

الدورة 12

مؤتمر تحلية المياه في الدول العربية

19-18 شعبان 1440 | 24-23 ابريل 2019

فندق انتركونتinentال سيتي ستارز، القاهرة، جمهورية مصر العربية



Beach wells as pre-treatment for sea water desalination

Grischek, T., Bartak, R., Paufler, S., Wahaab, R.A.

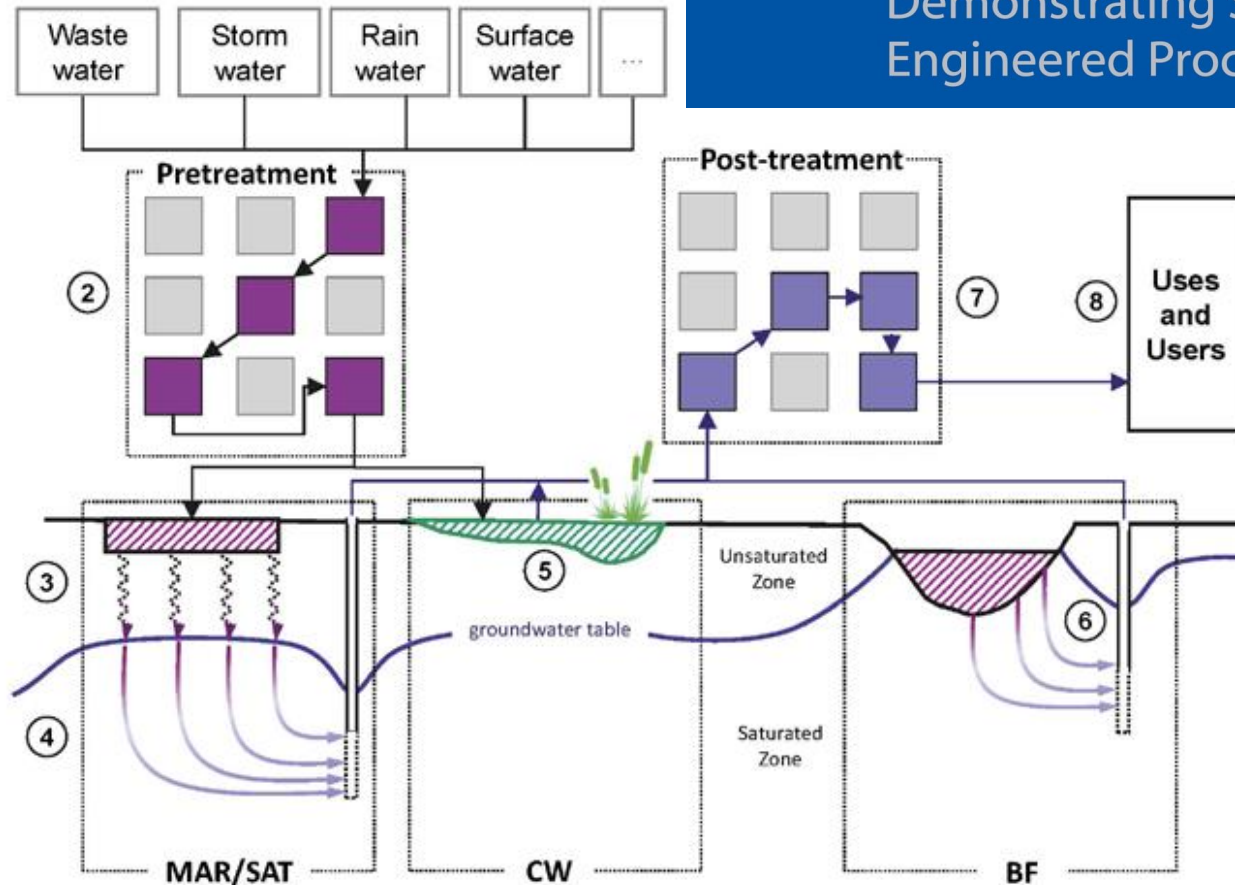


Motivation



AquaNES

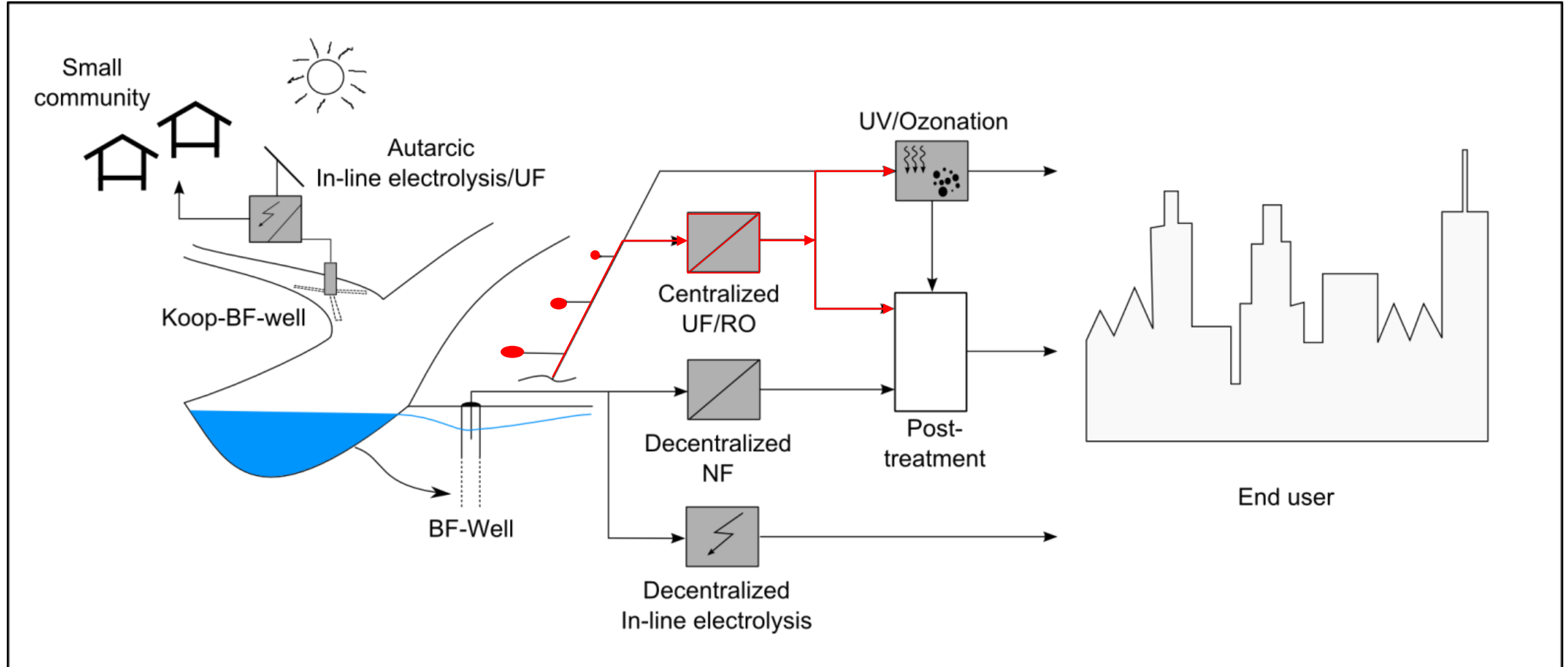
Demonstrating Synergies in Combined Natural and Engineered Processes for Water Treatment Systems



www.aquanes.eu

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Motivation



Motivation

RO desalination using semipermeable membranes



Undesired deposition of colloidal, organic and biological particulate and dissolved matter



Fouling of desalination membranes (colloidal, inorganic, organic, biological)



Energy and expensive chemicals required for cleaning



Pre-treatment necessary

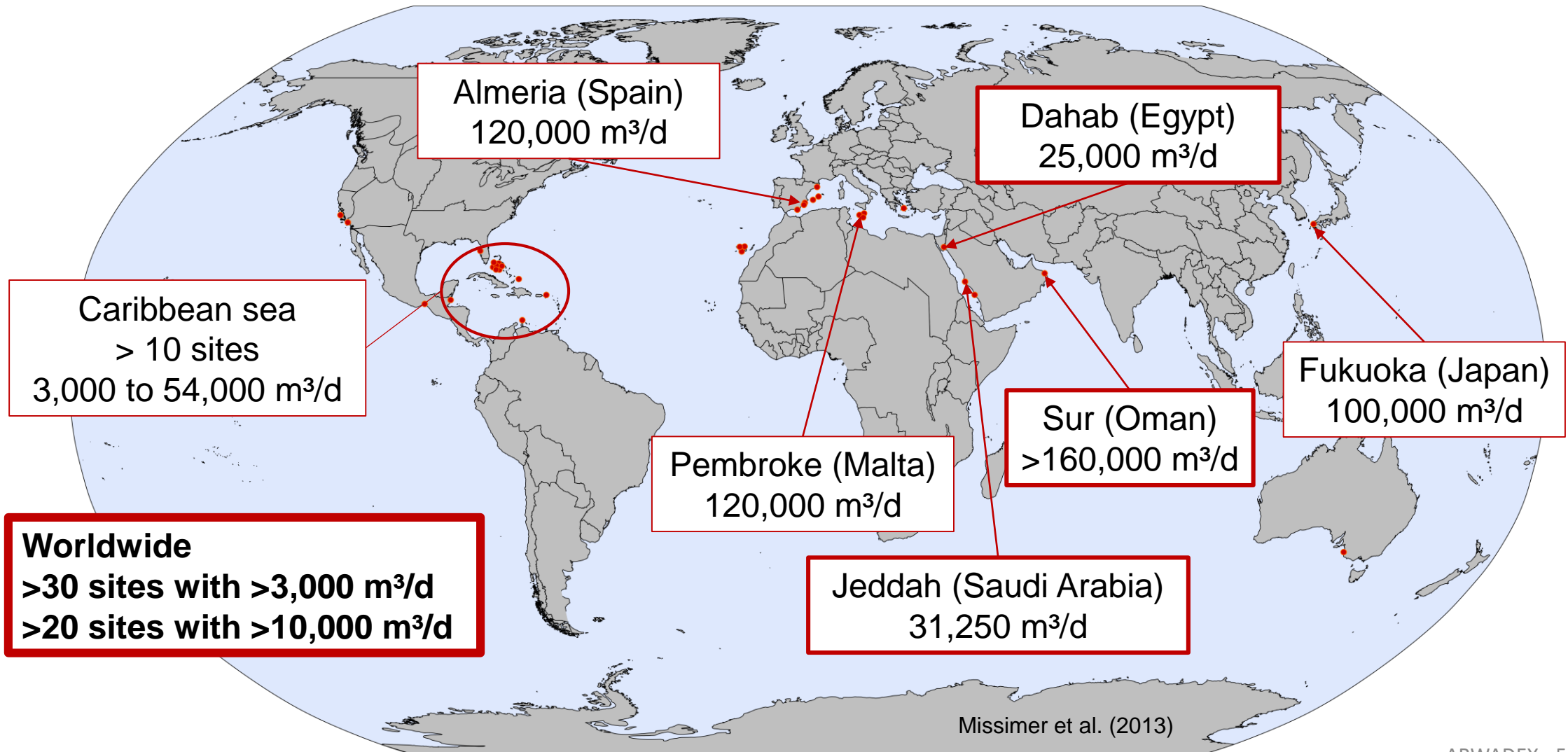
Slow sand filtration = Beach sand filtration

reduces turbidity, dissolved organic carbon (BDOC, AOC), nutrients



Beach wells

Increasing use of beach wells



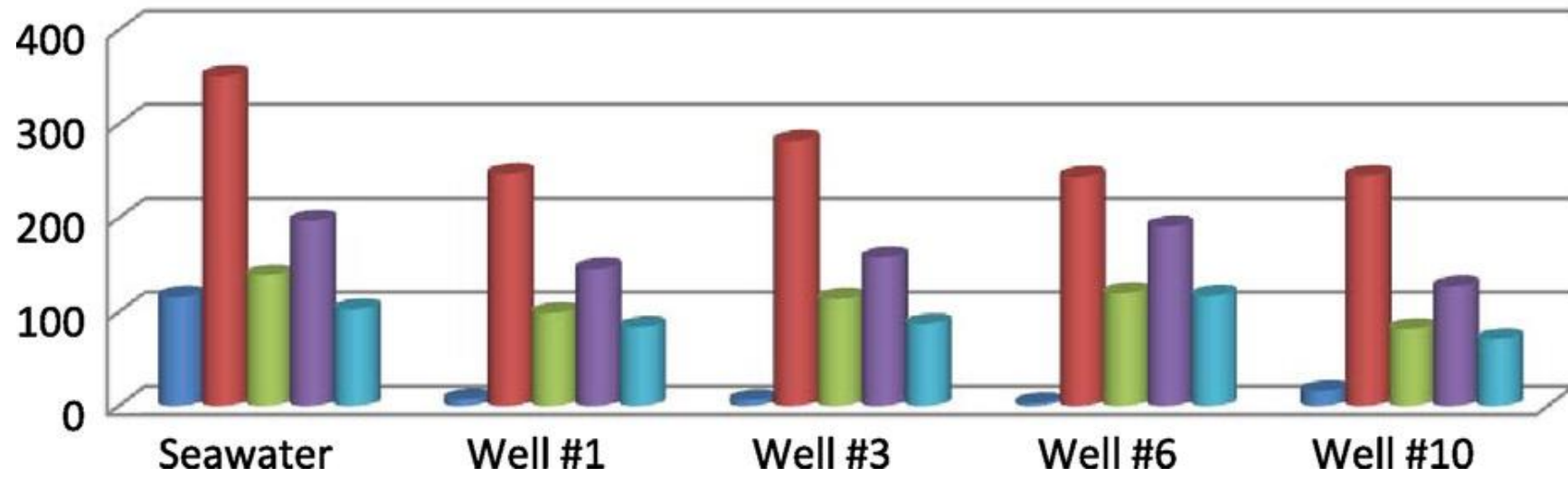
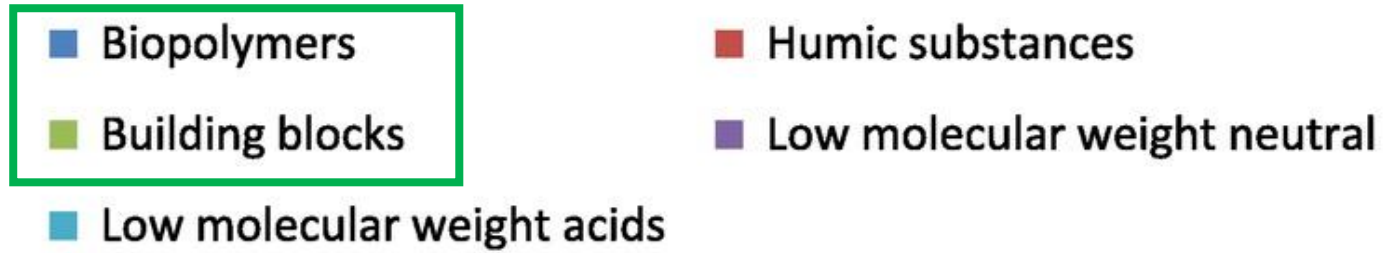
Results of pre-treatment using beach wells

Facility	Turbidity in NTU		DOC in mg/L	
	Seawater	Wells	Seawater	Wells
Sur (Oman) ¹	0.91	0.30 – 0.61	0.54	0.10 – 0.17
Jeddah (Saudi Arabia) ²	0.42	0.17 – 1.02	0.57	0.29 – 0.36
Providenciales, Turks and Caicos Islands (Caribbean Islands) ²	6.12	0.11 – 0.80	1.00	0.22 – 0.26

¹ Missimer et al. (2013); ² Rachmann et al. (2014)

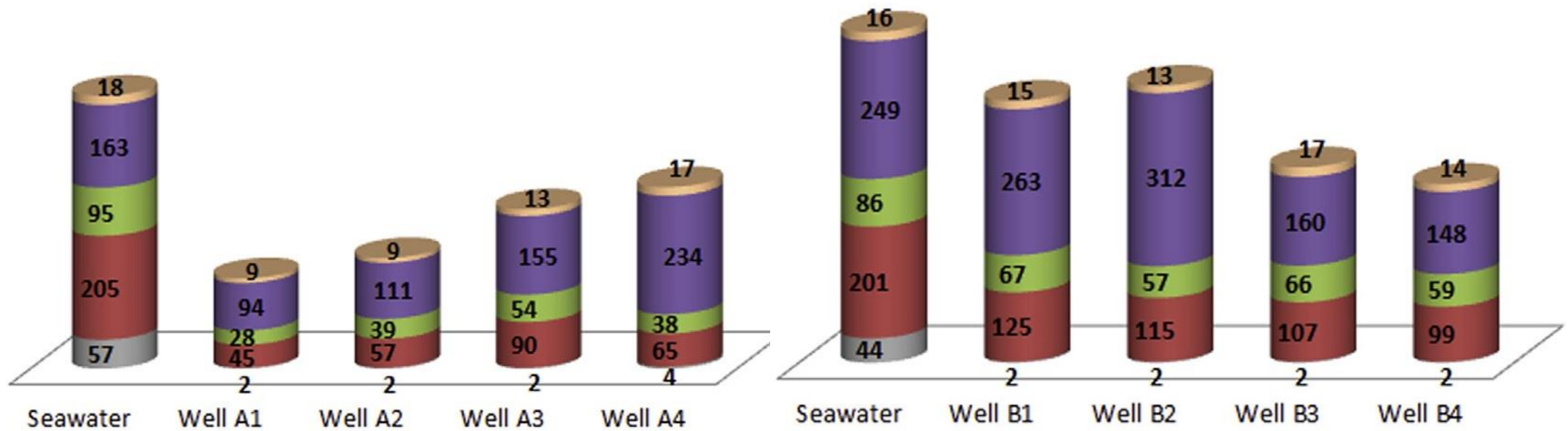
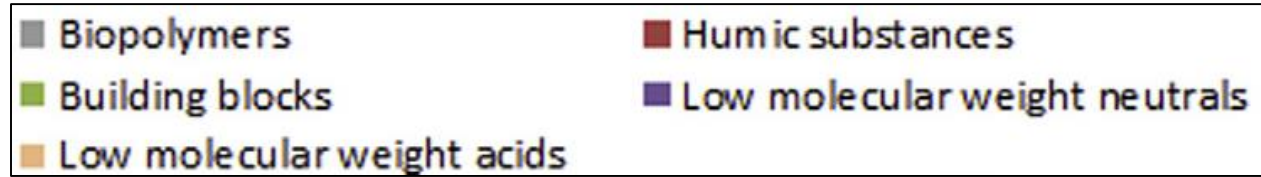
BDOC removal by beach well filtration

Natural organic concentration (ppb)



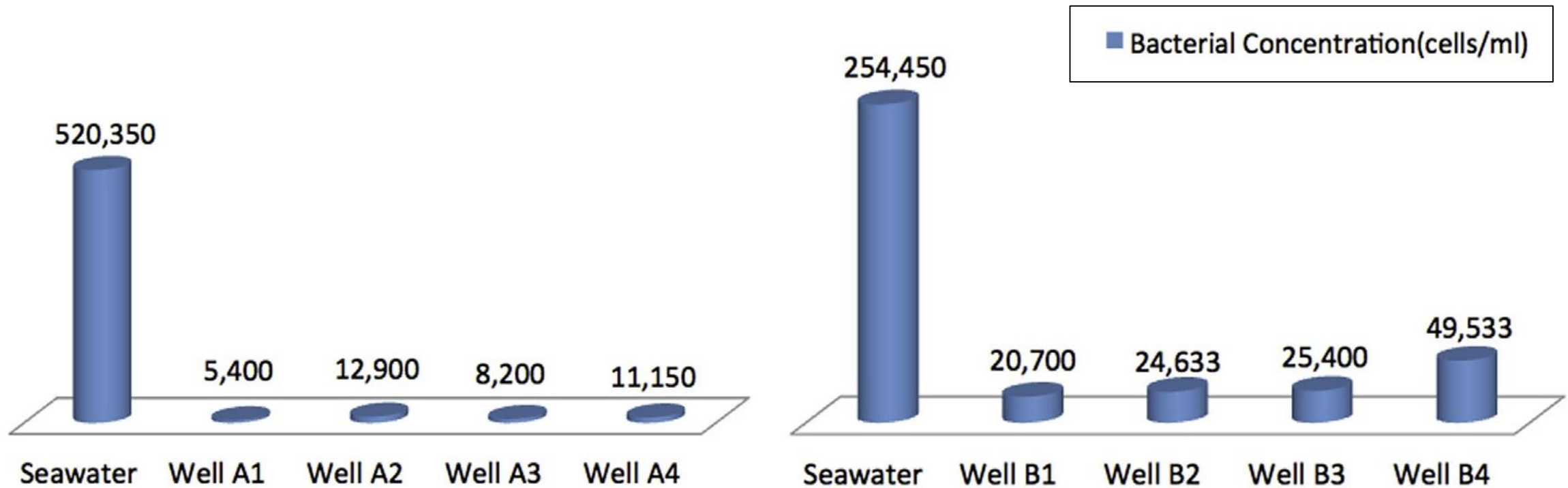
Dehwah et al. (2014)

BDOC removal by beach well filtration



NOM fraction concentrations in ppb at two beach well catchments in Jeddah (Dehwah & Missimer, 2016)

Removal of bacteria by beach well filtration



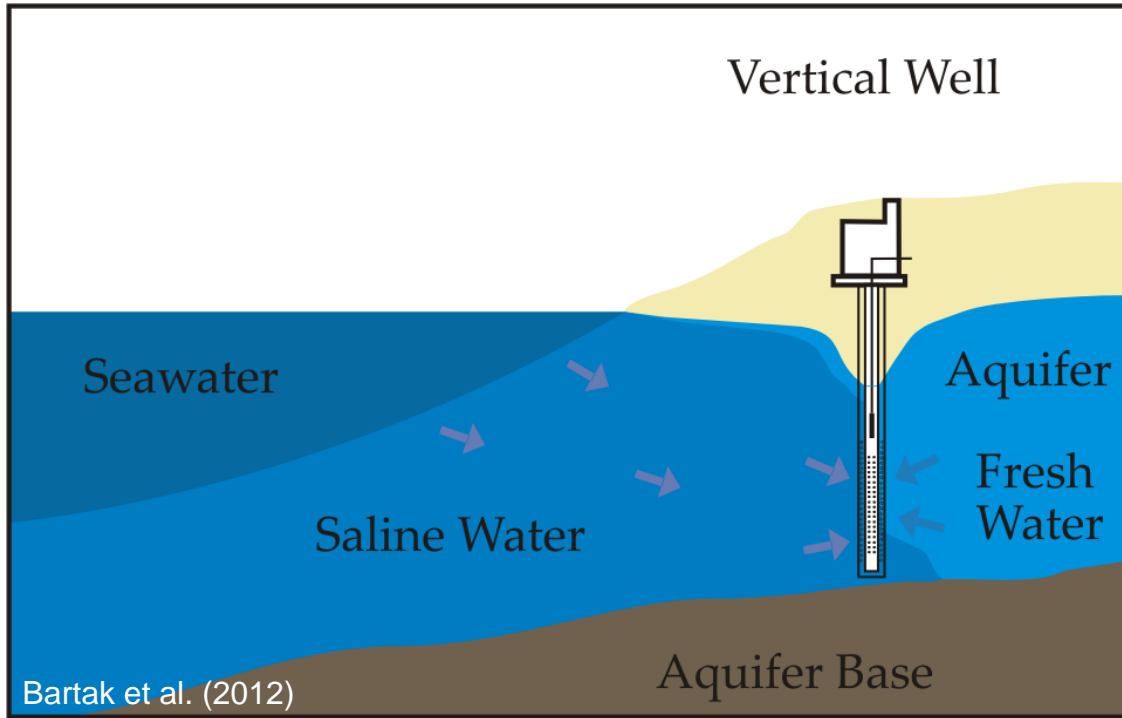
Bacterial counts at two beach well catchments in Jeddah (Dehwah & Missimer, 2016)

Size doesn't matter for RO pre-treatment

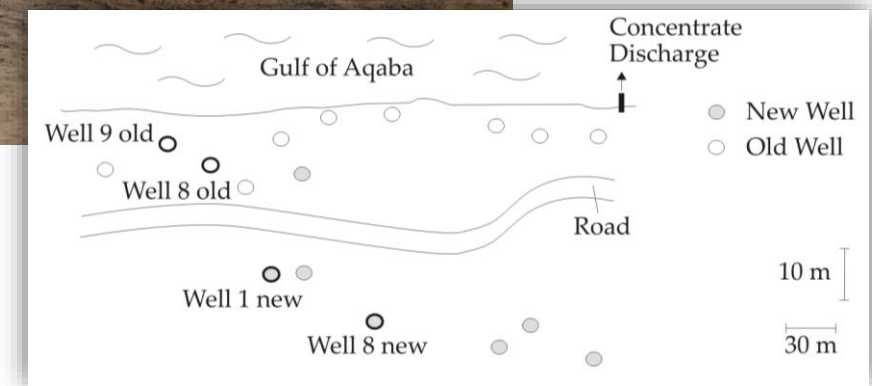
Facility	Capacity in m ³ /d	Well type	No. of wells
Sur (Oman)	up to 200,000	Vertical wells	28 ^{1,2}
Alicante (Spain)	130,000	HDD wells	30 ³
Tordera (Spain)	128,000	Vertical wells	10 ¹
Almeria (Spain)	120,000	Vertical wells	14 ¹
Fukuoka (Japan)	100,000	Infiltration gallery	- ⁴
Aruba (Caribbean Isl.)	80,000	Vertical wells	10 ^{1,5}
Ghar Lapsi (Malta)	45,000	Vertical wells	18 ¹
Salina Cruz (Mexico)	15,000	Horizontal Ranney wells	3 ¹
Morro Bay (USA)	4,500	Vertical wells	5 ^{1,5}

¹ Voutchkov (2017), ² Rachmann et al. (2014), ³ Dehwah (2017), ⁴ Shimokawa (2012), ⁵ Missimer et al. (2013)

Design of beach wells – Vertical wells



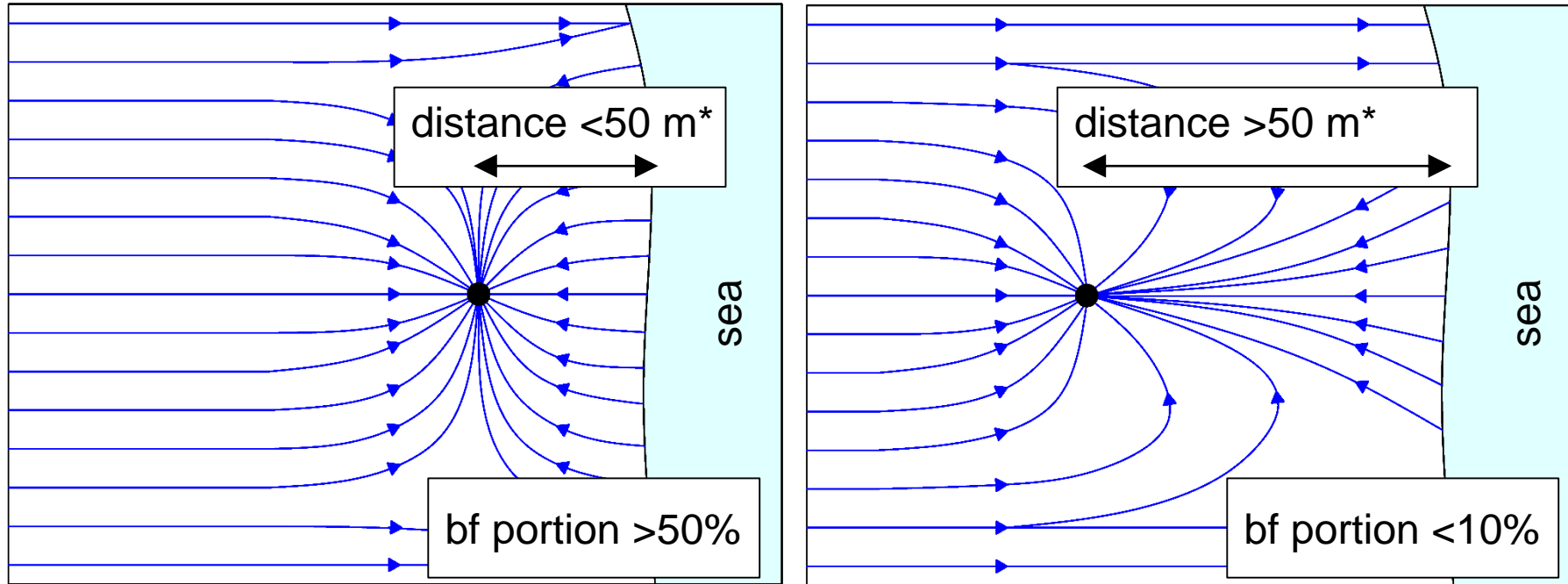
- ▶ Most common design
- ▶ Aquifer thickness >8 m
- ▶ Low abstraction rates per well
- ▶ High catchment capacity possible



Dahab well field (Egypt)

15 wells at a distance of 6 to 41 m
up to 0.6 mg/L iron

Impact of well positioning on feed water quality



*Distance depending on hydrogeological site conditions

Sea/Groundwater flow modeling advised

	Well groups	Well galleries
Drawdown	↑	↓
Travel time	↓	↑
bf portion	↑	↓

Supersize SWRO - Sur desalination plant (Oman)

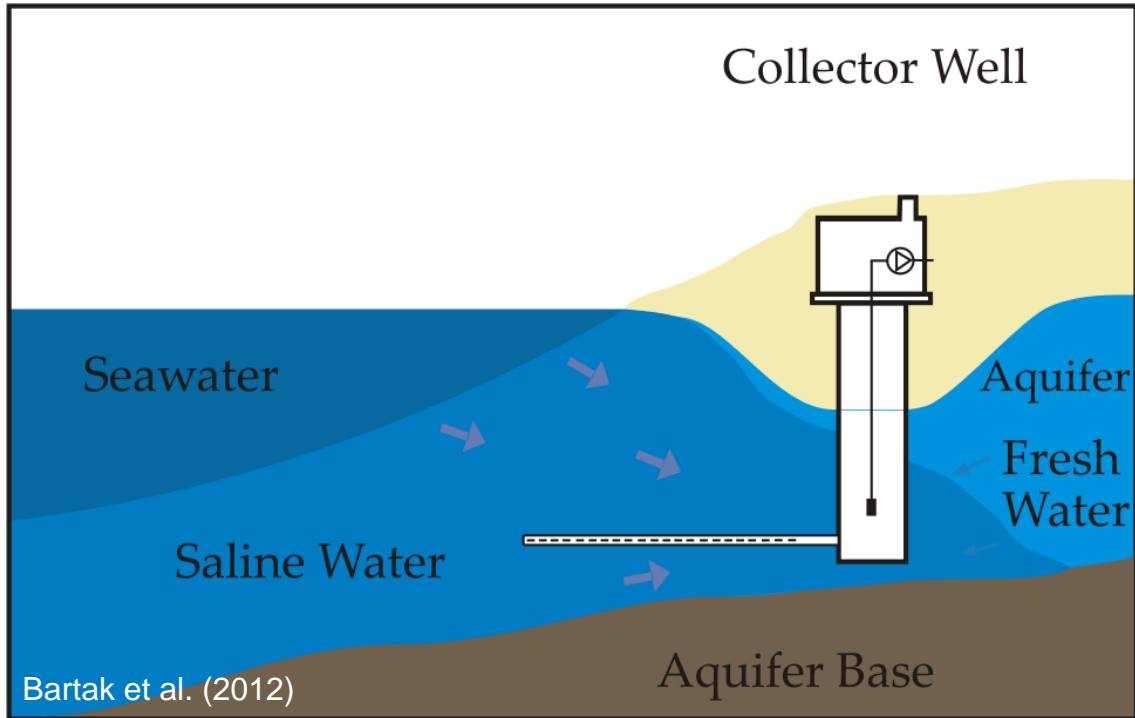


- ▶ Largest beach well catchment worldwide
- ▶ up to 83,500 m³ drinking water per day
- ▶ Total capacity of up to 200,000 m³/d
- ▶ serves 375,000 inhabitants
- ▶ 28 vertical wells, well depths 80-100 m



Source: www.sharqiyahdesalination.com

Design of beach wells – Horizontal (Ranney) wells

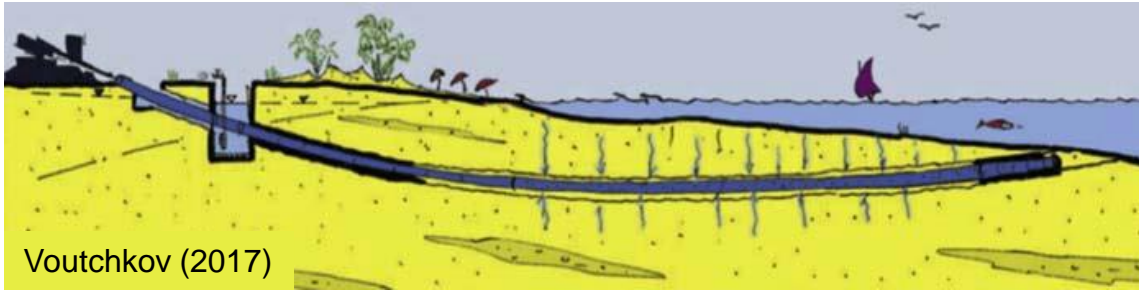


- ▶ Horizontal, lateral well screens
- ▶ High capacity, high cost
- ▶ Feasible for low aquifer thickness
- ▶ If access to the area is limited

Salina Cruz SWRO plant (Mexico)

3 wells abstracting up to 15,000 m³/d
high Fe and Mn concentrations

Design of beach wells – HDD wells



- ▶ Horizontal, perforated screens
- ▶ 5-10 m below the sea bed
- ▶ Typically inclined at 15-20 degrees

New Cartagena Canal plant (Spain) →
20 HDD wells abstracting up to 65,000 m³/d
arranged in a fan shape
Intakes are 500-600 m long



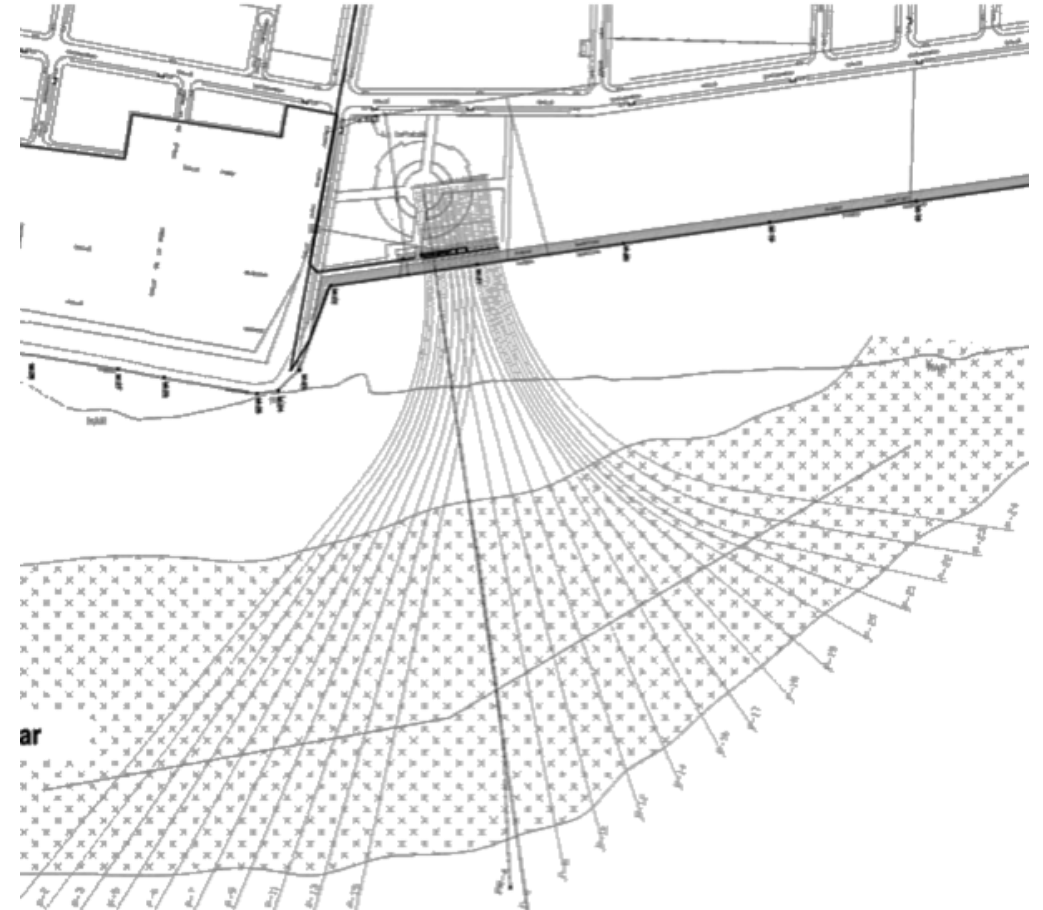
Voutchkov (2017)

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Supersize SWRO - San Pedor del piñata (Spain)



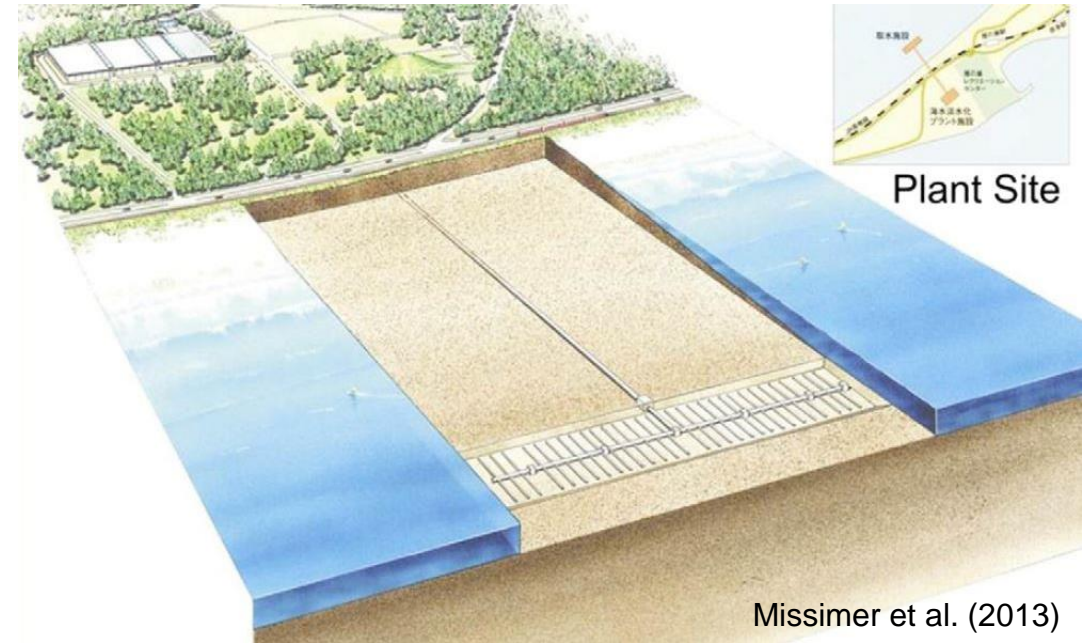
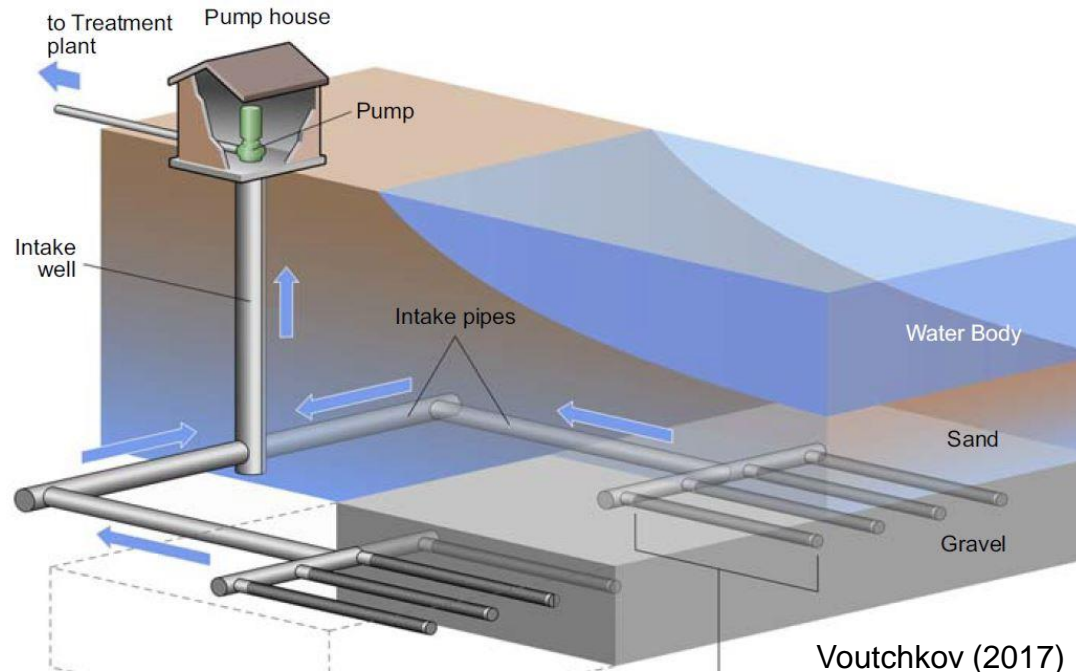
- ▶ Largest beach well catchment using HDD wells
- ▶ up to 130,000 m³/d
- ▶ Water used for irrigation
- ▶ 19 HDD wells, well depths 10 m below sea bed



Farinas & Lopez (2007)

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Design of beach wells – Infiltration galleries



- ▶ For unfavorable hydrogeological conditions (shallow aquifers, underlying rock)
- ▶ Feasible at locations with continuous wave movement
- ▶ Difficult construction (e.g. dewatering)

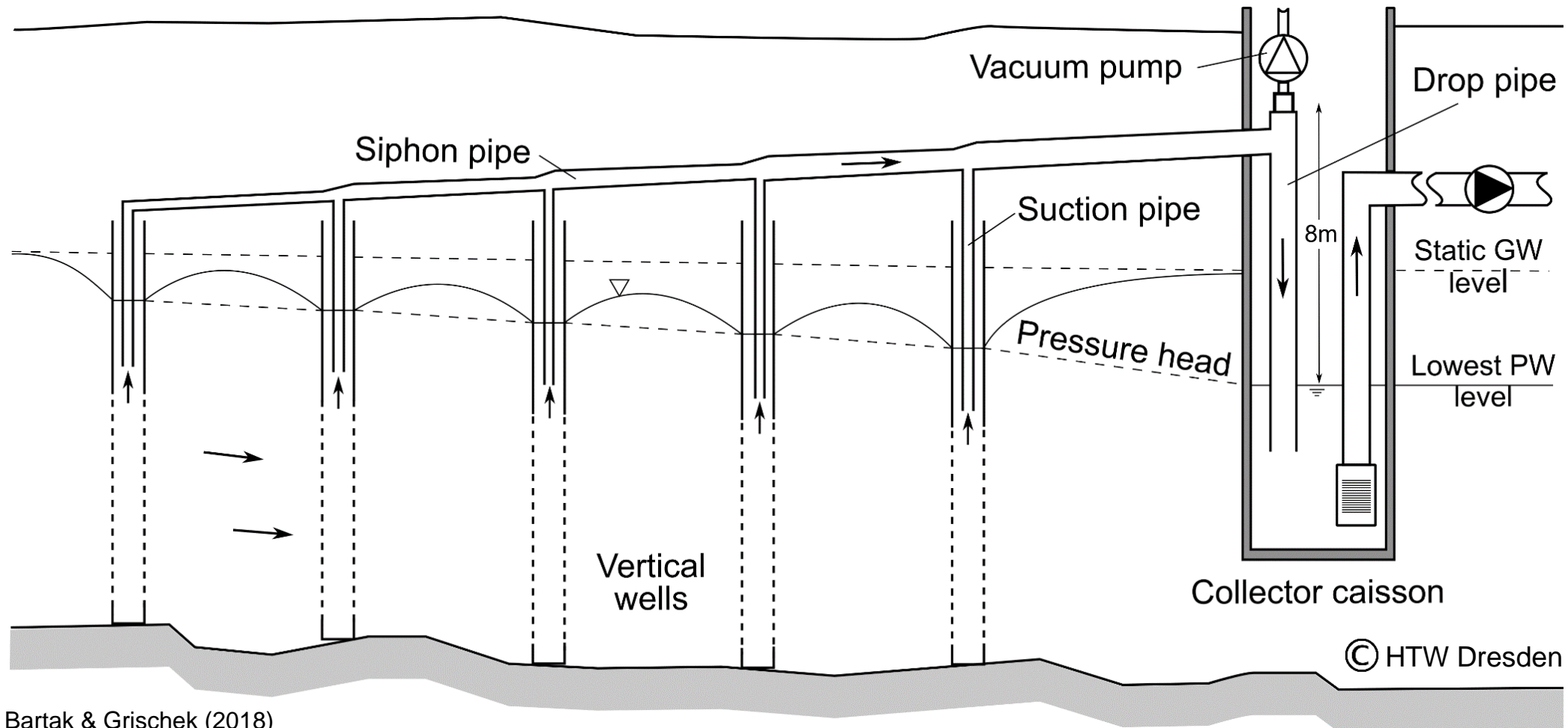
Fukuoka (Japan)

Abstracting up to 103,000 m³/d

Infiltration bed has an area of 2 ha

Abstracted water further treated with UF

Energy efficient siphon systems for beach wells



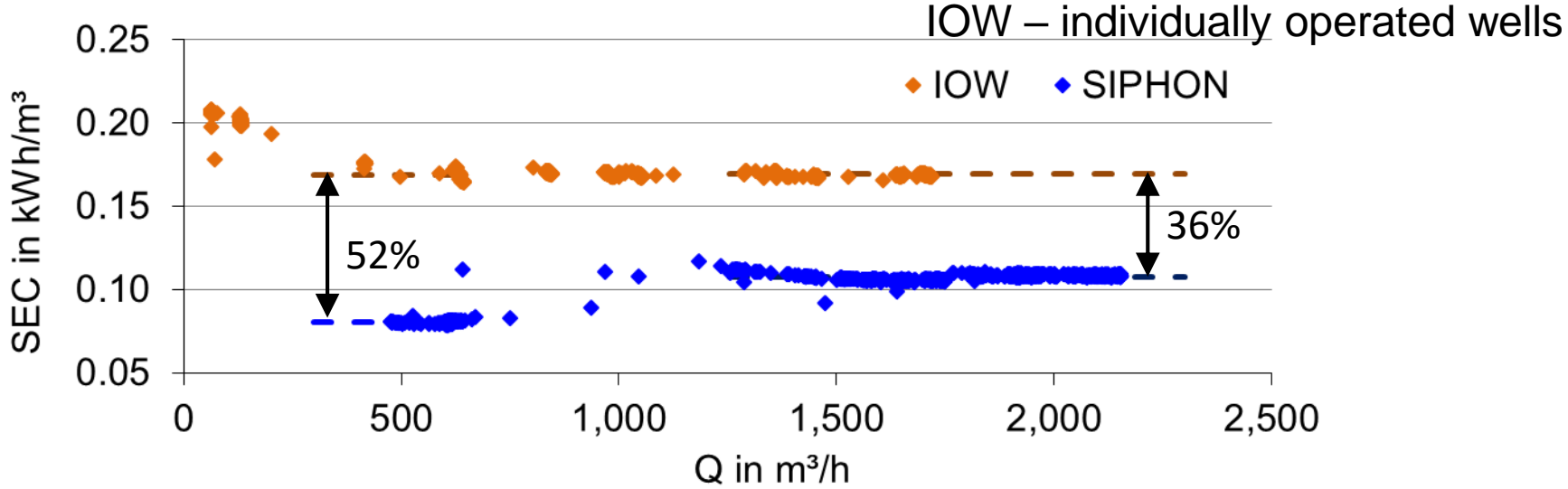
Bartak & Grischek (2018)

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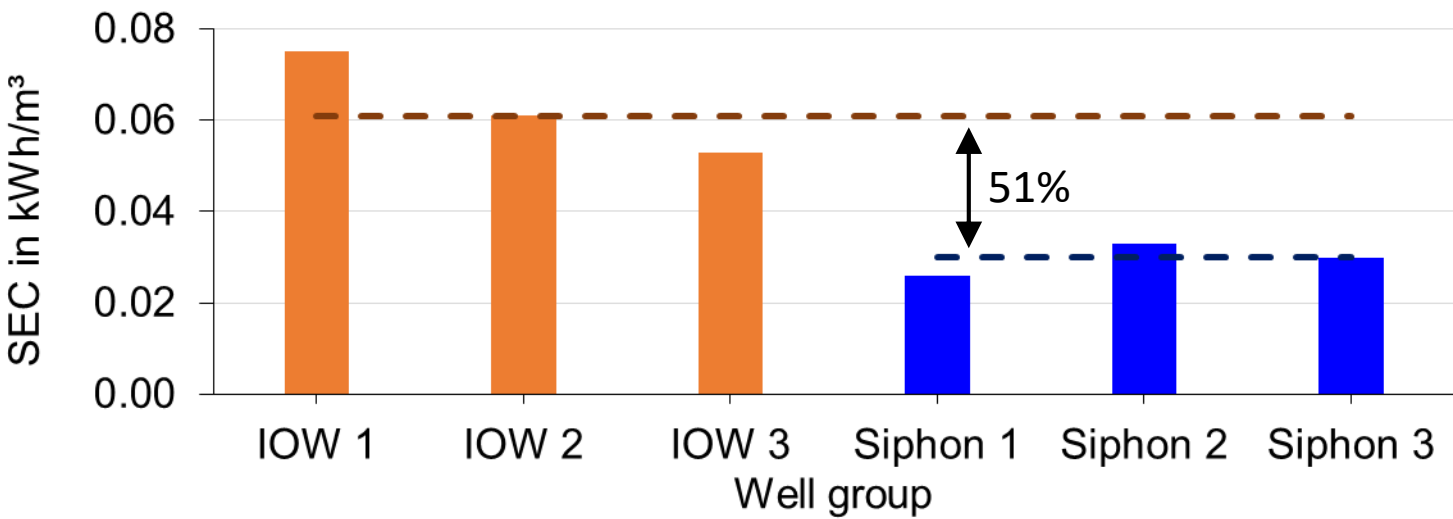
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Energy efficiency of siphon wells

Dresden



Budapest



SIPHON – a free Excel design tool (AquaNES tool)

SIPHON
Tool for the hydraulic calculation of siphon wells

What would you like to do?

1. Information about SIPHON tool
2. Workflow model set-up
3. Model set-up

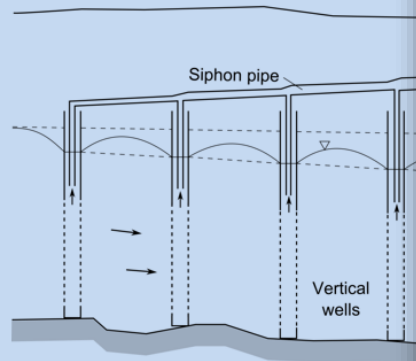


Figure: Schematic of a siphon well system with

↑ Workflow **1. Basic data input**

Aquifer

Type	[-]	unconfined	
H	[m]	25.0	Saturated thickness along the well group
M	[m]	6.5	Saturated thickness along the well group
K-value	[m/s]	8.00E-04	Representative hydraulic conductivity for the well group

Well set-up

$n_{\text{siphon pipes}}$	[-]	1	Number of siphon pipes (max 3)	only active if $n_{\text{siphon pipes}} > 1$
$n_{\text{Well (SIPHON 1)}}$	[-]	15	Number of wells along siphon pipe 1	
$n_{\text{SB (SIPHON 1)}}$	[-]	15	Last well before the collector caisson	

Note: The following parameters can be refined individually for every well in the next step

$L_{\text{well group}}$	[m]	602.0	Length of the well group
a_{Well}	[m]	43.0	Calculated well spacing
r_0	[m]	0.5	Well bore radius
h_{Screen}	[m]	3.0	Filter screen length
Q_i	[m ³ /h]	50.0	Mean single well abstraction rate, initial condition for iteration
L_{SL}	[m]	1170.0	Pipe length between last well and collector caisson
S_{SB}	[m]	4.80	Drawdown inside collector caisson (pre-defined internal boundary)
R	[m]	4000	Radius of influence of all wells (total abstraction from one single well or from model; $R > L_{\text{well group}}$ except for the case of a recharge boundary)

Recharge boundary

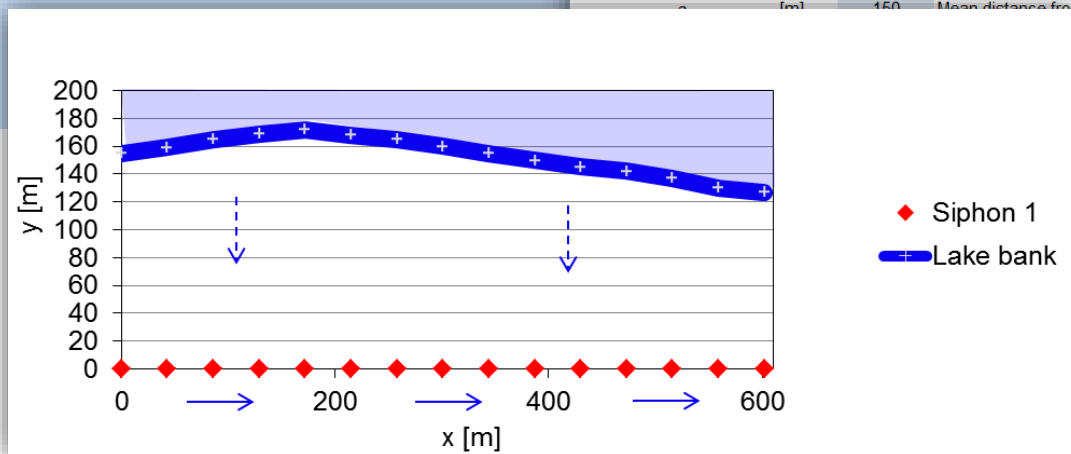
Lake/River	[-]	Yes	Recharge boundary in less than R/2 distance?
	[m]	150	Mean distance from the line of recharge

Selection:

Start calculation
(create and solve system of equations)

Create system of equation
(without solver, direct parameter refinement)

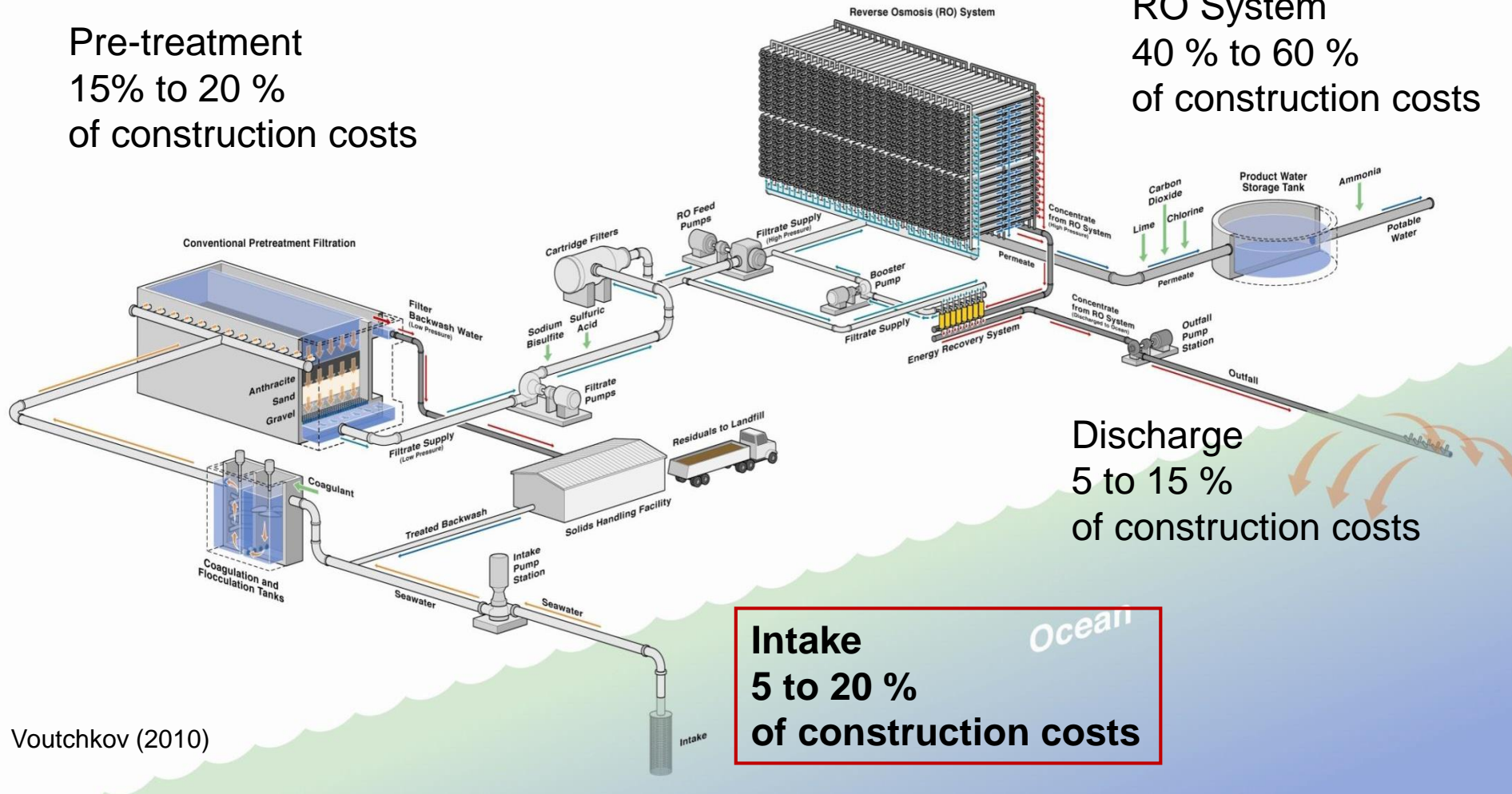
↓ Calculation



Seawater desalination plant construction costs

Pre-treatment
15% to 20 %
of construction costs

RO System
40 % to 60 %
of construction costs

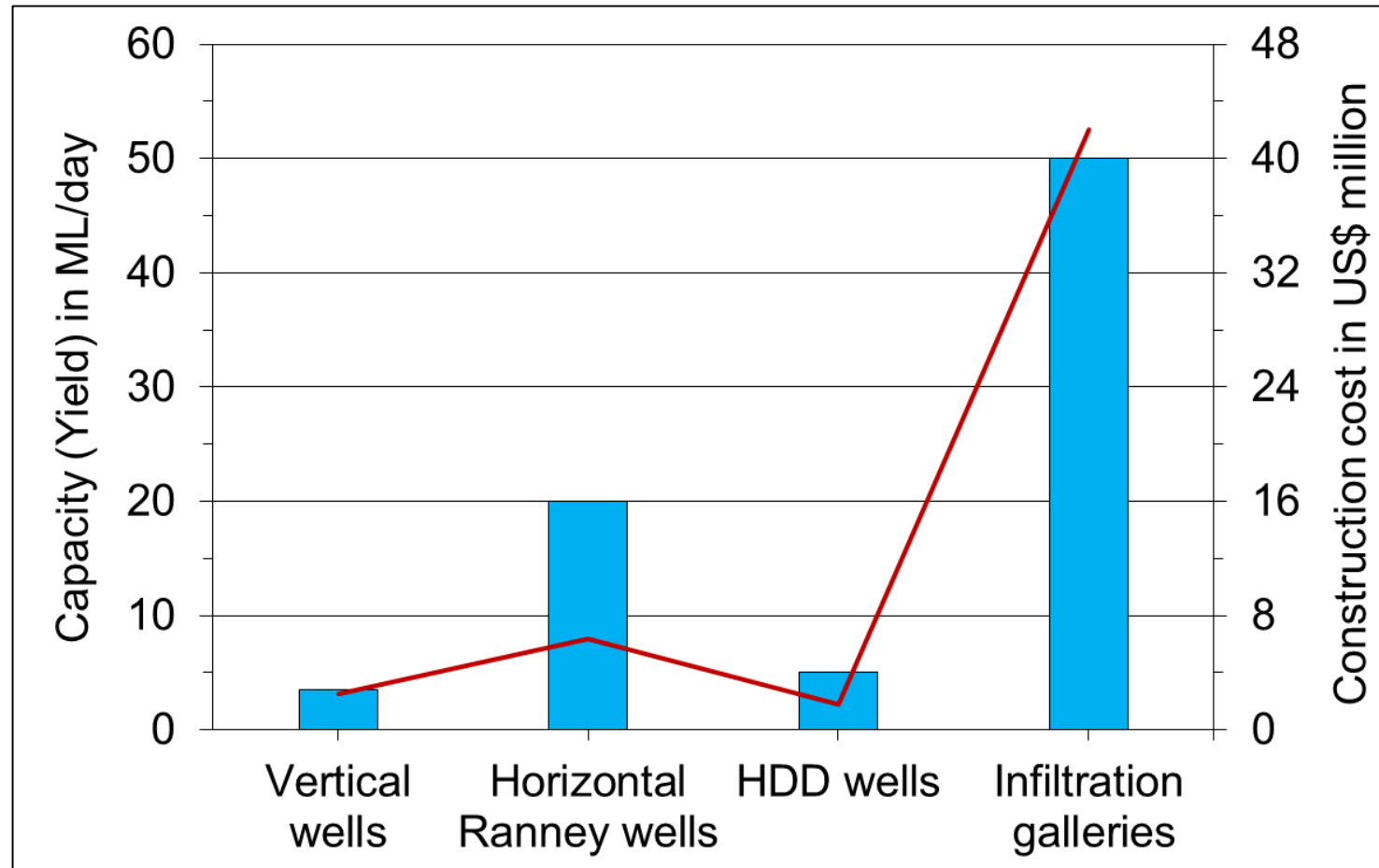


Discharge
5 to 15 %
of construction costs

**Intake
5 to 20 %
of construction costs**

Voutchkov (2010)

Construction costs of beach well systems



Comparison of **capacity** and **construction costs** for individual wells of each type (after Voutchkov, 2017)

Vertical wells



Most common, scalable
also feasible for small
desalination plants

Infiltration galleries

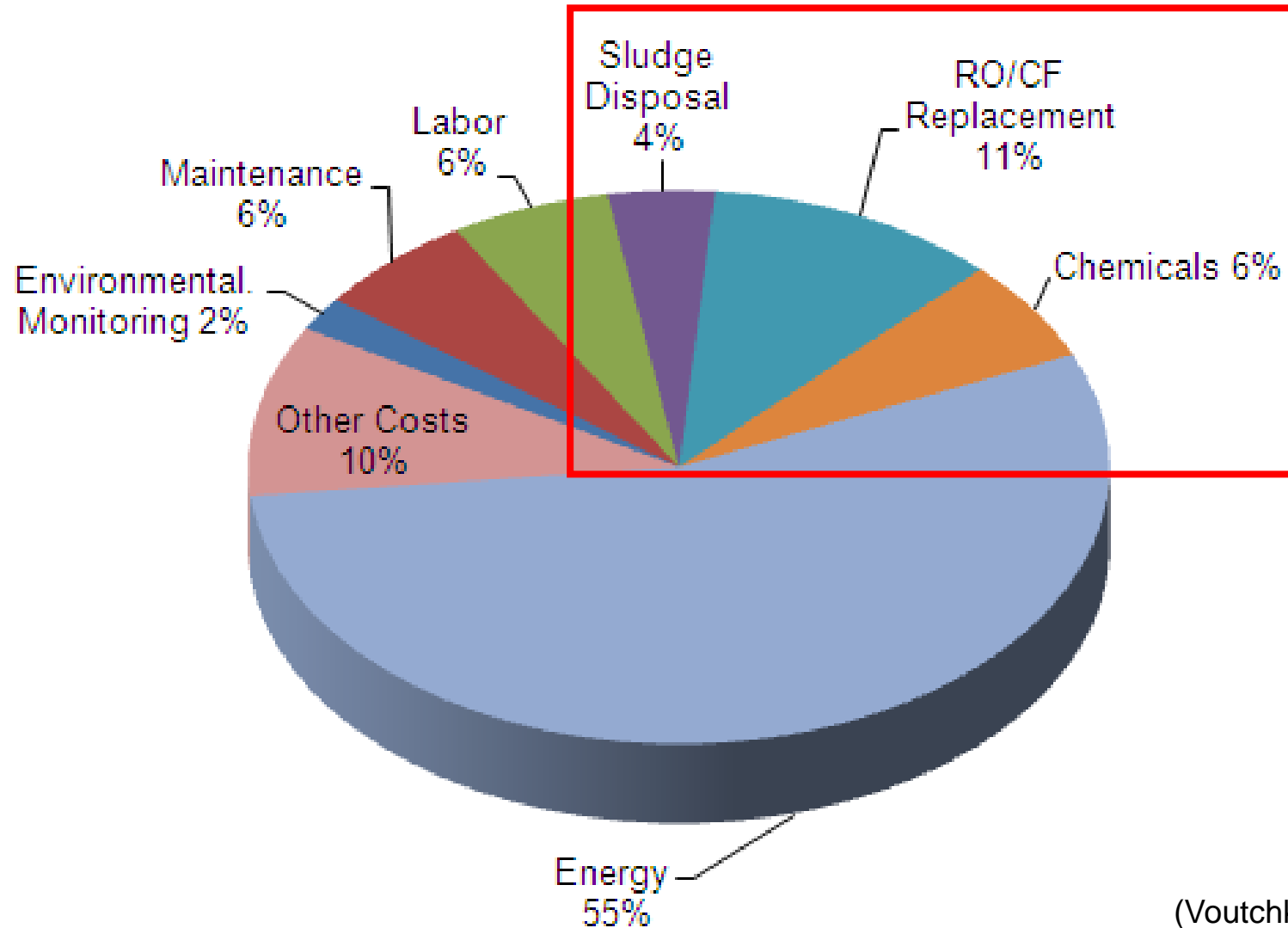


Construction of the intake
makes >50% of total
construction costs

New ideas required to reduce
construction costs

all other types: 10-30%

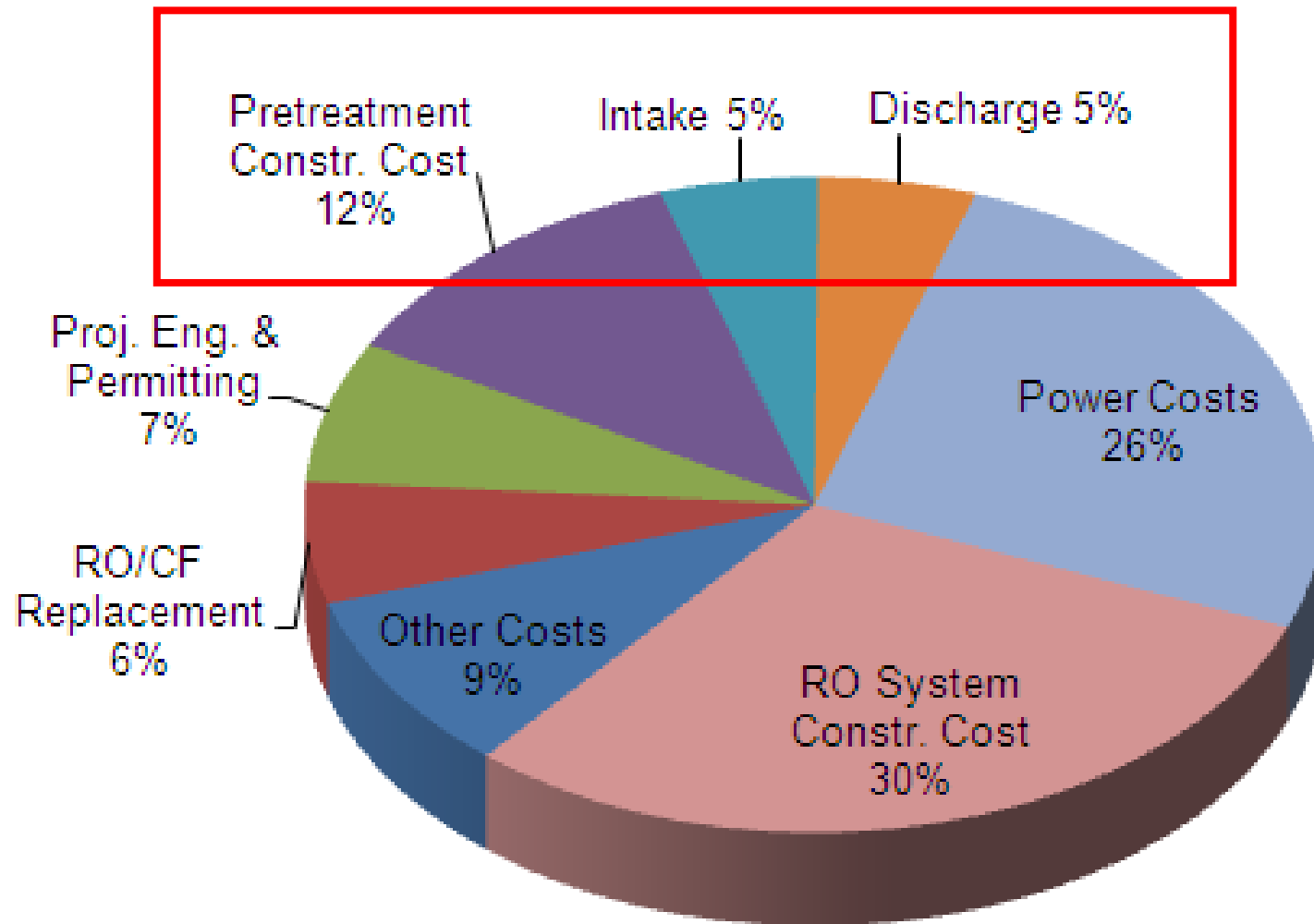
Operation and maintenance cost breakdown



(Voutchkov, 2010)

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Cost of water breakdown



(Voutchkov, 2010)

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Cost considerations at one glance

- ▶ Costs for open intakes from 50 – 150 €/m³*d
- ▶ Pre-treatment construction costs usually 60 – 300 €/m³*d
- ▶ Horizontal wells cost up to 400 €/m³*d
- ▶ Vertical wells are less costly

- ▶ Very dependent on source water quality & type of treatment technologies
- ▶ High quality well water sources require only cartridge filtration (low-cost pre-treatment)
- ▶ Single-stage granular media filtration usually is less costly than membrane pre-treatment

Conclusions

- ▶ Beach well design depends on hydrogeology and required capacity → wide variety of design options
- ▶ Additional investment costs
- ▶ Long-term cost savings in operation and maintenance
- ▶ Potential cost savings for intake structures depending on location of waterworks, water quality, mussels, hydraulics

**Let's think about it –
even 5% energy saving can make a difference, also for climate change**



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