  - ***radical active***

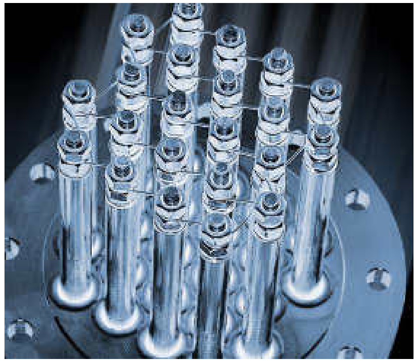
- **Selecting the AOP tools right results in:**
  - ***a multiple barrier for a wide range of substances***
  - ***with reduced energy consumption***
  - ***with an optimized overall cost of ownership***

Thank you for your attention!

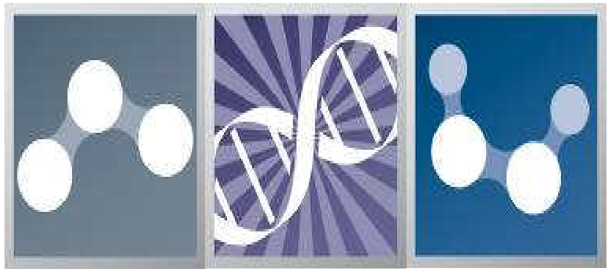
UV Disinfection



Ozone Oxidation



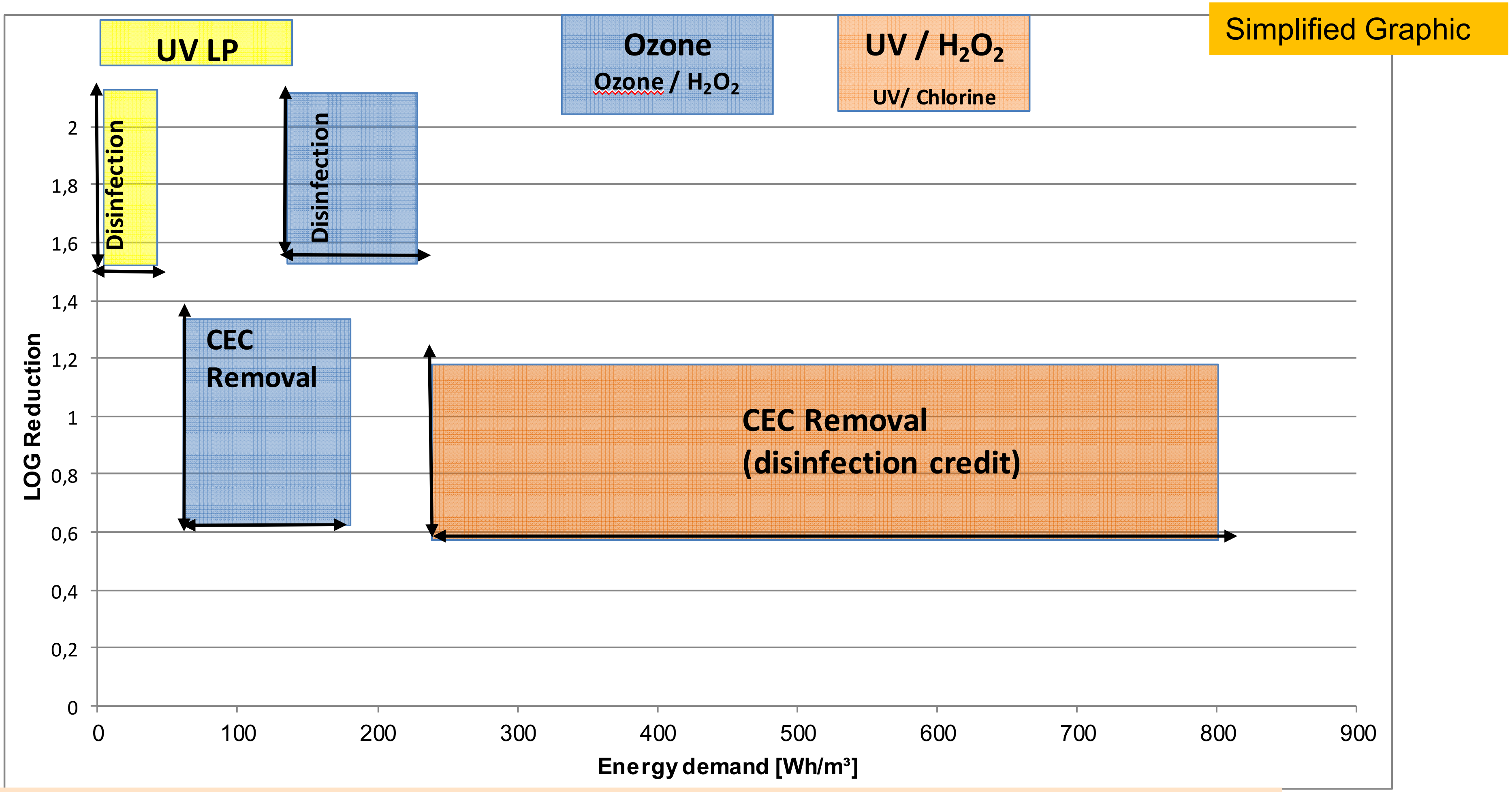
Advanced Oxidation



The right Advanced Oxidation Solution to solve your problem

xylem
Let's Solve Water

Energy demand in Muni Wastewater Reuse



Ozone dose for Disinfection : 1-1.5 g O3/ g TOC and for MP removal 0.5 – 0.7 g O3 / g TOC.
UV dose for disinfection is based on UVDGM report.
UV dose for UV AOP 600 – 1700 mJ/cm2 .
Wh/ g Ozone = 18
UVT = 70%

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