21.02.2019

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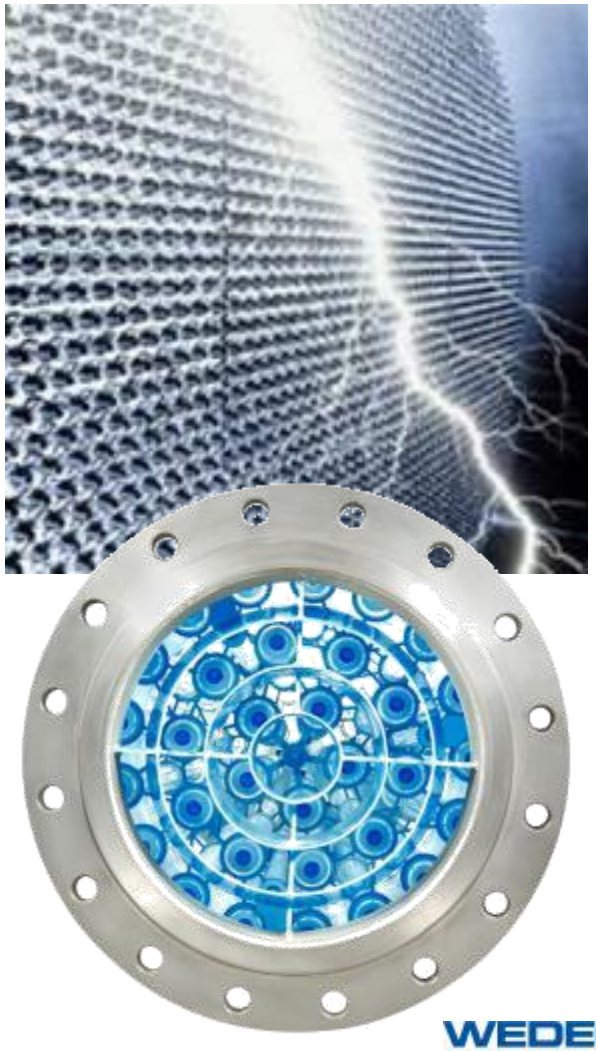
Overview of Ozone and UV Products and Applications

LUDWIG DINKLOH, MANAGER OF GLOBAL WEDECO PRODUCT MANAGEMENT

Topics to be covered

1. Introduction: global Ozone and UV Markets
2. Ozone
   1. Ozone Generator Set-up
   2. Wedeco Portfolio
   3. Municipal Applications
   4. Industrial Applications
3. UV
   1. Basics on UV
   2. Wedeco Portfolio for Drinking Water
   3. Wedeco Portfolio for Wastewater



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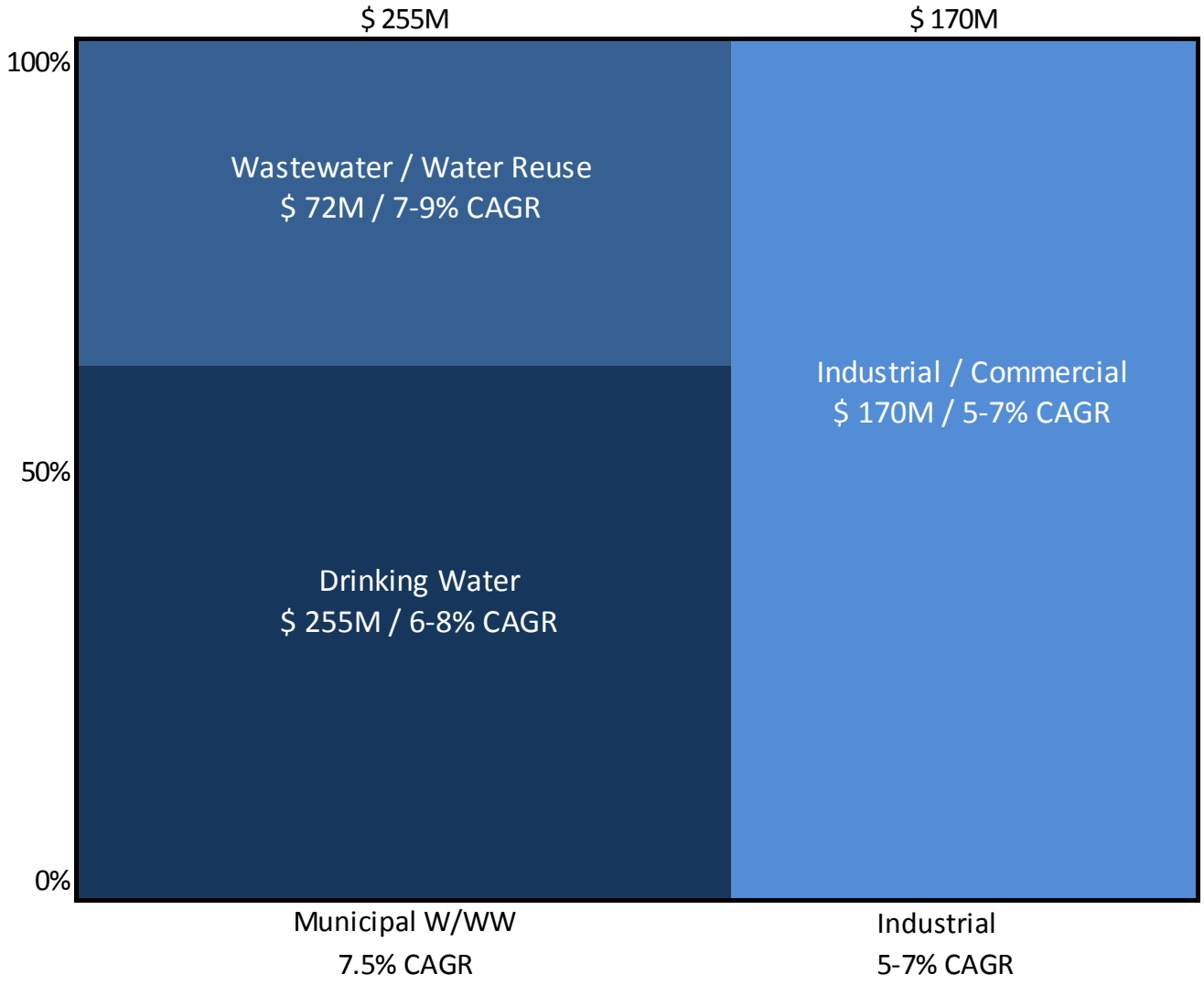
Ozone Market Volume & CAGR 2015-2020

CAGR= Compound Annual Growth Rate



Wedeco market share ~ 10%

Global W/WW: $ 425 Mio @ CAGR ~ 7 %

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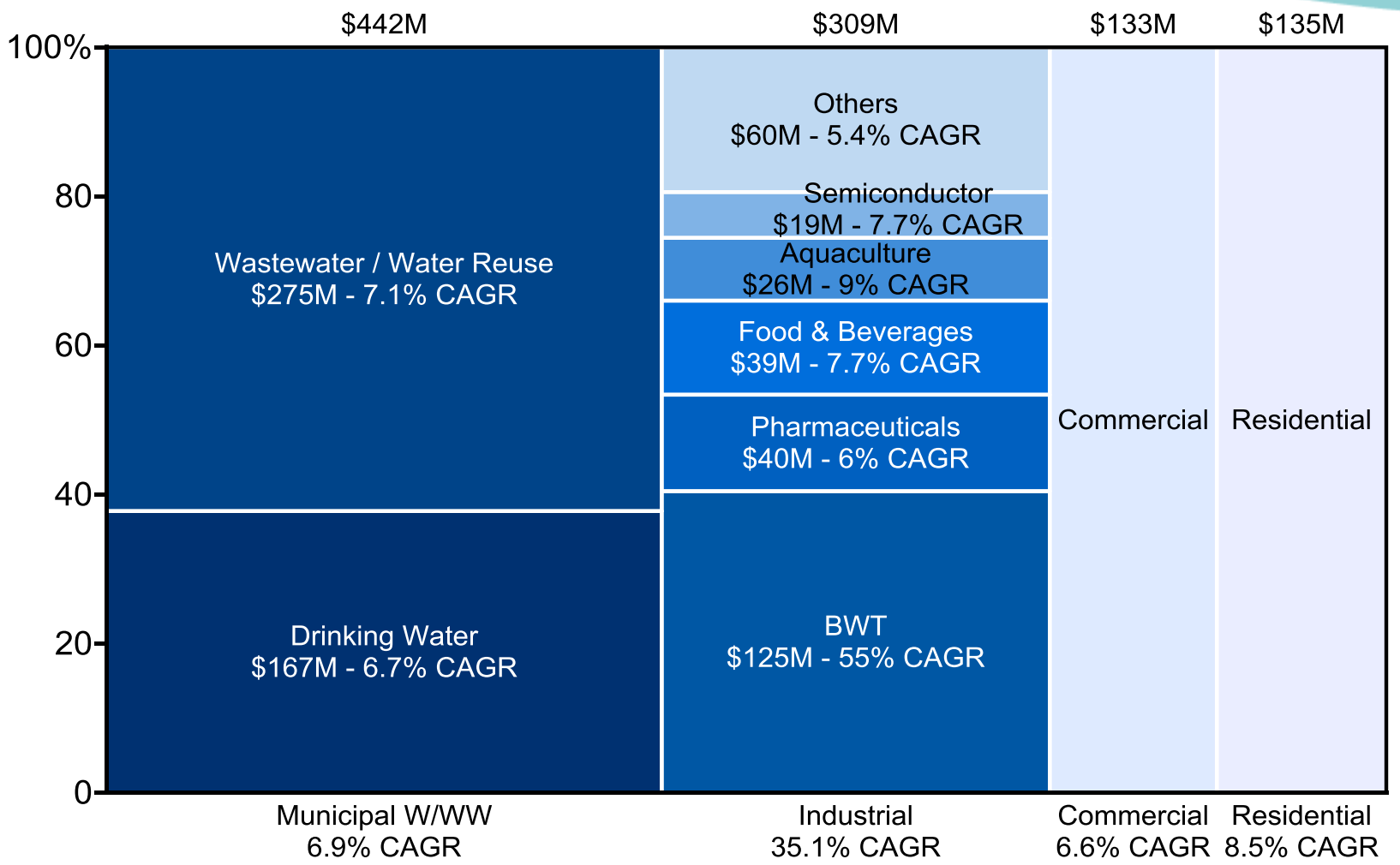
UV Market Volume & CAGR Rate 2015-2020



Global W/WW: $ 1 Mrd @ CAGR ~ 7 %

Wedeco market share = ~ 8%

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Communalities (a Selection)

UV (Disinfection)	O3 (Oxidation)
„Chemical-free“ water treatment	
by conversion of electrical energy	

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Differences (a Selection)

UV (Disinfection)	O3 (Oxidation)
Mainly disinfection	Mainly oxidation (but always with disinfection) => many diverse applications

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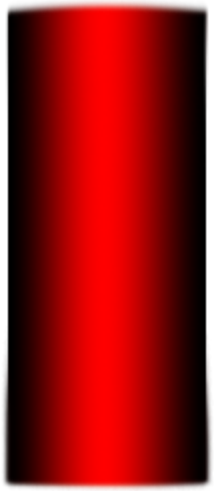
Welcome to WEDECO´s Ozone World

Main Requirements for Ozone Production

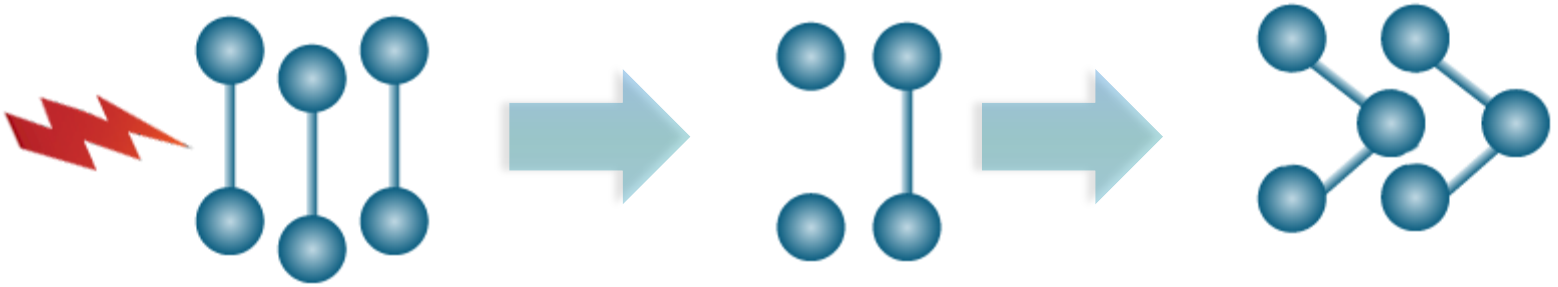
The Three “PILLARS”

1. Feed gas



2. Energy

3. Cooling water



The Ozone Generator

A Shell & Tube Heat Exchanger Vessel and a Power Supply Unit

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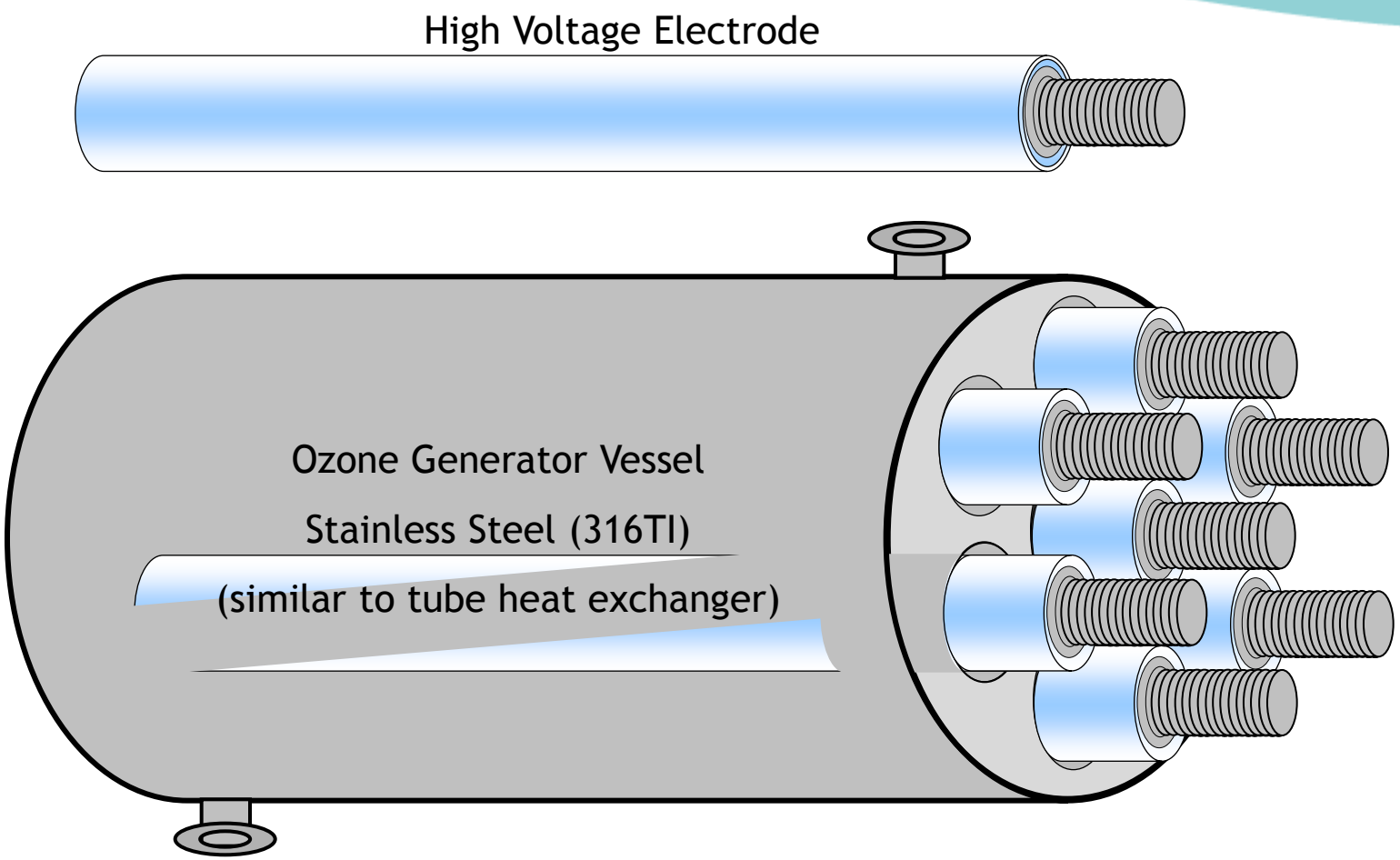
Ozone Generator containing Electrodes



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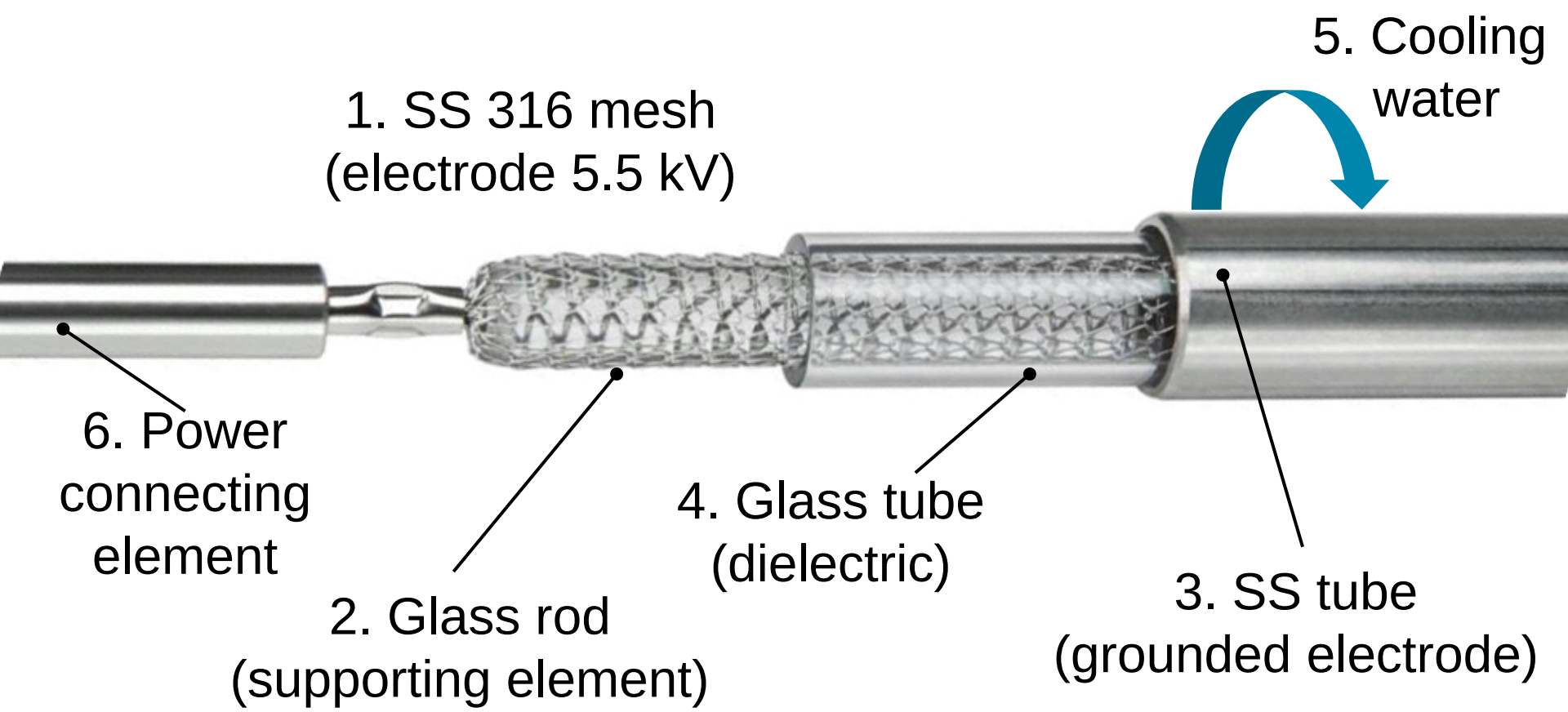
Inside the Ozone Generator: the Electrode

Wedeco's Effizon® 2G evo Electrode Module



Materials: Borosilicate glass / stainless steel (316)

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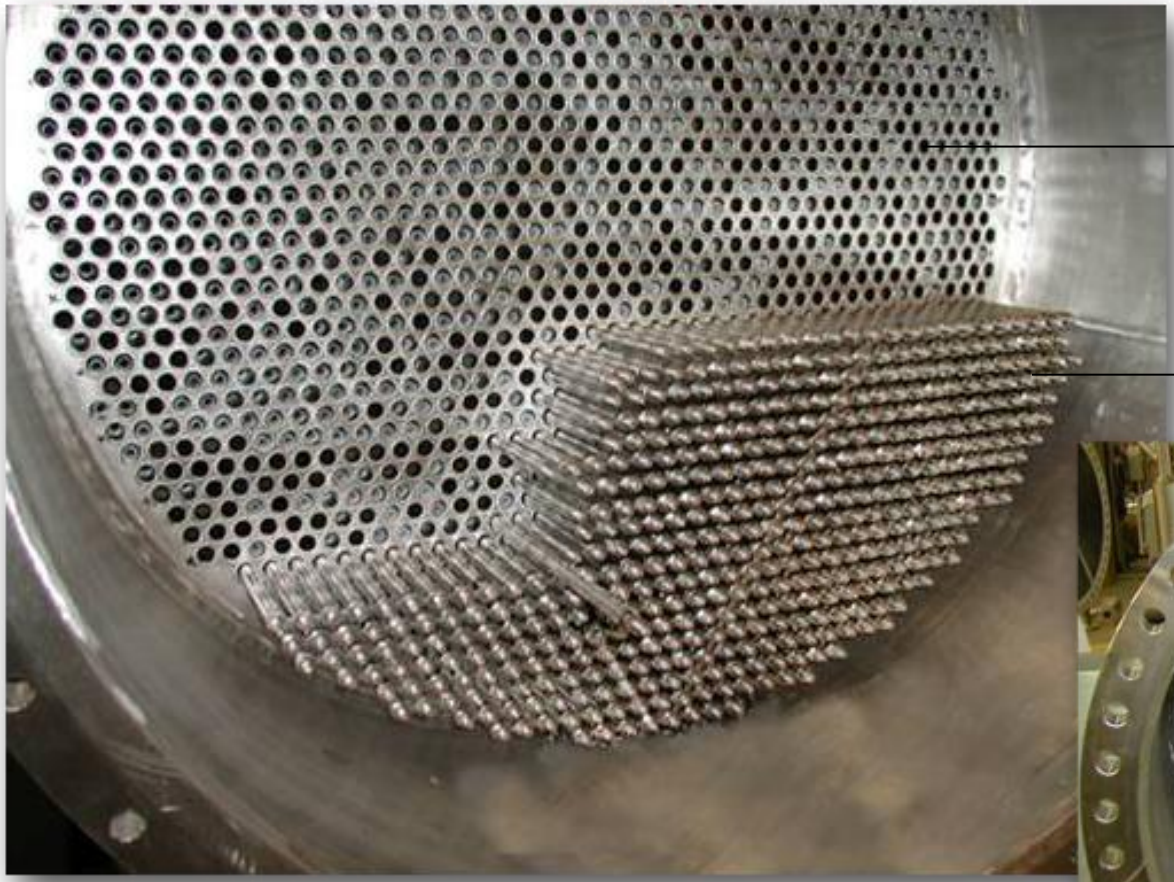
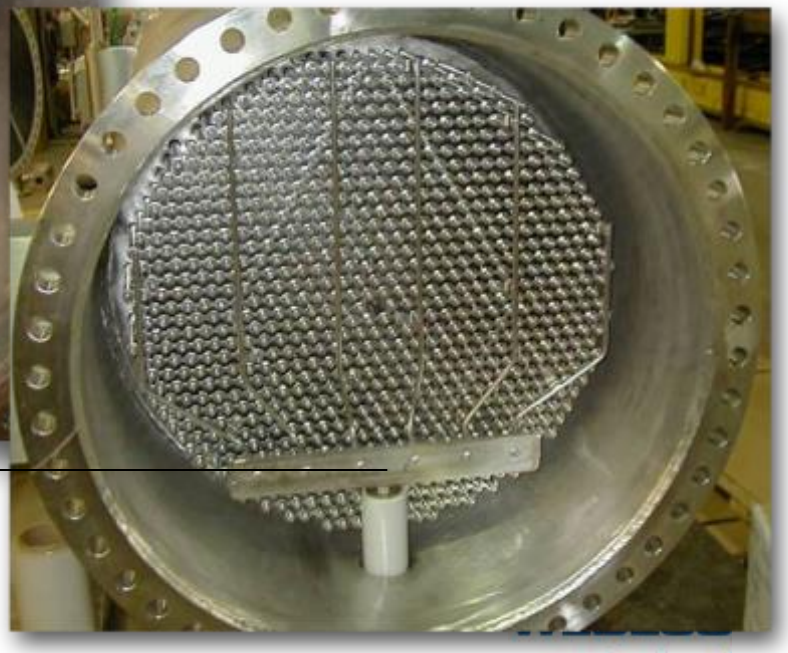
Details of Electrodes inside Ozone Generator



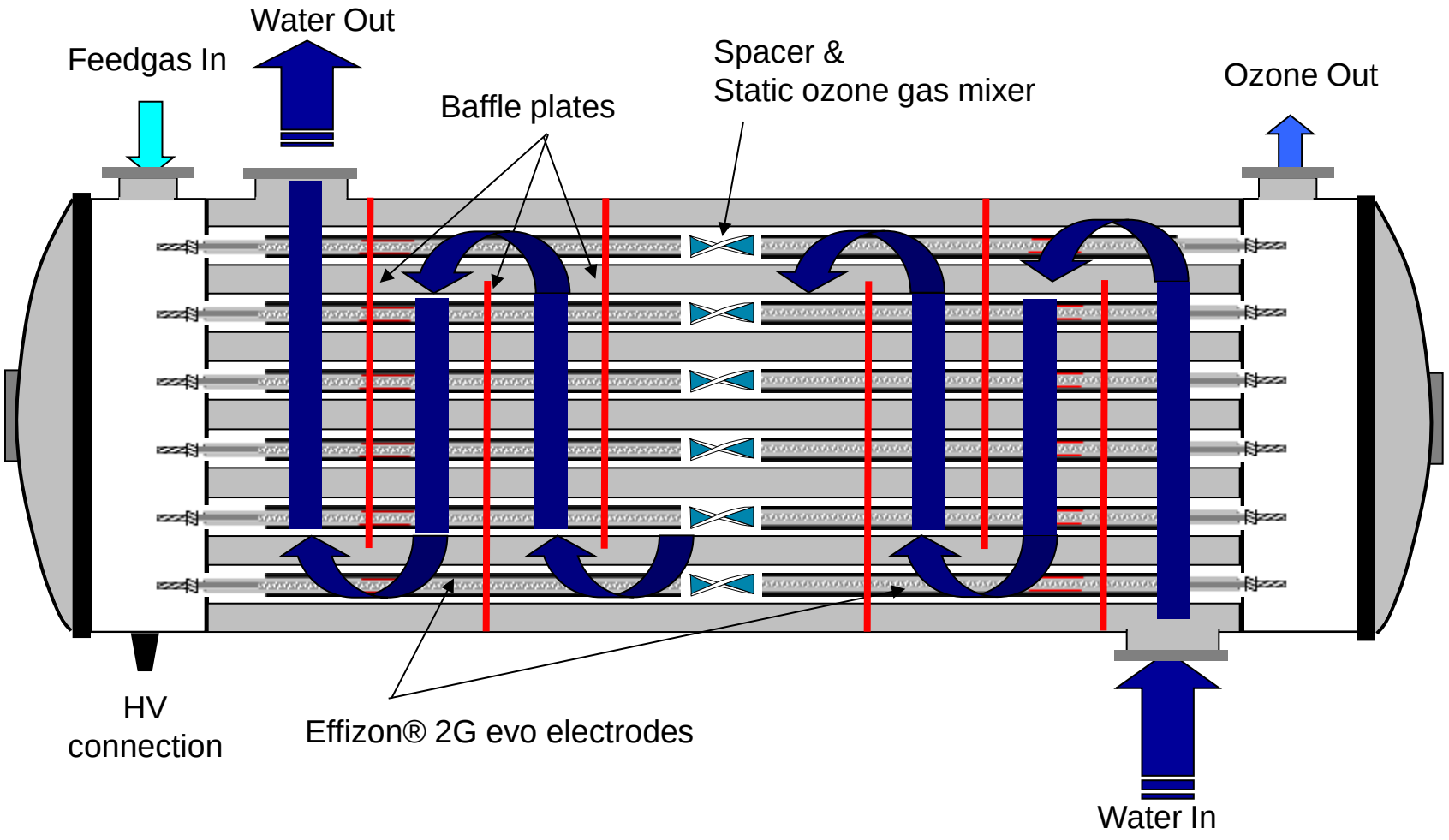
Tubes

Dielectrics are loaded into tube sheet in vessel



High voltage connection to electrodes

Simulation of the total Assembly



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Wedeco‘s Portfolio for Ozone

PDOevo
up to 300,000 g/h O3
(up to 15,800 PPD

SMOevo 410-960
300 – 21,400 g/h O3
(16 -1,130 PPD)

SMO100-200
400 – 1,100 g/h O3
(21 - 58 PPD)

GSO 40-50
200 – 400 g/h O3 (11 – 21 PPD)

GSO 10-30
3 – 100 g/h O3 (1 – 5 PPD)

Modular
0.2 – 8 g/h O3
(0.01 – 0.42 PPD)

WEL
0 – 4 g/h O3
(0.05 -0.21 PPD)

Note: This product is using the electrolytic process to produce ozone

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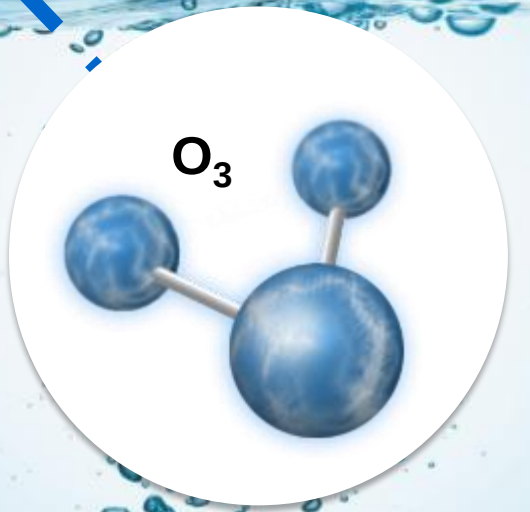
Ozone in Municipal Drinking Water

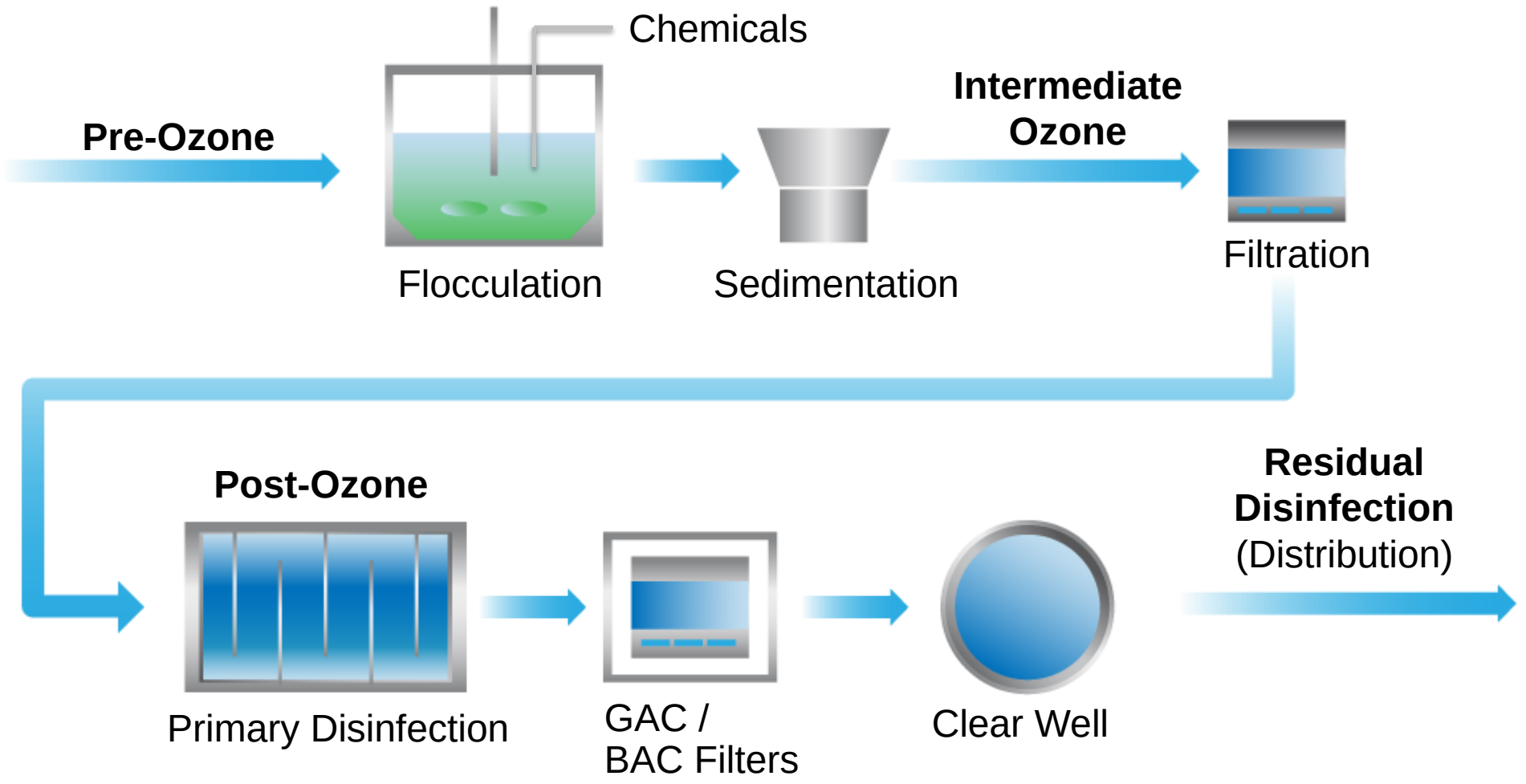
Applications



- Improved flocculation
- Color removal
- Taste & odor control
- Fe/Mn oxidation
- Disinfection
- Algae control
- TOC reduction
- Oxidation of emerging contaminants / micro-pollutants

(**TOC**=**T**otal **O**rganic **C**arbon))

Example of a Surface Water Treatment Plant



GAC= Granular **A**ctivated **C**arbon… *1g **AC** hat 3000m^2 Oberfläche(!)*
BAC= **B**iological **A**ctivated **C**arbon

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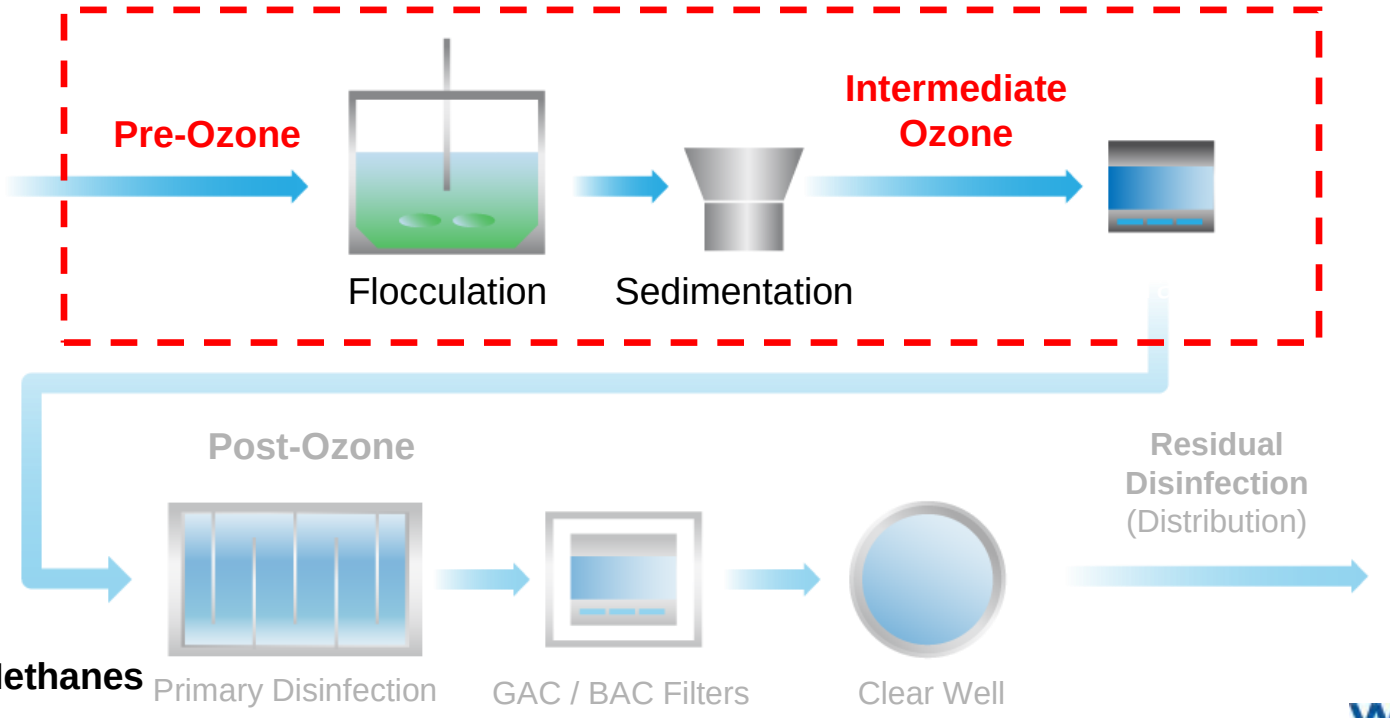
Ozone Application Points
Pre & Intermediate Ozonation

Pre-Ozone:

- Color removal
- Taste & odor oxidation
- THM & HAA pre-cursor oxidation
- Enhanced particle removal

Intermediate Ozone:

- Iron & manganese oxidation
- Hydrogen sulfide oxidation
- Pesticide, phenol removal
- Algae control



THM=TriHaloMethanes

HAA=HaloAceticAcids

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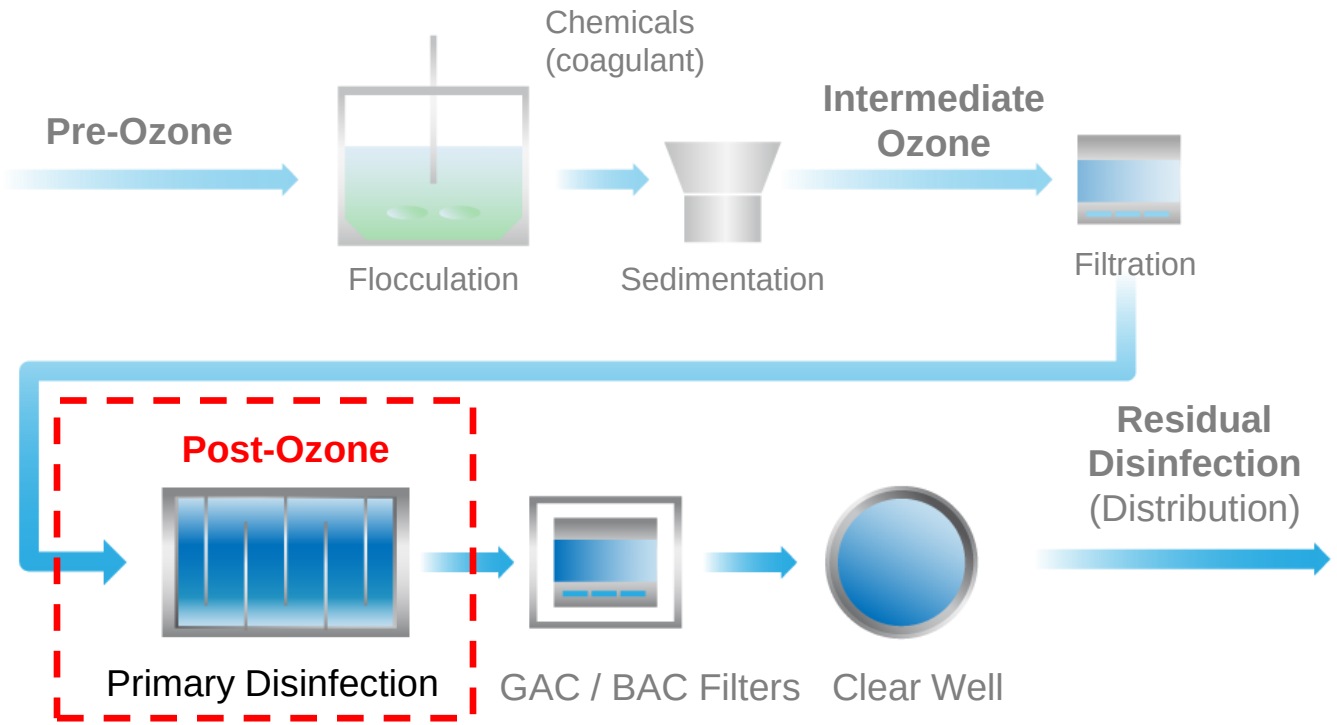
Ozone Application Points
Post Ozonation

- **Virus Disinfection Credit**
- ***Cryptosporidium* Disinfection Credit**
- **Organic Oxidation**



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Waterworks Am Staad
Düsseldorf, Germany

Application/Challenge: Pre-treatment of river bank filtrate prior to activated carbon filtration for the city of Düsseldorf (treatment capacity at Am Staad: ~ 21 million m³/a)

Design Data: **3,000 m³/h** (~ 19 MGD) of pre-filtered drinking water with max. 1 mg/l of ozone = **6 kg of ozone/hr** from oxygen

Wedeco Solution: 2 x LWO 3000 ozone systems

Start-up Date: April 1995

40 YEARS OF PASSION FOR WATER

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Waterworks Am Staad
Düsseldorf, Germany

Over 20 years clean water thanks to the “Düsseldorf Method“

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Ozone Dosages for first Evaluation

Drinking Water Applications

Application		Ozon Dosage	Retention time [min.]
Pre-oxidation			
improved Coagulation		0,5 – 1,5 gO3/m³	2-5
Iron oxidation		0,45 gO3/gFe	2-3
Manganese oxidation		0,9 gO3/gMn	2-3
taste and odour removal		0,5 – 2 gO3/m³	2-5
Algae and algae by-products			
pre-ozonation		2 gO3/m³	3
inter-ozonation		3 – 5 gO3/m³	10
Nitrite oxidation (ground water)		1.04 gO3 / g NO2	1-3
Hydrogen sulfide (ground water)		3.5 mgO3 / mg NO2	1-3
Main-oxidation			
Reduction of organic matters		3 gO3/m³	15
Iron oxidation		0,45 gO3/gFe	2-3
Manganese oxidation		0,9 gO3/gMn	2-3
Algae and algae by-products			
pre-ozonation		2 gO3/m³	3
inter-ozonation		3 – 5 gO3/m³	10
Nitrite oxidation (ground water)		1.04 gO3 / g NO2	1-3
Colour reduction		2 – 4 gO3/m³	3
Presticides		3 gO3/m³	15
Disinfection	3 log TC	3 gO3/m³	4

TC=TotalCarbon

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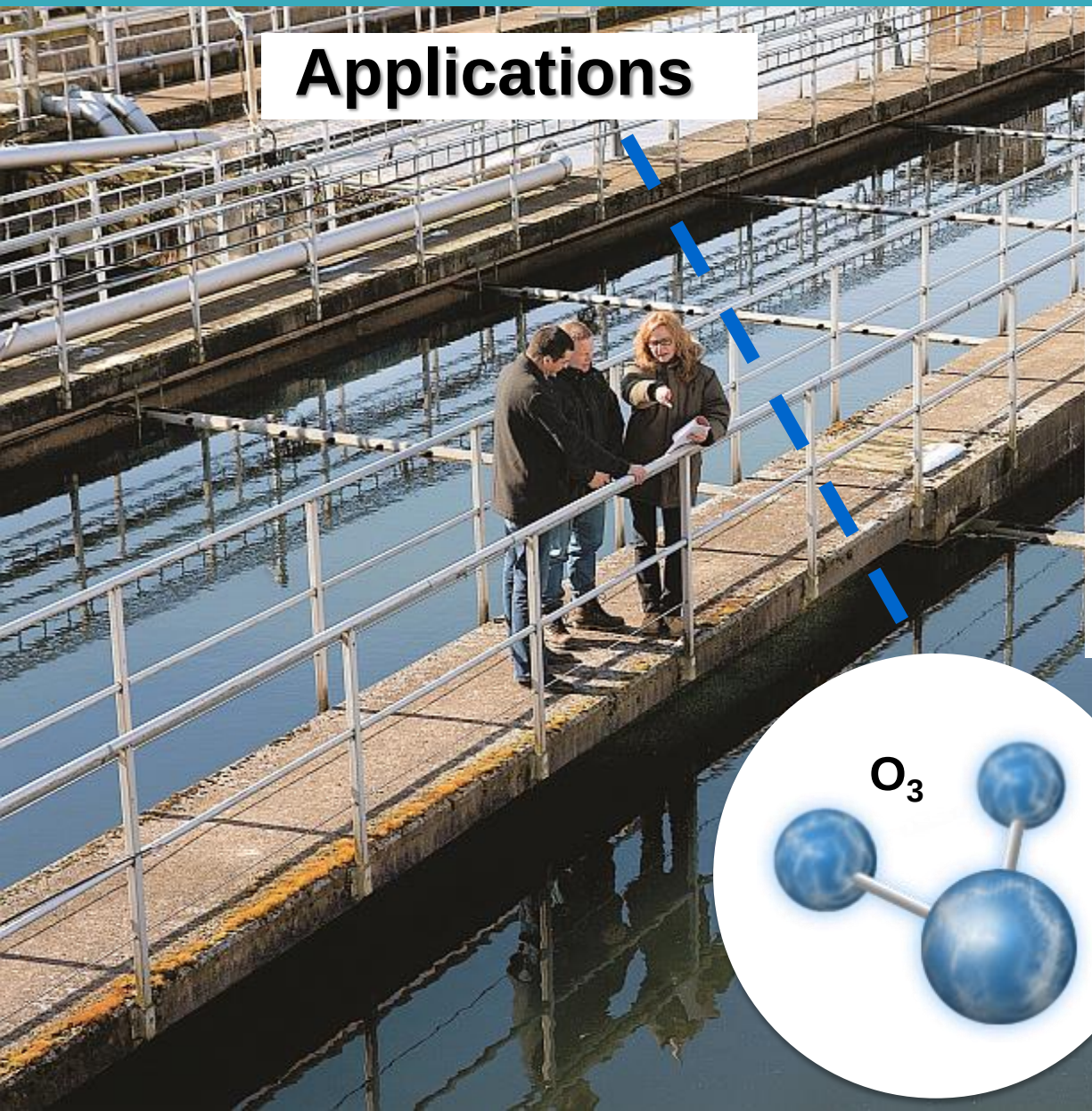
Ozone in Municipal Wastewater

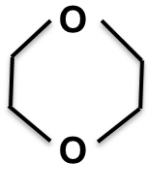


Applications

- COD reduction
- Color removal
- Excess sludge reduction
- Elimination of phenols and/or cyanides
- Disinfection
- Reduction of emerging contaminants (e.g. endocrine disruptors, dioxanes, etc.)

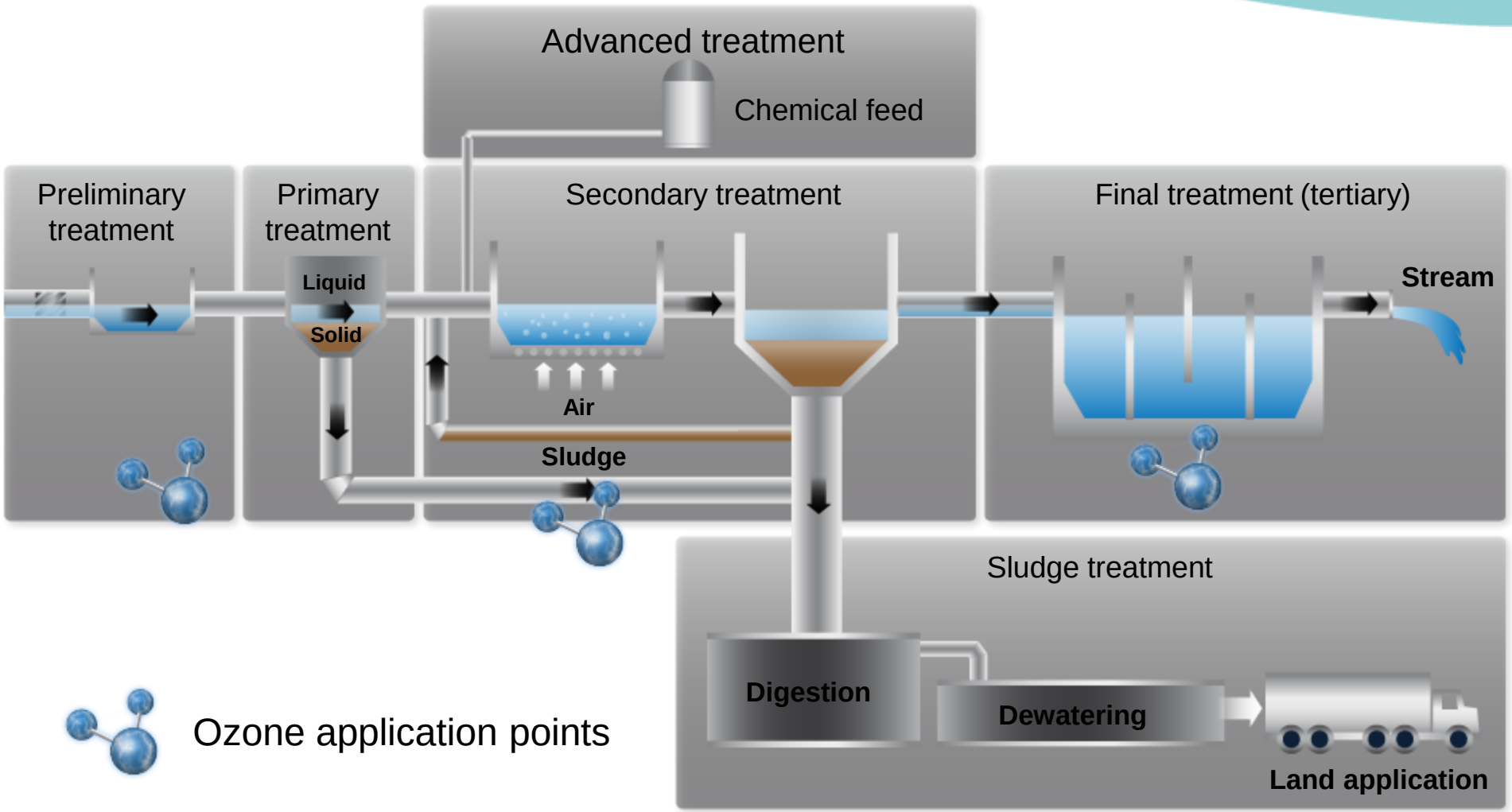
COD=Chemical-Oxigen-Demand

Dioxane:



Endocrine Disruptors
=hormonaktive Substanzen

Typical Wastewater Treatment Process



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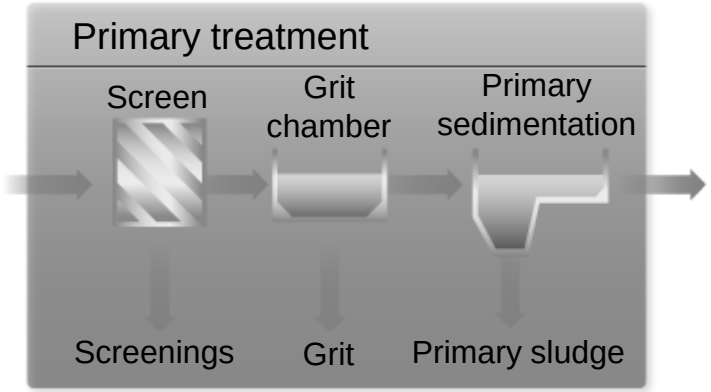
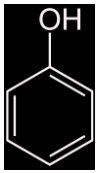
Typical Wastewater Treatment Process

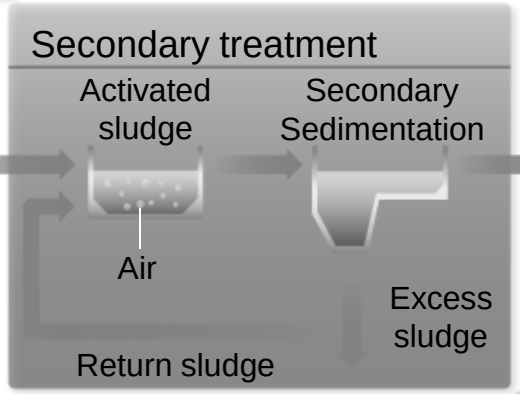


To secondary (if necessary)

Ozone applications:
Removal of toxic substances
Detoxification, e.g. Phenols



From primary

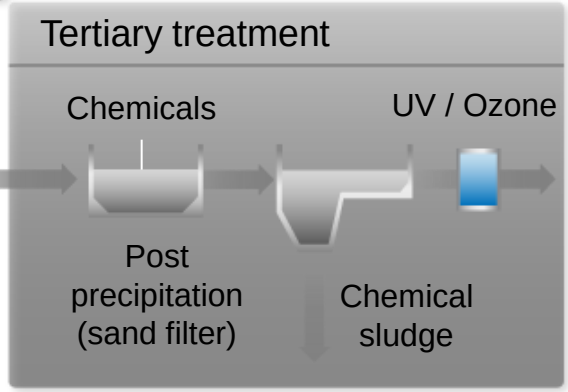


To tertiary (if necessary)

Ozone applications:
Sludge reduction
Bulking sludge treatment

Ozone applications:
Removal of Micropolutants
Disinfection
Decoloration / Deodorisation
COD Removal

From secondary



Ozone Dosages for first Evaluation

Waste Water Applications

Application		Ozon Dosage	Retention time [min.]
COD – reduction	< 20%	2 gO3/gCODelim.	15
	< 50%	3 gO3/gCODelim.	30
	< 80%	4 gO3/gCODelim.	45-60
Disinfection	3 log TC	15 gO3/m³	15
	2 log TC	7 gO3/m³	10
Micropollutants		(90 % reduction @ 1 µg/l inlet)	
Reuse ww quality		3 gO3/m³	5-10
Discharge ww quality		7 gO3/m³	
Decoloration			
Reuse ww quality		10 gO3/m³	5-10
Discharge ww quality		20 gO3/m³	5-10
Sludge Reduction			
40% reduction rate		0,07 gO3/gdrySludge	Tbd

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Eastern Treatment Plant
Melbourne, Australia

Application/Challenge: Improve water quality for ocean discharge and provide class A water for reuse of municipal waste water.

40 YEARS OF PASSION FOR WATER

This includes: colour reduction, increase UV light transmittance, disinfection, foam prevention and oxidation of emerging contaminants

Design Data: 29,166 m^3/h (185 MGD)

Wedeco Solution: **5 x 122 kg/h**
Wedeco PDO Ozone generators plus ozone destruction, ozone injection, oxygen generation incl. process controls and monitoring

Start-up Date: 08/2012

(PDO=**P**rojekt spezifisches **D**esign **O**xygen **)**

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Eastern Treatment Plant
Melbourne, Australia

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Overview of Industrial Ozone Applications

Ozone oxidation for industrial wastewater treatment

- COD-reduction
- AOX-reduction
- Reduction of toxic substances in water, e.g.: Cyanides, Pesticides
- Decoloration / De-odorization
- Disinfection
- Improvement of filtration processes
- Improvement of biodegradability

Ozone oxidation for industrial product treatment

- Bleaching (e.g. of kaolin, pulp and paper)
- Synthesis of chemical and pharmaceutical products, etc.
- Improvement of product shelf-life of food, etc.
- Washing of bottles, products, etc.
- Modification of starch, surfaces, etc.

AOX=Adsorbable Organic Halides

1. Example:
Industrial Wastewater Treatment

Everlight Chemical (Taiwan): Color Removal & COD Reduction

Wastewater discharge before ozone treatment

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Oxidation Results for Color & COD Reduction

O_3 Oxidation applied for tailored water quality meeting customers discharge consent

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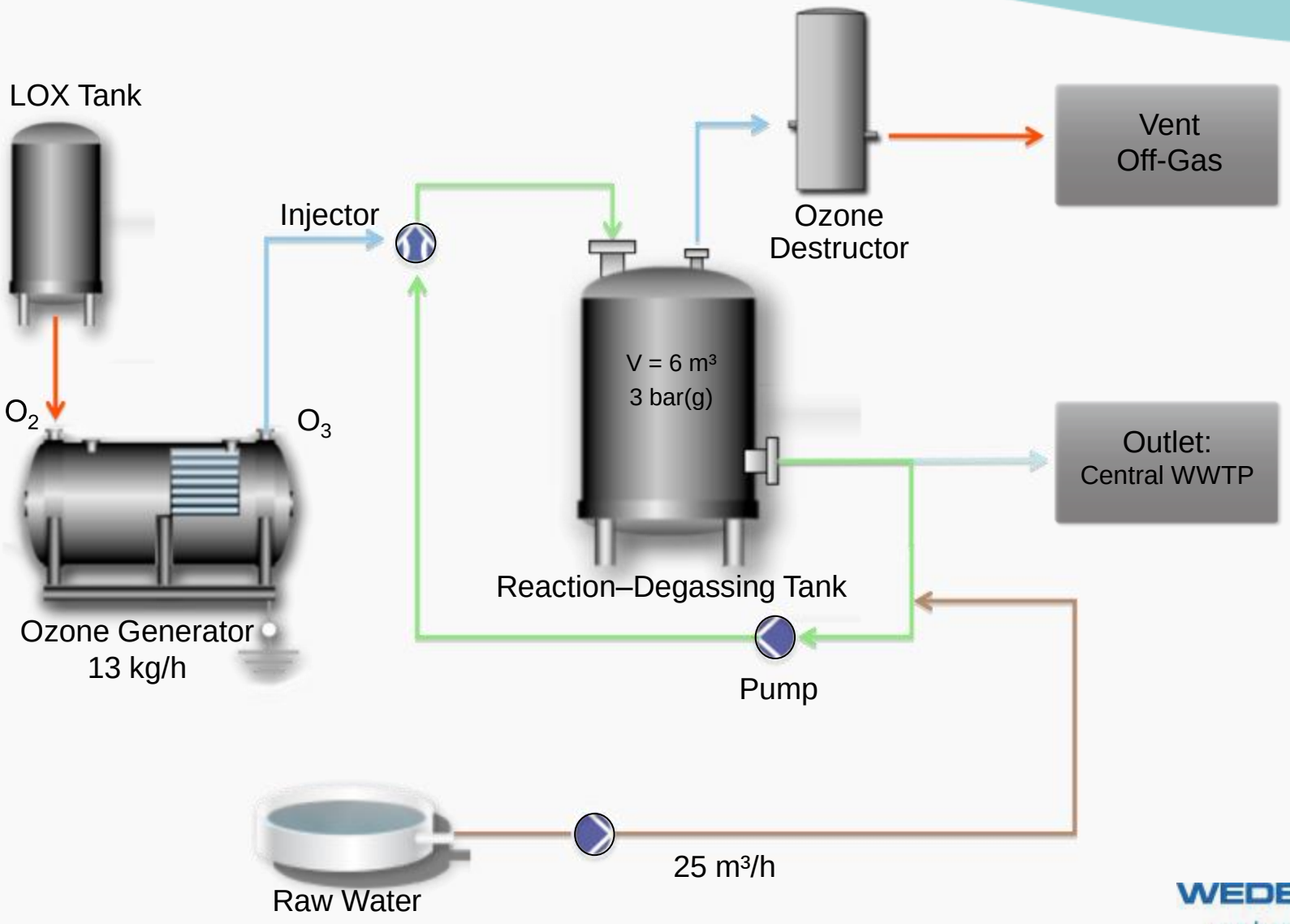
Ozone Process Flow for Everlight



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Containerized Ozone Equipment Everlight

Everlight Chemical

Customer:	Everlight Chemical
Location of Project:	Taiwan
Application:	Waste water treatment
Treatment Goal:	Decoloration & COD
Ozone Capacity:	13 kg O_3/h
Maximum flow rate:	25 m^3/h

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2. Example:
Bottle Rinsing Water at Beverage Industry

Ozone utilized at Adelholzener (Germany)

- Total of 8 filling lines:
  - 3 for PET recycled bottles
  - 2 for PET single use bottles
  - 3 for recycled glass bottles
- Total filling rate: **240,000 bottles per hour**
- Product range: mineral water, flavored water, soft drinks, oxygen enriched water

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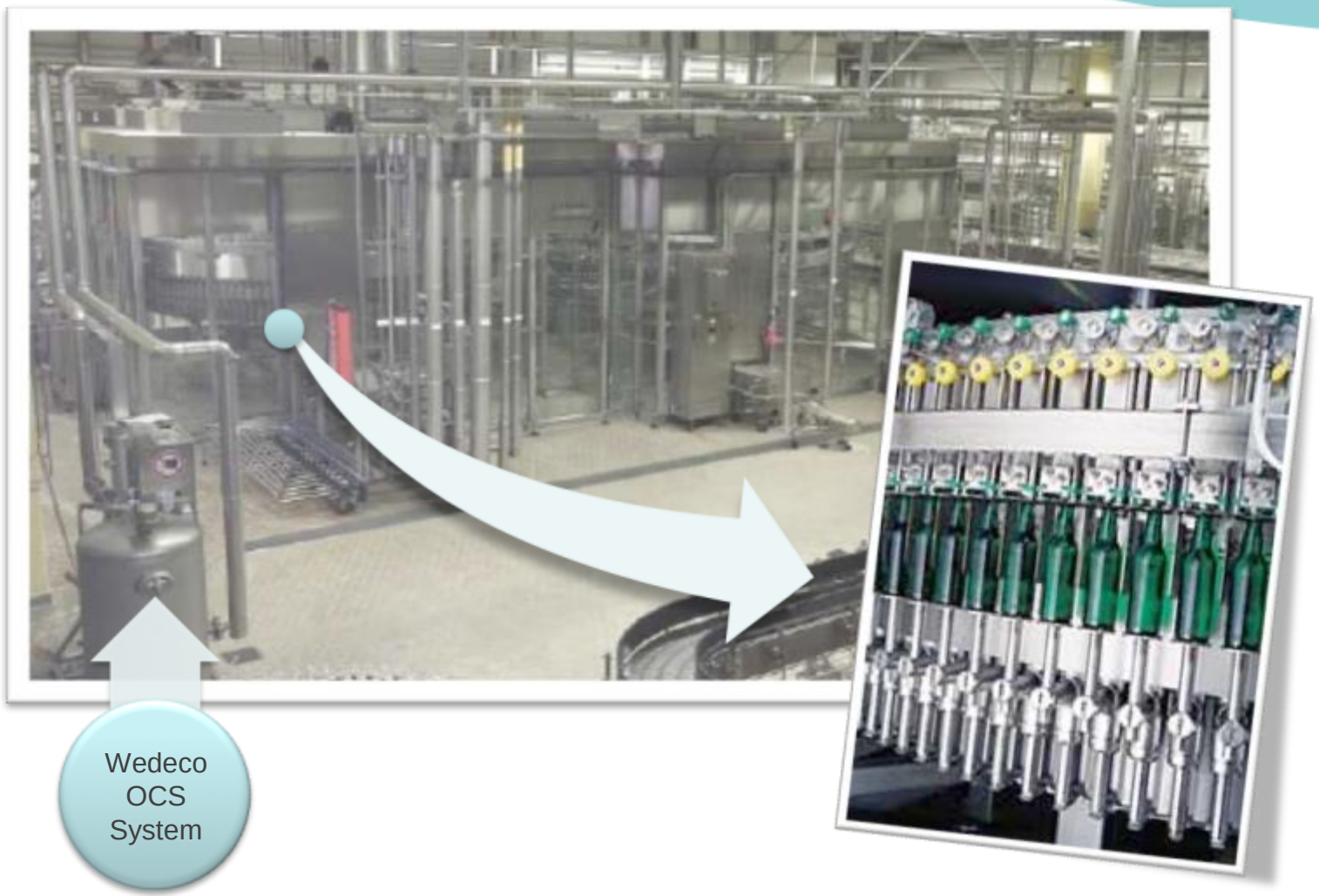
Ozone Rinsing & Filling Lines at Adelholzener



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3. Example
Process Water for Pharmaceutical Industry

Example of Ozone for Procter & Gamble (Italy)

Procter & Gamble

Procter and Gamble (P&G) plant Gattatico (Italy) produces detergents for cleaning purposes such as “Mr. Proper”

P&G decided to improve the sanitization of existing process water loops, while decreasing the consumption of chlorine based biocides

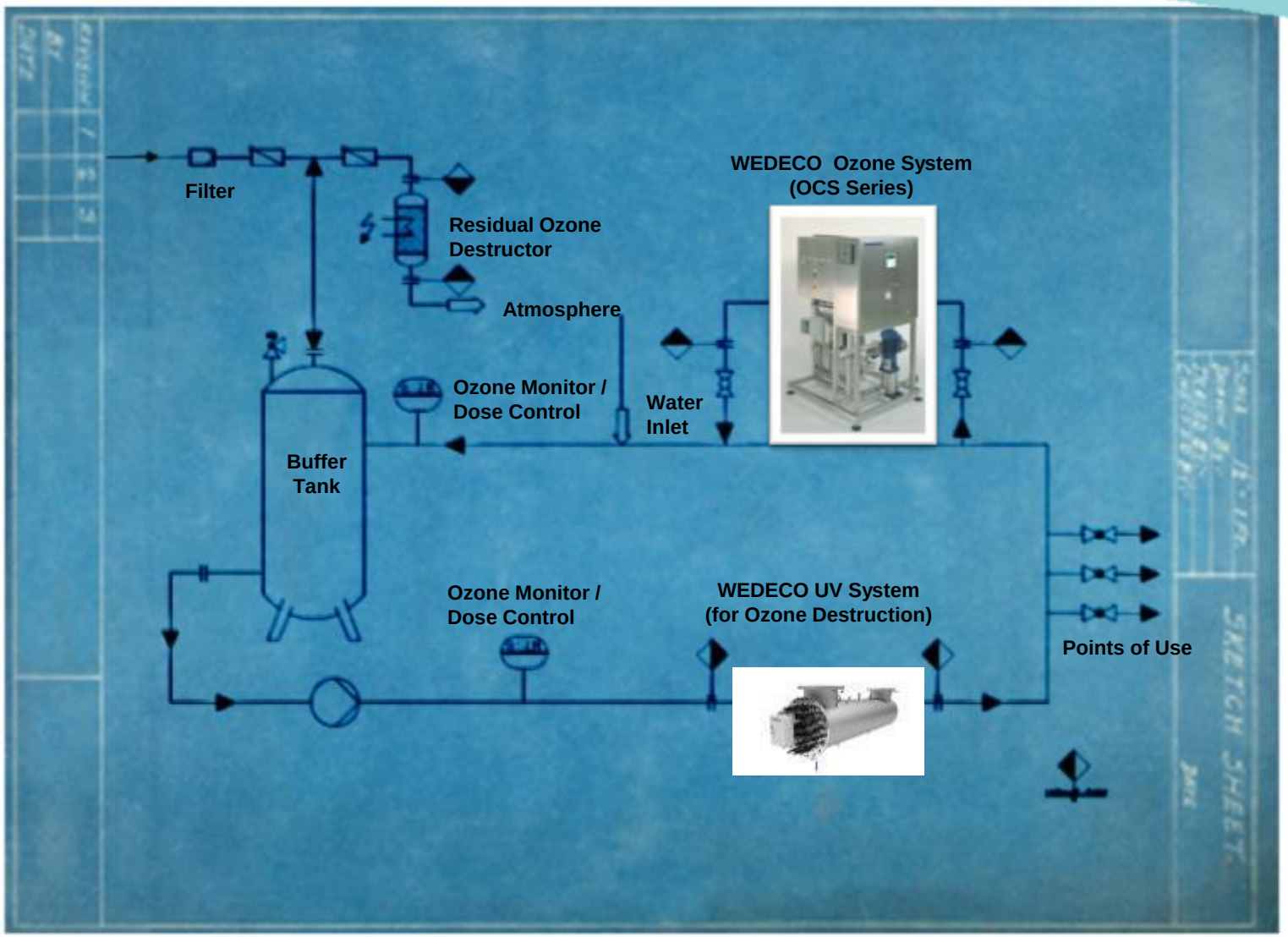
P&G – Sanitization of Process Water Loops

- Typical process water systems incorporate a water storage tank with re-circulating main loop to distribute **DI water** to the process machines and applications

DI=Delonized (HIGH Purity!)

- Problem: systems subject to biofilm development on pipe walls and in the storage tank
- Control of **biofilm** can only be achieved by circulating a disinfectant or biocide throughout the entire system
- Ozone is an excellent biocide to treat existing biofilm and prevent new formation
- Interestingly, once the ozonation solution is used, the ozone residual must be removed before using the water for product production (UV is used to destroy the ozone residual in the water!)

Ozone + UV Process Flow at P&G



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Packaged Ozone and UV Solution for P&G

Compact Ozone System type OCS-GSO30 (100 g O_3/h)

- Feedgas supply
- Ozone introduction
- Re-cooler for cooling water
- Ozone in water monitoring
- Ambient air monitoring
- Offgas destruction with COD 73 (70 m³/h filling rate of buffer tank)

- UV-system type LBA 80 (UV dose 850 J/m² at 80 m³/h)

- PLC system to control and monitor all system functions

COD=Cathalytic Ozone Destruction

PLC=Programmable Logic Controller

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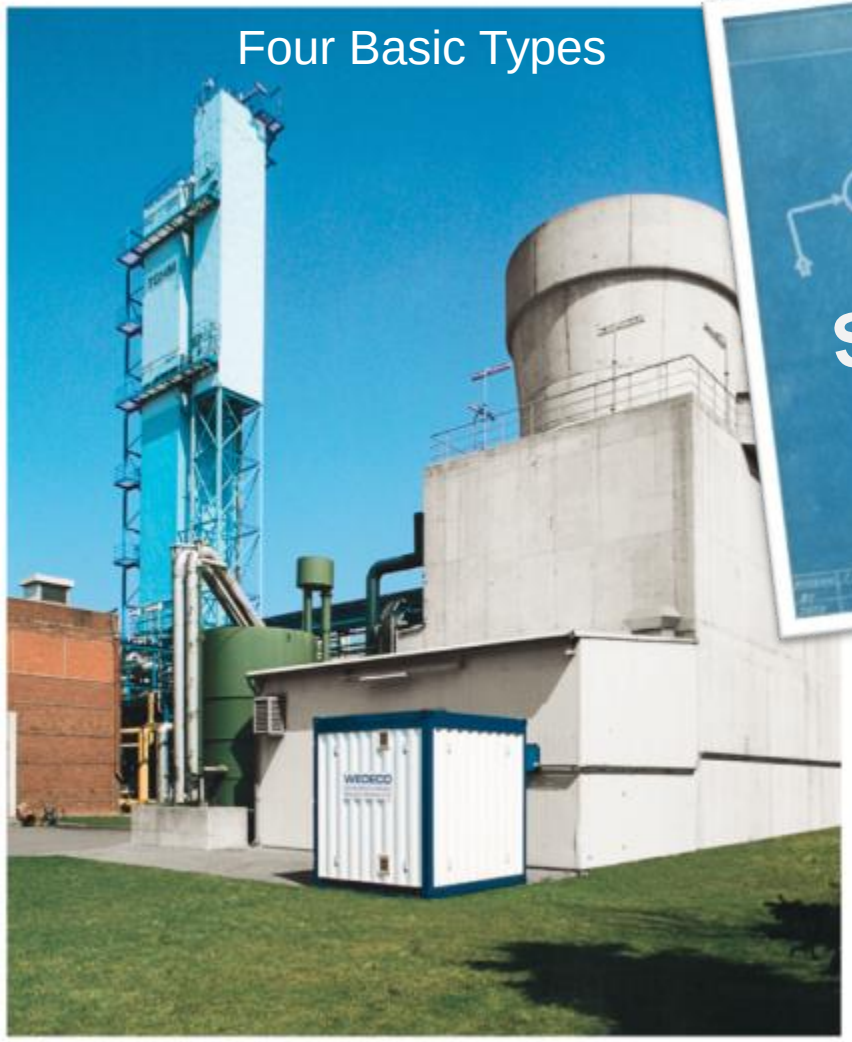
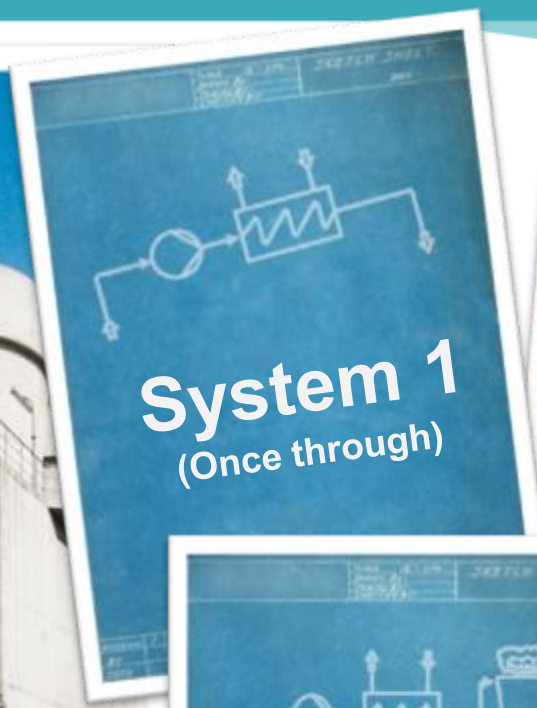
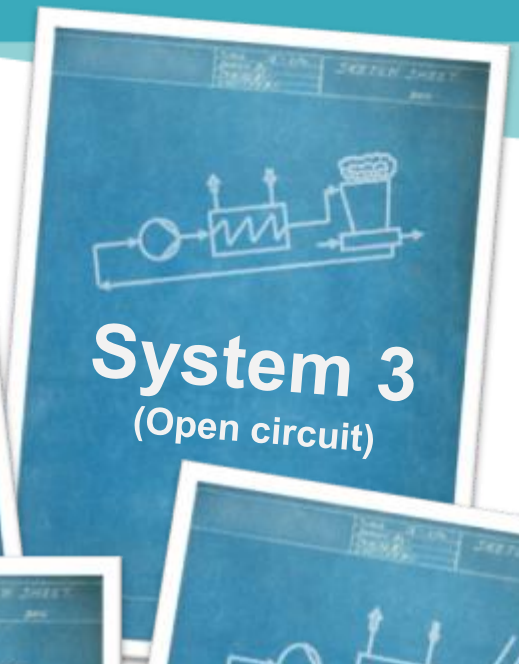
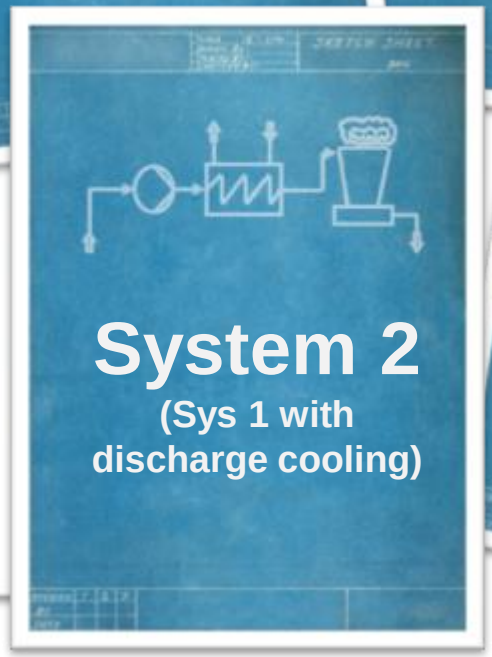
4. Example: Ozone for Cooling Water

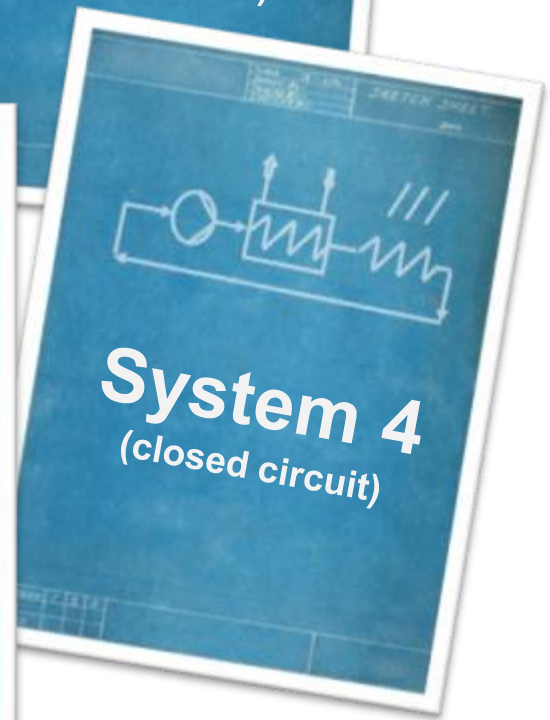
Ozone for Water at Cooling Towers











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Main Advantage: Prevention of Biofilms

Use of Chemical Biocide

Use of Ozone as Biocide

Heat Exchanger Plate before and after Ozone

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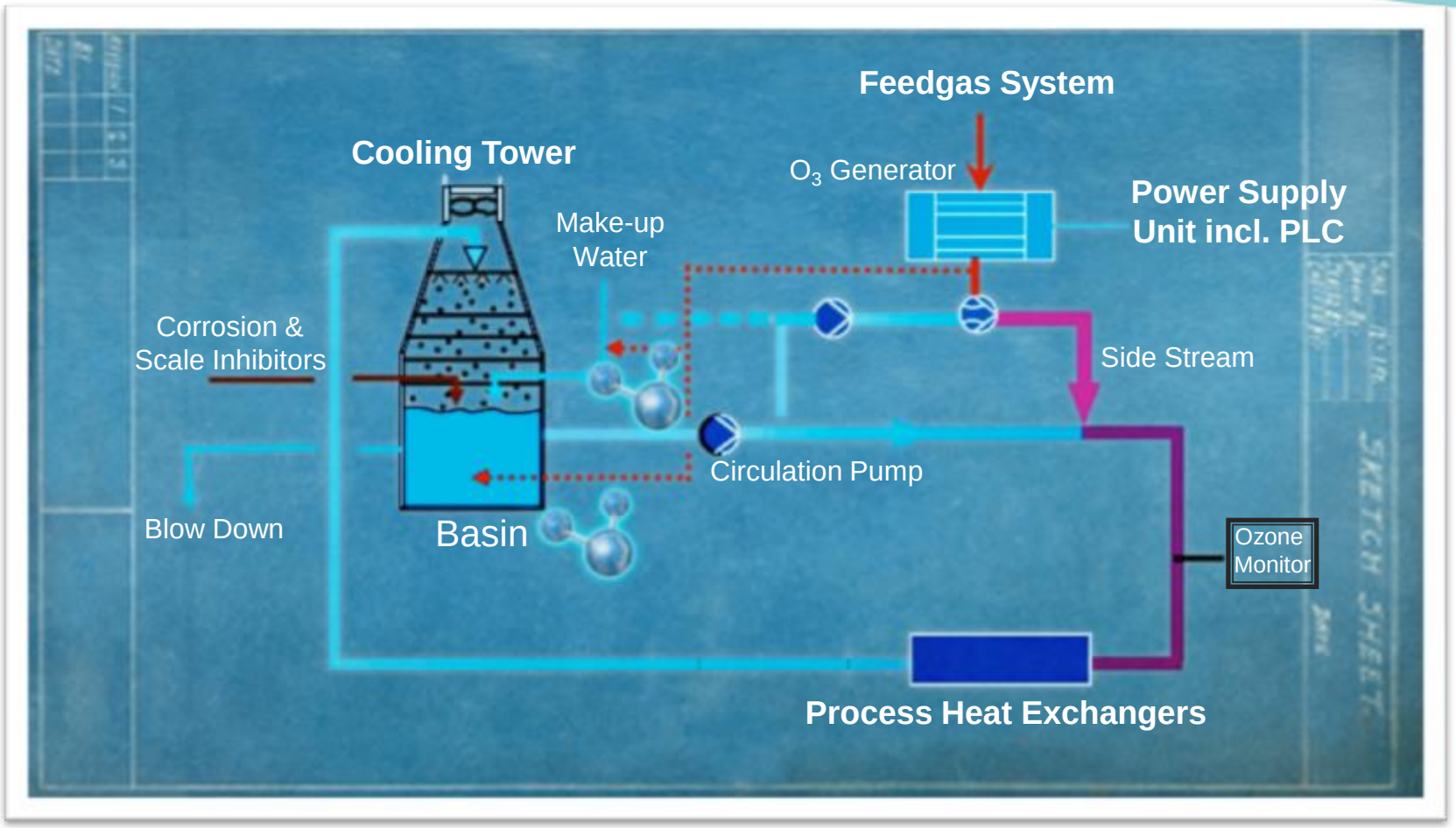
Ozone Process Flow for Cooling Towers



= Optional dosing points

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Containerized Solution for INFRASERV (Germany)

Customer:
INFRASERV GENDORF

- Industrial site for several chemical production plants
- Application goal: microbiological Control
- Ozone production capacity:
- 2.4 kg/h + 1.6 kg/h

- Treated cooling water flow:
  - 12,000 m³/h total (three loops)
- - 4,800 m³/h (upgrade to 9,600 m³/h)

- Start-up:
  8/2001 and 05/2005
- Returning customer - over 20 ozone systems installed by 2016

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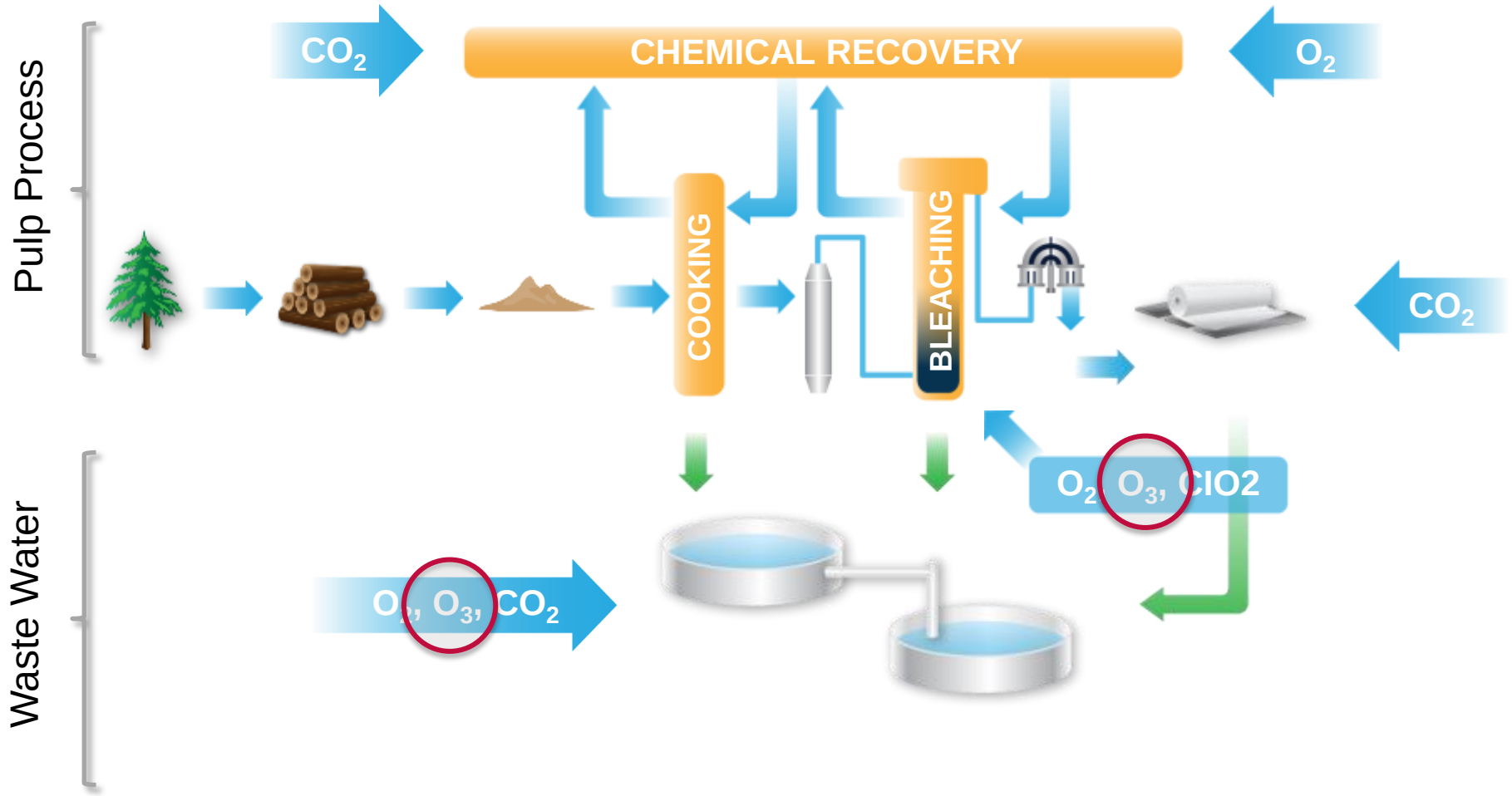
5. Example: Pulp & Paper Industry

Where can Ozone be used in Pulp & Paper?



Ozone Application

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Example for Fibria Jacarei Pulp Mill, Sao Paulo, Brazil

Application/Challenge:
2 pulp bleaching lines for 3,600 tons of eucalyptus pulp per day

Design Data:
Line C: 3 x 175 kg/h
Line B: 1 x 250 kg/h

Wedeco Solution:
Line C: 3 Z-Compact Systems type PDO
Line B: 1 Z-Duo Z-Compact Systems type PDO

Start-up Date:
Line C: 10/2002
Line B: 06/2012

40 YEARS OF PASSION FOR WATER

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Fibria Jacarei Pulp Mill, Sao Paulo, Brazil

World‘s largest Ozone Plant for Pulp Bleaching

with 99% Availability for up to 1,000 kg/h of Ozone

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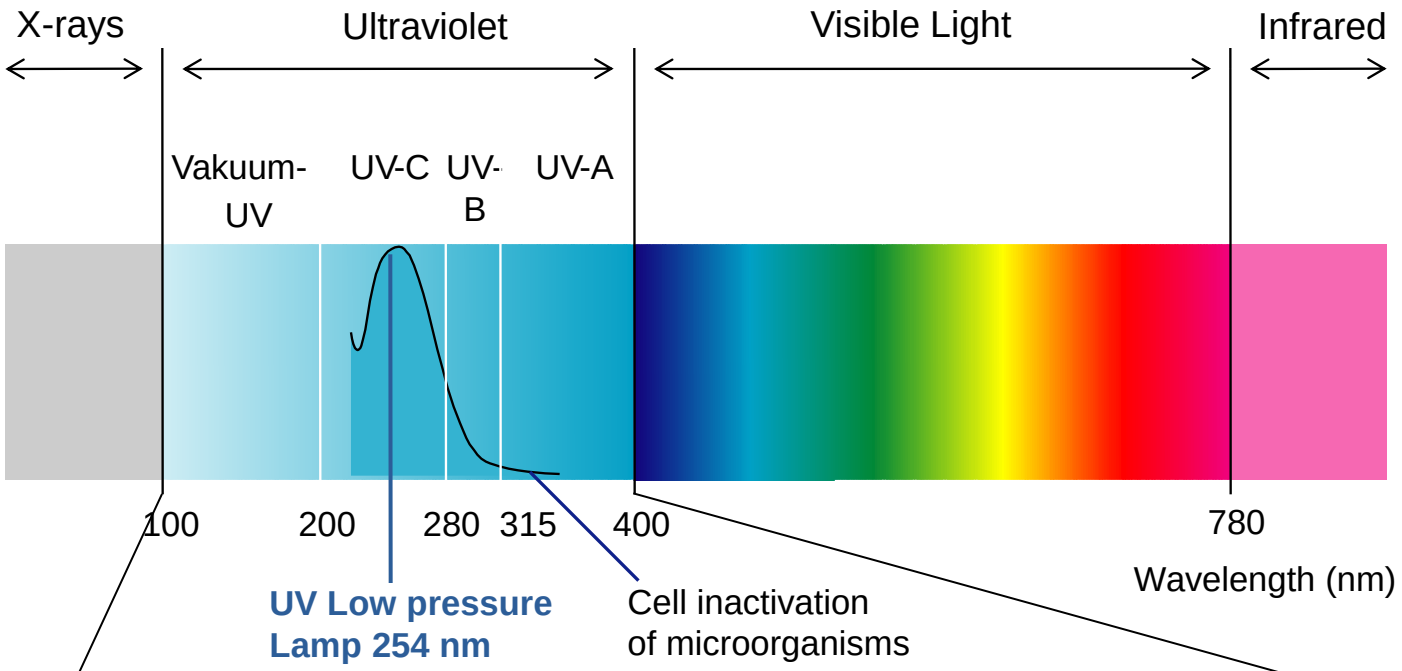
Welcome to WEDECO´s UV World

Principle of UV – Light Spectrum

Inactivation of pathogenic microorganisms via photo-oxidation of DNA



UV Range	Wavelengths [nm]	Applications
UVA	315-400	Sunburn, Blacklight
UVB	280-315	Sunburn, Germicidal
UVC	**200-280**	**Germicidal Photochemistry**
Vacuum UV	100-200	High-energy Applications

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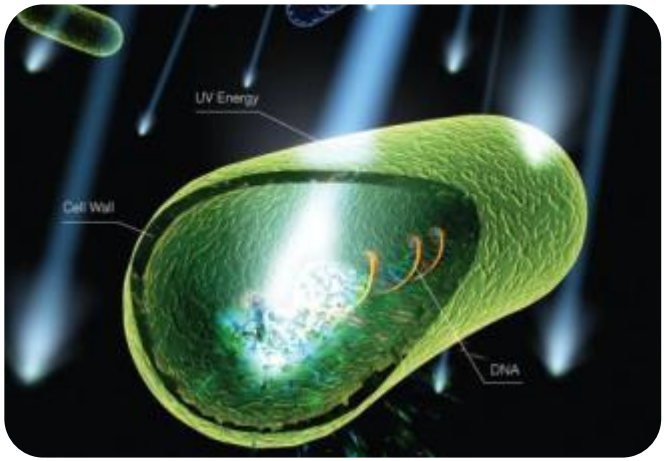
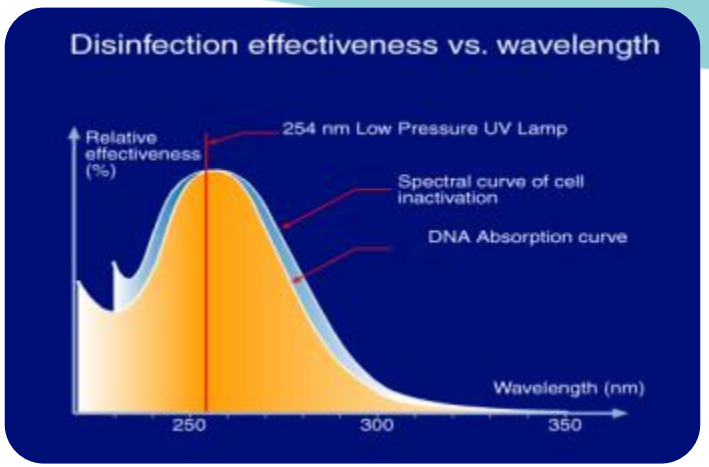
Principle of UV – DNA Absorption Curve

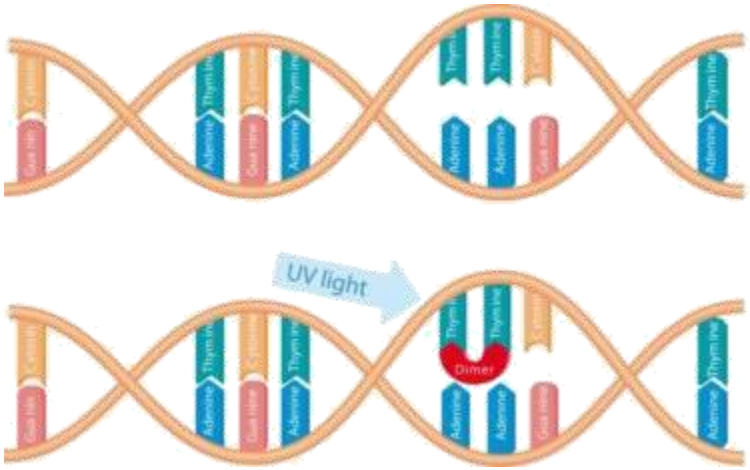




UV-C irradiation @ 254 nm optimum for disinfection

DNA & RNA absorbing light in the UVC range emitted by UV lamps

The microorganisms are inactivated and rendered unable to reproduce or infect.



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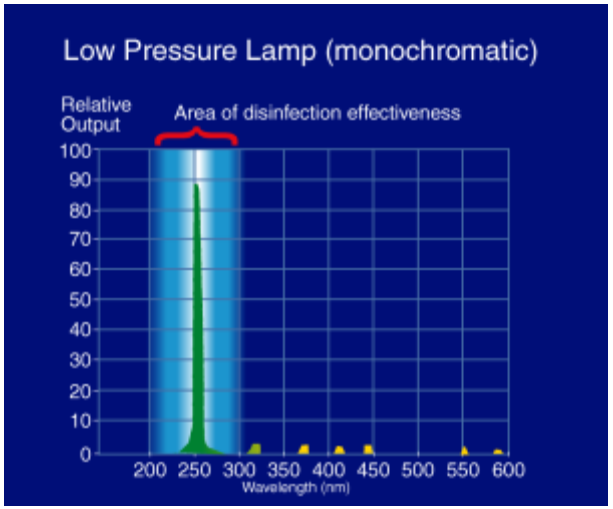
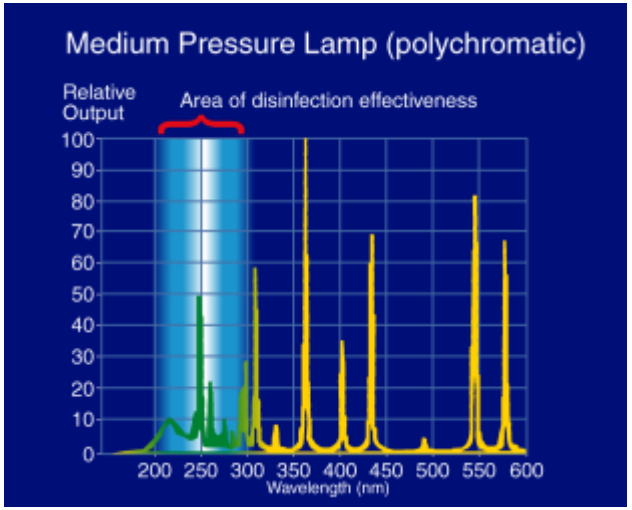
In General: 2 different Types of UV Lamp



- Hg vapour pressure < 0,1mbar
- Power per lamp ≤ 1 kW
- Efficiency ~ 41%
- Lamp life up to 15,000 hrs
- Lamp temperature ~120°C
- No cool-down before re-start
- Liquid (conventional) or solid state (amalgam) mercury
- No solarisation of quartz sleeve



- Hg vapour pressure > 0,4 bar(a)
- Power per lamp up to 20 kW
- Efficiency ~ 12%
- Lamp life 3,000 – 8,000 hrs
- Lamp temperature 600 – 800°C
- Cool-down before re-start
- Liquid mercury
- Solarisation of quartz sleeve

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General Concept of a UV System

Reactor

Lamp

Quartz Sleeve

Sensor

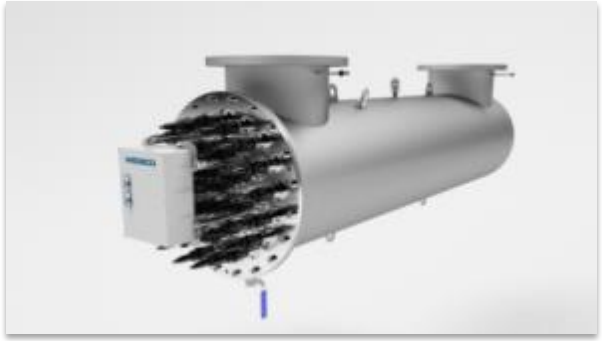
Ballast

Cabinet & Controller

In General: 2 different Types of UV Systems

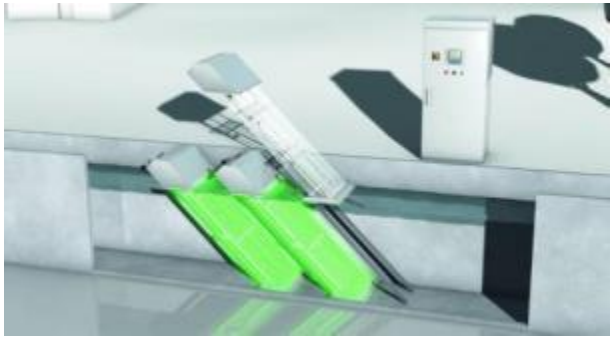
Closed Reactors (pressurized)

- Main applications: drinking water, water reuse, industrial applications
- Typically standardized systems
- Installation in pipework
- Isolation valves required



Open Channel (Gravity fed)

- Main applications: wastewater, aquaculture
- Modular design
- Installation typically in concrete channels
- Water level control required



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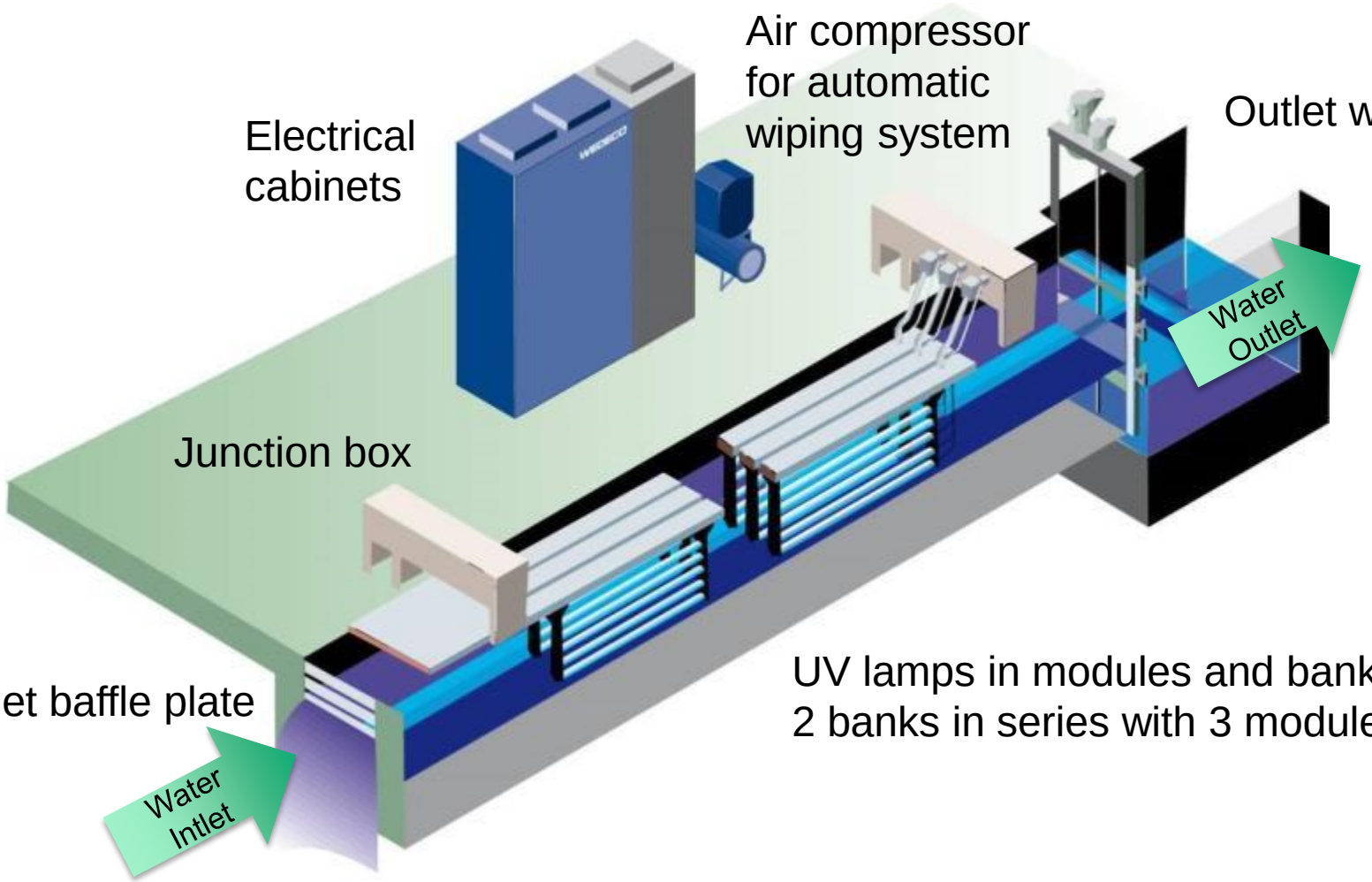
Components of Open Channel UV Systems



UV lamps in modules and banks; here:
2 banks in series with 3 modules each

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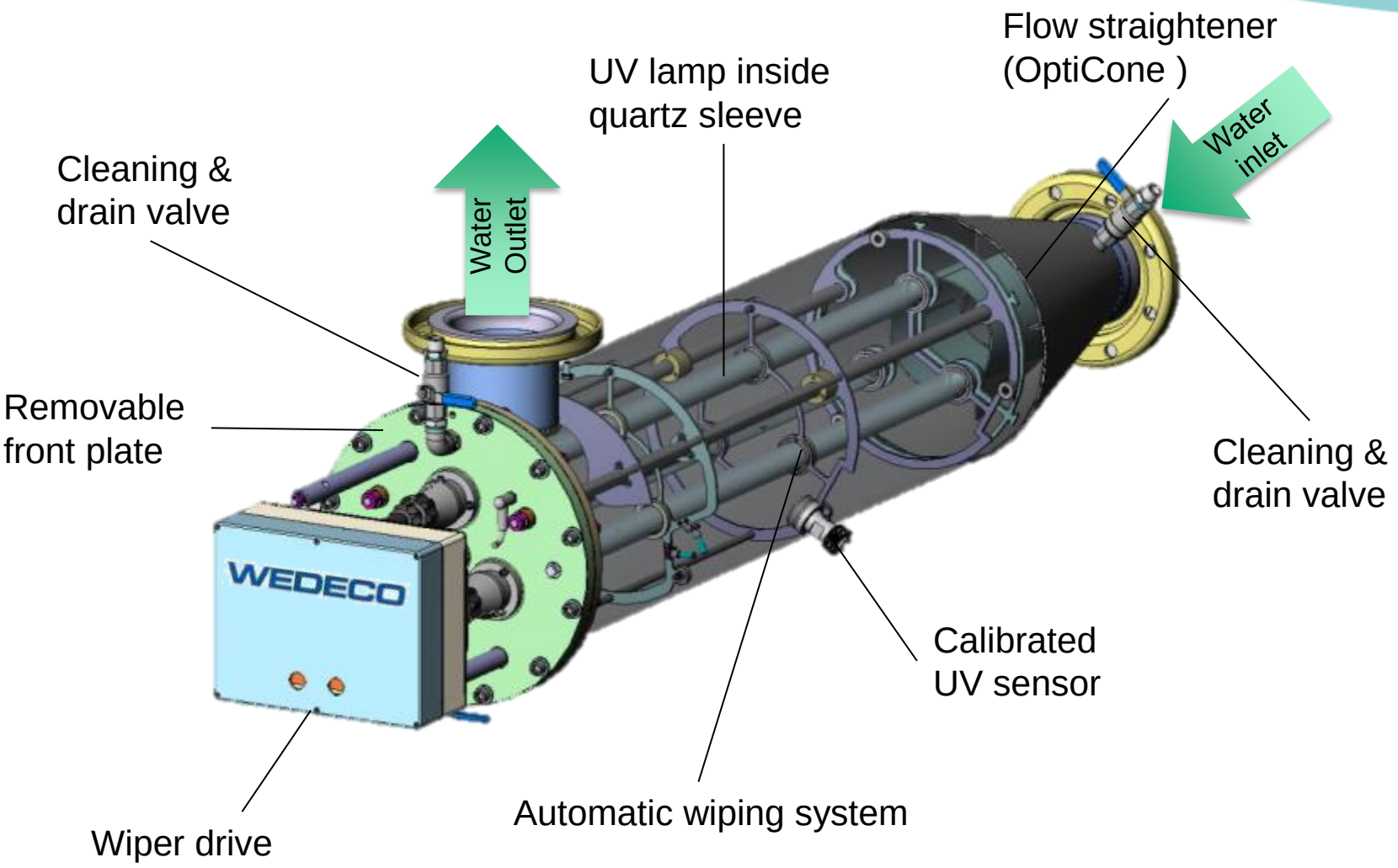
Components of a closed Vessel UV System



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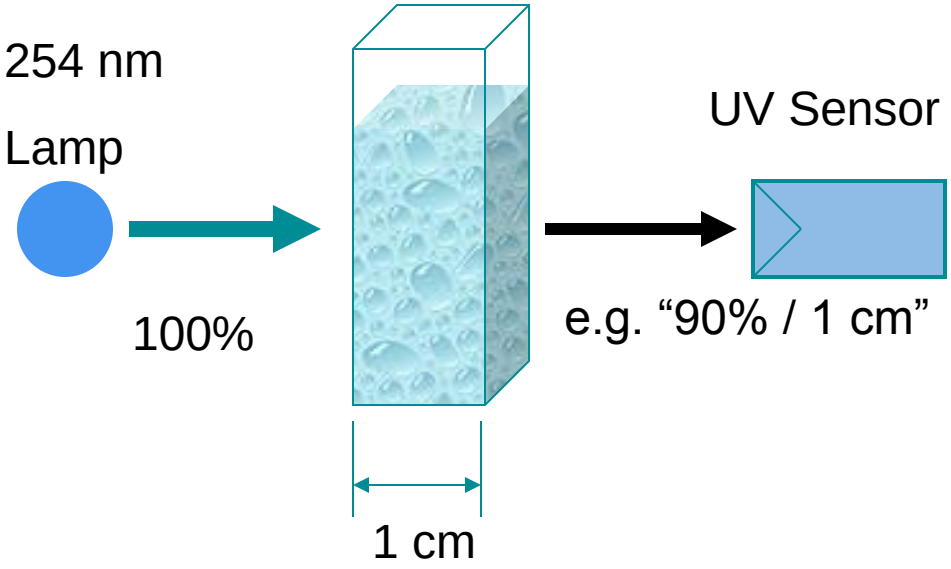
Key Design Parameters

- Flow rate / flow distribution
- UV transmittance
- Disinfection target
  - UV dose (definition?)
  - Type of pathogen
  - Inlet/outlet level => log reduction
  - Pathogen's UV sensitivity (D_L)
- Suspended solids (in wastewater)
- Fe content

UV Transmittance (UVT)



Typical drinking water UVT: ~ 85 – 95% / 1 cm @ 254 nm

Typical wastewater UVT: ~ 50 – 65% / 1 cm @ 254 nm

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UV Dose – Simple Concept…

- **Average Retention Time:**
  - **flow rate** / reactor volume
  - min. velocity
  - max. velocity

- **Average Intensity:**
  - lamp output and age
  - quartz sleeve transmittance + fouling
  - reactor design
  - water quality (**UV transmittance**)

UV Dose = Retention Time x Intensity

[mJ/cm²] = [s] x [mW/cm²]

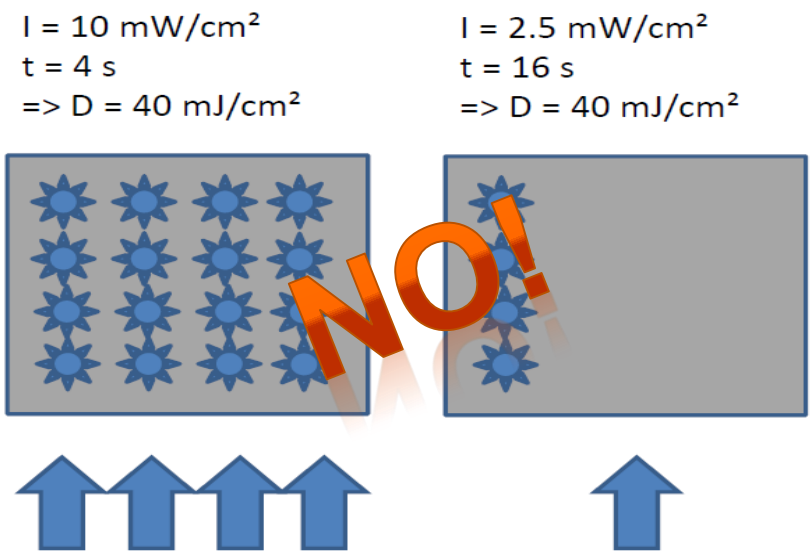
But not in Reality

UV dose can NOT directly be measured

Traditional design based on UV dose calculation (PSS)

UV dose = Irradiation Time x UV Intensity

Will these systems deliver the same disinfection performance as they deliver the ***same calculated*** UV dose?



The client doesn't need a UV dose, but a log reduction!

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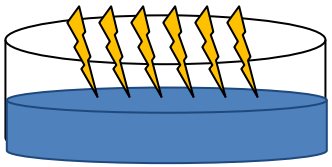
=> Validation

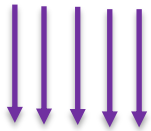
Testing Results are compared to Dose Response Curve to calculate Reduction Equivalent Dose

CB-tests

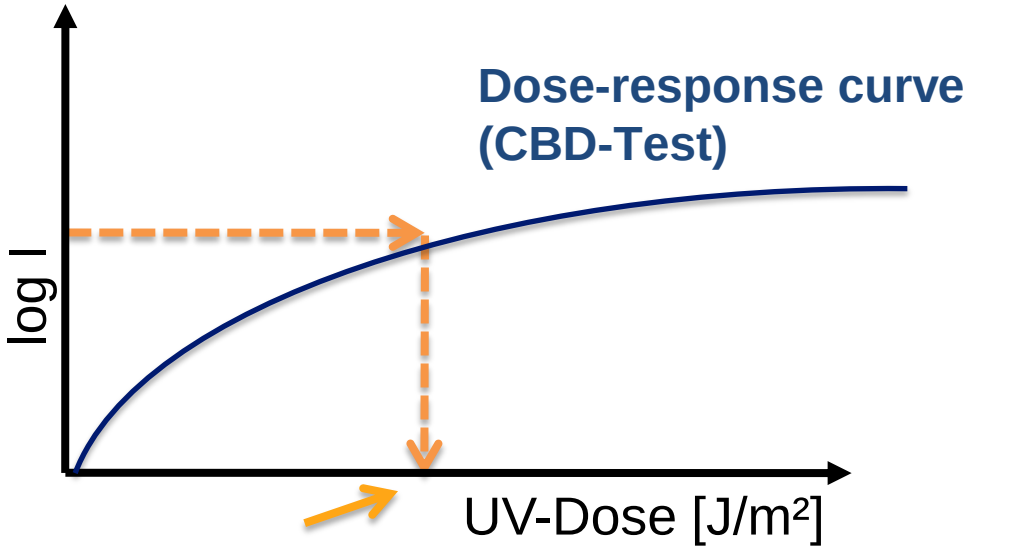


Field testing on UV reactor

CB=**C**ollimated **B**eam



log reduction (Field testing on UV reactor)



Dose-response curve (CBD-Test)

RED (Reduction Equivalent Dosage)

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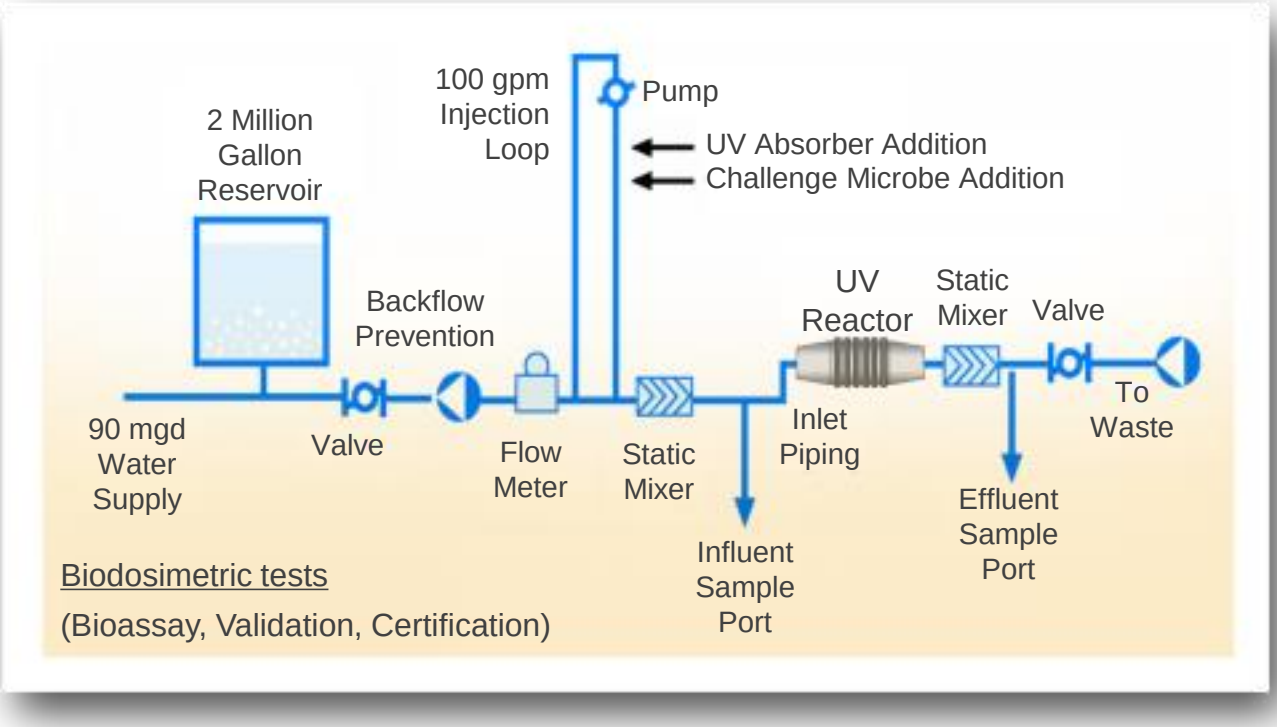
Bioassay = UV Reactor Test

Example of a Bioassay Set-up



Complex and expensive but provides real microbiological data for design

Test protocols exist acc. to USEPA, DVGW, NWRI, IUVA etc.

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Overview of Wedeco Products

Drinking Water Disinfection

Aquada:
up to 13 m³/h
(59 GPM)

BX:
up to 530 m³/h
(3.4 MGD)

Spektron:
up to 4,150 m³/h
(26.5 MGD)

Quadron:
up to 4,000 m³/h
(25.4 MGD)

K143:
> 11,000 m³/h
(> 70 MGD)

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Europe‘s largest plant located in a mountain cavern

New Oset Waterworks
Oslo, Norway

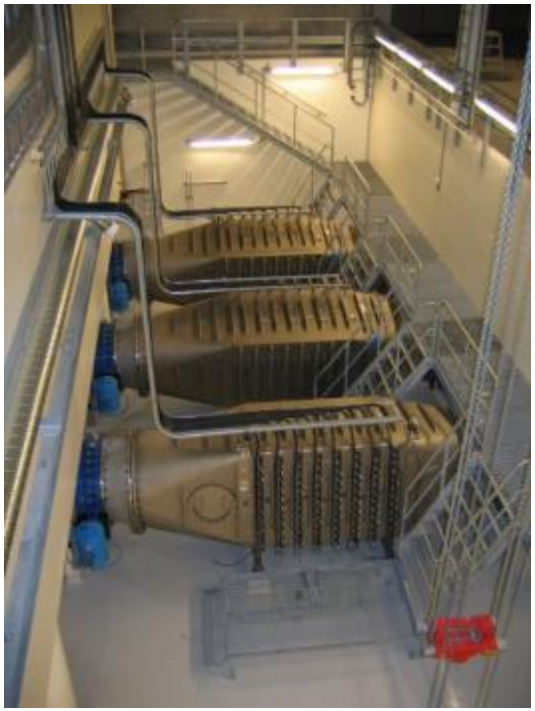
Application/Challenge: Disinfection of pre-treated and filtered drinking water from the Maridal lake to serve ~ 90% of Oslo‘s population (total 620,000 people)

Design Data: 16,500 m³/h (104.6 MGD), UV transmittance 90-92%, validated UV dose **40 mJ/cm²**

Wedeco Solution: 6 x K143 UV disinfection systems 12/8 (4 duty, 2 stand-by)

Start-up Date: Summer 2008

40 YEARS OF PASSION FOR WATER



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Seymour Capilano Filtration Plant
British Columbia, Canada

40 YEARS OF PASSION FOR WATER

Application/Challenge:
Primary disinfection barrier of surface water after filtration

Design Data:
94,620 m³/h (600 MGD) , 91% UVT,
21 mJ/cm² Tier 1 RED (2003 UVDGM draft)

Wedeco Solution:
24 UV Systems type K143
(4 rows with 12 lamps each,
one additional row empty)

Start-up Date:
Summer 2008

Optimised Control Philosophy:
for 99% Crypto inactivation in summer 2016
(additional OPEX savings)

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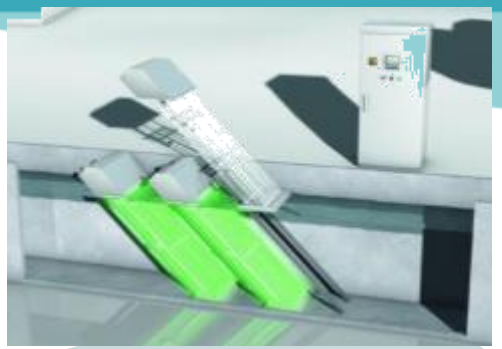
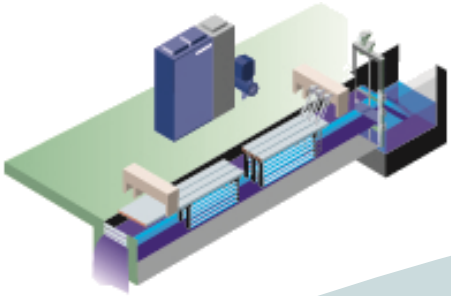
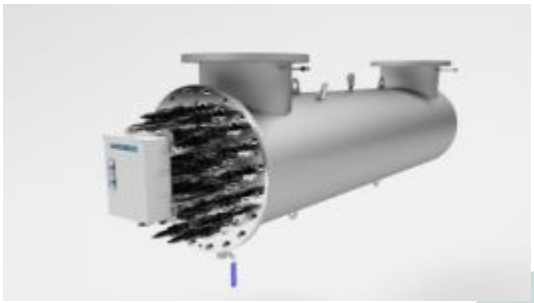
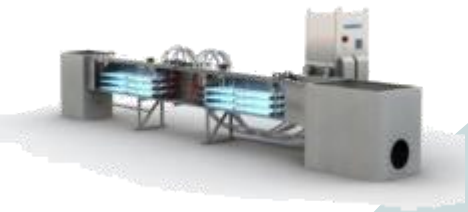
Overview of Wedeco Products

Waste Water Disinfection









Duron:
>10,000 m³/h
(> 60 MGD)

TAK55:
> 10,000 m³/h
(> 60 MGD)

LBX Series:
up to 2,100 m³/h
(13.5 MGD)

TAK Smart:
up to 1,000 m³/h
(6.5 MGD)

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1st Validated UV System for Stormwater

Chichester Wastewater Treatment Works
West Sussex, United Kingdom

40 YEARS OF PASSION FOR WATER

Application/Challenge: Reduce undisinfected spills due to stormwater into the Chichester Harbour, a designated shellfish area, of > 90% with a EA consented UV dose

Design Data: 1,080 m^3/h (6.8 MGD) with highly variable UV transmittance (40-69%)

Wedeco Solution: Duron UV System with 10 UV Banks in Series in 1 Channel

Start-up Date: March 2014

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Largest UV System in Wastewater Treatment

Mangere Sewage Treatment Plant
Manukau, New Zealand

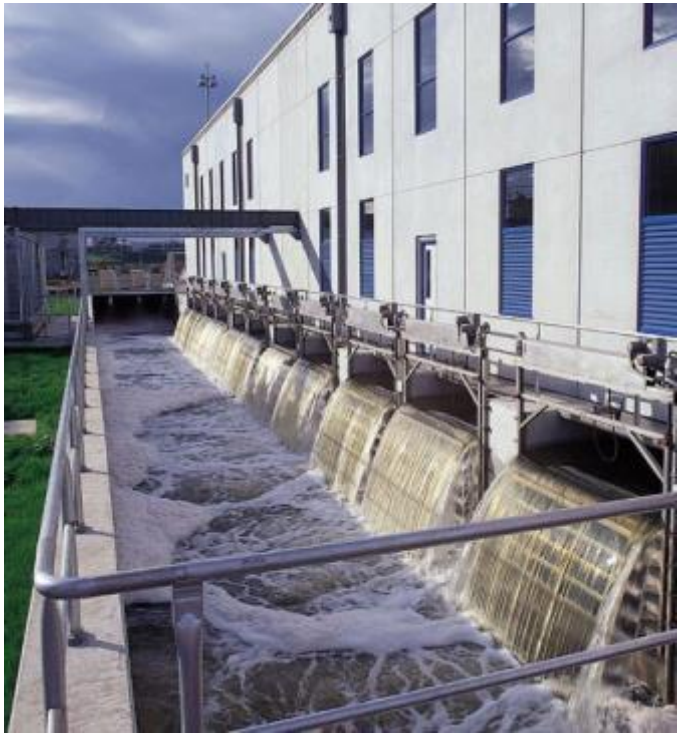
40 YEARS OF PASSION FOR WATER

Application/Challenge: Disinfection of the pre-treated effluent of the City of Auckland at the Mangere Sewage Treatment Plant prior to discharge into the Manukau Harbour

Design Data: 59,400 m^3/h (377 MGD)

Wedeco Solution: TAK55 in 12 channels (total of 7,776 lamps)

Start-up Date: April 2003



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Mangere Sewage Treatment Plant
Manukau, New Zealand

The largest UV system in Wastewater Treatment

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Thank You!

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