DE NORA
our research - your future

Emerging Contaminants and Micropollutants treatment

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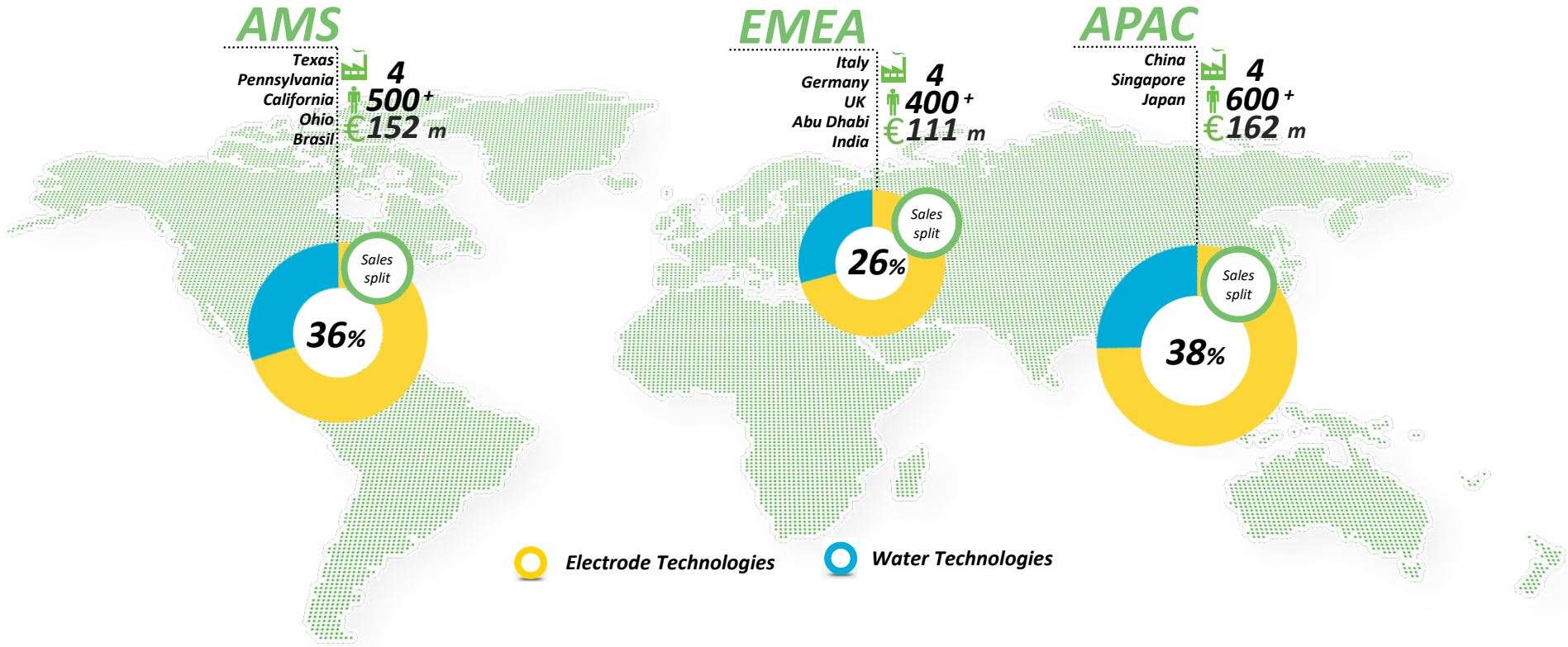
WATER MADE EASY

MARINE | ENERGY | MUNICIPAL | INDUSTRIAL

Agenda

- **De Nora**
- **MPs: The new Challenge of Water Reuse**
- **Snapshot on Water Frame Work Directive**
- **Technology Map**
- **De Nora's experience and next step**

De Nora at a glance



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19 *Locations*

90+ *Years of Innovation*

€425 Mio *Sales 2017*

1500+ *People*

De Nora future challenges

Based on our experience, we are committed to provide new solutions for the global needs

- Climate change
- Population growth
- Carbon footprint
- Resource scarcity

Strategic arenas

Energy storage

Water treatment

Mining

Resource efficiency

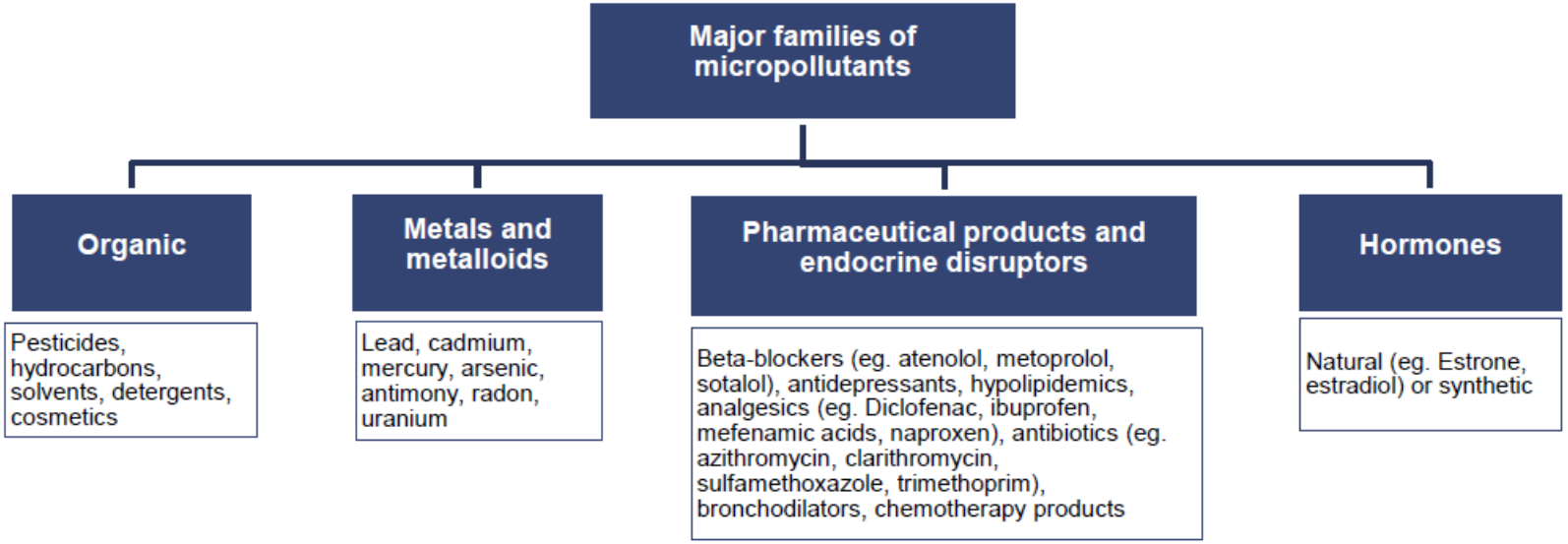
Micropollutants

The new challenge of water reuse

- Micropollutants describe chemical substances of **very low concentrations** (ppb, ppt) with negative effect on the environment and/or organisms.

- **Endocrine disrupting effects**: pharmaceuticals such as birth control pills and synthetic hormones can interfere with natural hormones in the body and cause deformities in wildlife

- A very wide range of substances belongs to this group, such as **pesticides, personal care products, metalloids, pharmaceuticals and hormones**



Source: Amane Advisors

Water Frame Work Directive

WFD was established in 2000 with the objective to:

- Achieve "**good ecological status of water" bodies by 2015**
- **Identify a list of priority substances** which present a significant risk to or via the aquatic environment.
- Achieve the **elimination of priority hazardous substances**
- **In 2013 (EU Directive 2013/39/EU (2013) meet the new EQS for 45 priority substances between 2015 and 2027**

Europe: Status of WFD application

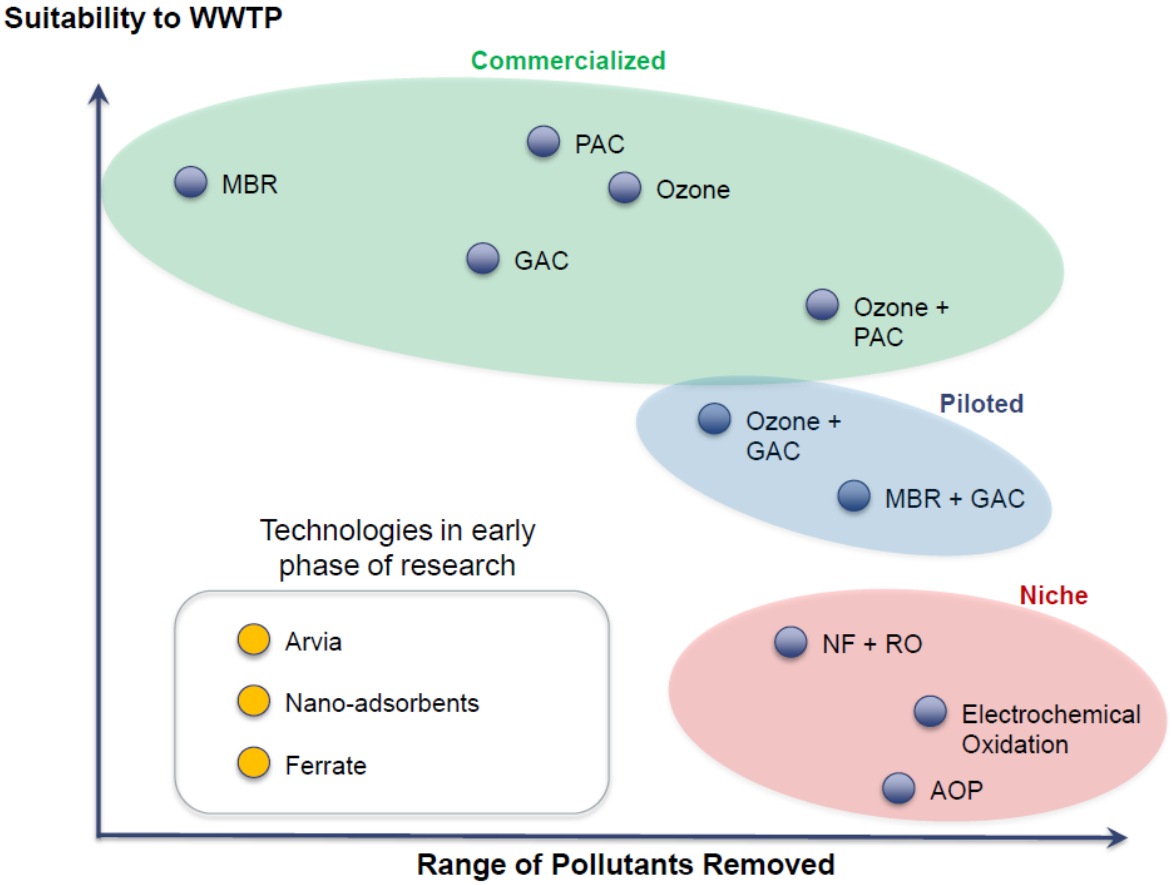
Number	CAS number	EU number	Name of priority substance	Date of effect	Date Limit to achieve good surface water chemical status	Identified as priority hazardous substance
30	not applicable	not applicable	Tributyltin compounds	22 December 2015	22 December 2021	X
31	12002-48-1	234-413-4	Trichlorobenzenes	22 December 2015	22 December 2021	
32	67-66-3	200-663-8	Trichloromethane (chloroform)	22 December 2015	22 December 2021	
33	1582-09-8	216-428-8	Trifluralin	22 December 2015	22 December 2021	X
34	115-32-2	204-082-0	Dicofol	22 December 2018	22 December 2027	X
35	1763-23-1	217-179-8	Perfluorooctane sulfonic acid and its derivatives (PFOS)	22 December 2018	22 December 2027	X
36	124495-18-7	not applicable	Quinoxyfen	22 December 2018	22 December 2027	X
37	not applicable	not applicable	Dioxins and dioxin-like compounds	22 December 2018	22 December 2027	X
38	74070-46-5	277-704-1	Aclonifen	22 December 2018	22 December 2027	
39	42576-02-3	255-894-7	Bifenox	22 December 2018	22 December 2027	
40	28159-98-0	248-872-3	Cybutryne	22 December 2018	22 December 2027	
41	52315-07-8	257-842-9	Cypermethrin	22 December 2018	22 December 2027	
42	62-73-7	200-547-7	Dichlorvos	22 December 2018	22 December 2027	
43	not applicable	not applicable	Hexabromocyclododecanes (HBCDD)	22 December 2018	22 December 2027	X
44	76-44-8/ 1024-57-3	200-962-3/ 213-831-0	Heptachlor and heptachlor epoxide	22 December 2018	22 December 2027	X
45	886-50-0	212-950-5	Terbutryn	22 December 2018	22 December 2027	

Source: Amane Advisors

Technology Map

Overview

- Muni WWTPs need to add an **additional barrier** with advanced water treatment technologies.
- There **is no single complete solution established**



As of today, **Ozone and Inactivated Carbon** and the combination of the two **(O3+BAF)** are considered appropriate for WWTPs

RO+AOP is an alternative

Source: Amane Advisors

Development of a cost effective solution

De Nora's experience

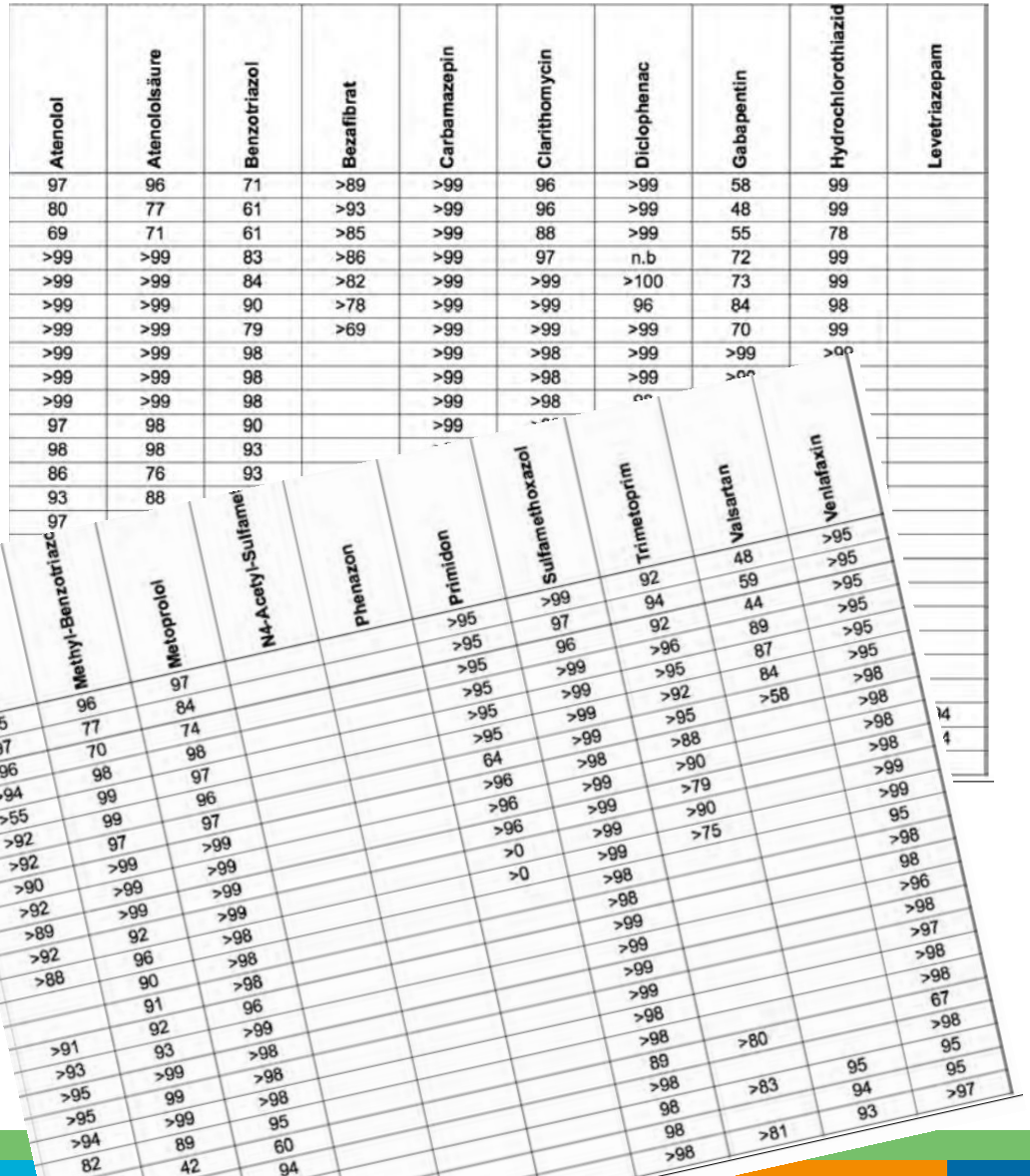
The goal of this pilot project was to improve and optimize the treatment process of micropollutant in wastewater

Layout and pilot unit (from 2011)

Water Flow rate	6 m3/h
Feed gas (Oxygen+Nitrogen)	96-97%
Ozone generator	140 gO3/h
Ceramic dome diffuser	Microbubble
Contact tanks	0,5m3 each (5min contact time)




Results



Atenolol	Atenololsäure	Benzotriazol	Bezafibrat	Carbamazepin	Clarithomycin	Diclophenac	Gabapentin	Hydrochlorothiazid	Levetriazepam
97	96	71	>89	>99	96	>99	58	99	
80	77	61	>93	>99	96	>99	48	99	
69	71	61	>85	>99	88	>99	55	78	
>99	>99	83	>86	>99	97	n.b	72	99	
>99	>99	84	>82	>99	>99	>100	73	99	
>99	>99	90	>78	>99	>99	96	84	98	
>99	>99	79	>69	>99	>99	>99	70	99	
>99	>99	98		>99	>98	>99	>99	>99	
>99	>99	98		>99	>98	>99			
>99	>99	98		>99	>98				
97	98	90		>99					
98	98	93							
86	76	93							
93	88								
97									

Methyl-Benzotriazo	Metoprolol	N4-Acetyl-Sulfame	Phenazon	Primidon	Sulfamethoxazol	Trimetoprim	Valsartan	Venlafaxin
95	97			>95	>99	92	48	>95
97	84			>95	97	94	59	>95
96	74			>95	96	92	44	>95
94	98			>95	>99	>96	89	>95
55	97			>95	>99	>95	87	>95
92	96			>95	>99	>92	84	>98
92	97			64	>98	>95	>58	>98
90	>99			>96	>99	>88		>98
92	>99			>96	>99	>90		>98
89	>99			>96	>99	>79		>99
92	92			>0	>99	>90		>99
88	96			>0	>98	>75		95
	90				>98			>98
	91				>99			98
>91	96				>99			>96
>93	92				>99			>98
>95	93				>98			>97
>95	>99				>98			>98
>94	99				>98			>98
82	>99				>99			67
	89				>99			>98
	42				>99			95
	94				>98			95
					89	>80		>97
					>98			
					98	>83	95	
					98		94	
					>98	>81	93	

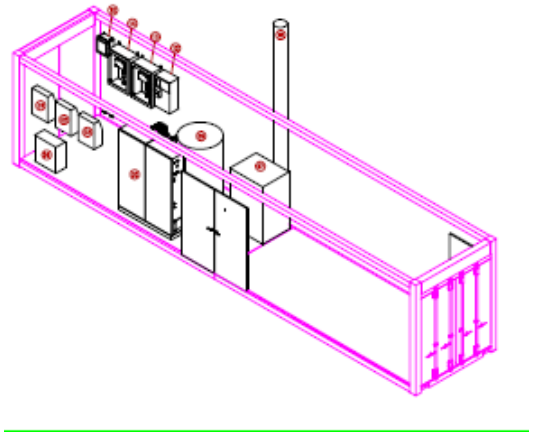
Most of the time the **abatement is +80%**

Some of the selected micropollutants were in such low concentration that the reduction could not be analyzed

Less than 5ppm dosage has been considered the optimal dosage with negligible ozone residual and no potential harm for the environment or for public health, even without a subsequent sand filter.

Containerized solution for field tests

- We are part of WERF
- Containerized O_3+BAF pilot plant (2 x 20 feet containers) available
- We are interested to evaluate field for tests



Containerized solution

De Nora Water Technologies O_3-BAF Pilot – Technical Informations

MCP1-XTL Ozone Generator

BAF Columns

Equipment fundamental

- Up to 1 m_3/h water flow-rate
- Fully equipped 2x20 ft containers including technical air, cooling water, feed gas preparation systems
- 100 g/h Ozone Generator, by Oxygen or by Air
- Dosing and mixing systems for hydrogen peroxide, chloramine, NaOH (pH correction in AOP processes)
- Dome diffusers and pump-injection contact system for O_3 mixing
- Ozone destruction unit

Instrumentation and Automation

- Main PLC and data logging
- In-line TOC, UVT, Turbidity, ORP analyzers
- Safety monitors (Ozone and Ossigen)
- 3 meter BAF columns with spent GAC media
- Up to EBCT (Empty Bed Contact Time)

Industrial Pilot Unit

De Nora Water Technologies O_3-BAF Pilot – Technical Informations

MCP1-XTL Ozone Generator

BAF Columns

Specific aspects we investigate

- TOC-UVT-Turbidity-O_3 Dosage ratio and optimizitazion
- High concentration O_3 VS low concentration O_3 in bromate and oxidation by-products formation
- Diffusers VS pump-injection contact system in bromate and oxidation by-products formation
- O_3 only VS AOP
- TOC removal at various O_3/TOC dose rates
- TOC targets for aquifer recharge applications
- EBCT requirements for targeted pollutant removals
- by-product generation and mitigation schemes if by-products are present (pre-formed chloramines for NDMA, H_2O_2 for bromate)
- log removal of viruses and parasites
- screening and removal of specific micropollutants as identified on a site-specific basis

De Nora Water Technologies

water made easy

De Nora Water Technologies is a leader in the field of water and wastewater treatment. We offer the most reliable, effective and trusted brands, developed over the course of 50 years' experience across municipal water, energy and marine applications.

Our **global support** network, skilled staff and a solid infrastructure with nine factories located across five continents provide the highest level of support to our customers.





De Nora Portfolio: disinfection and filtration technologies


CAPITAL CONTROLS®
Gas Feed Disinfection & Chlorine Dioxide and Ozone Disinfection

DE NORA TETRA™
Denitrification Filters, Biological Filtration, Tertiary Filtration

SORB®
Inorganic Removal

SEACLOR®/SANILEC®
Seawater Electrochlorination

EST™
Scrubbers

ClorTec®
Brine Electrochlorination

UAT™
Membrane Filtration

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