Professional networking

"You are not ever a genius all by yourself.
Your ideas are a function of the people
you are connected with..."
– Carol Dweck, Author, Mindset

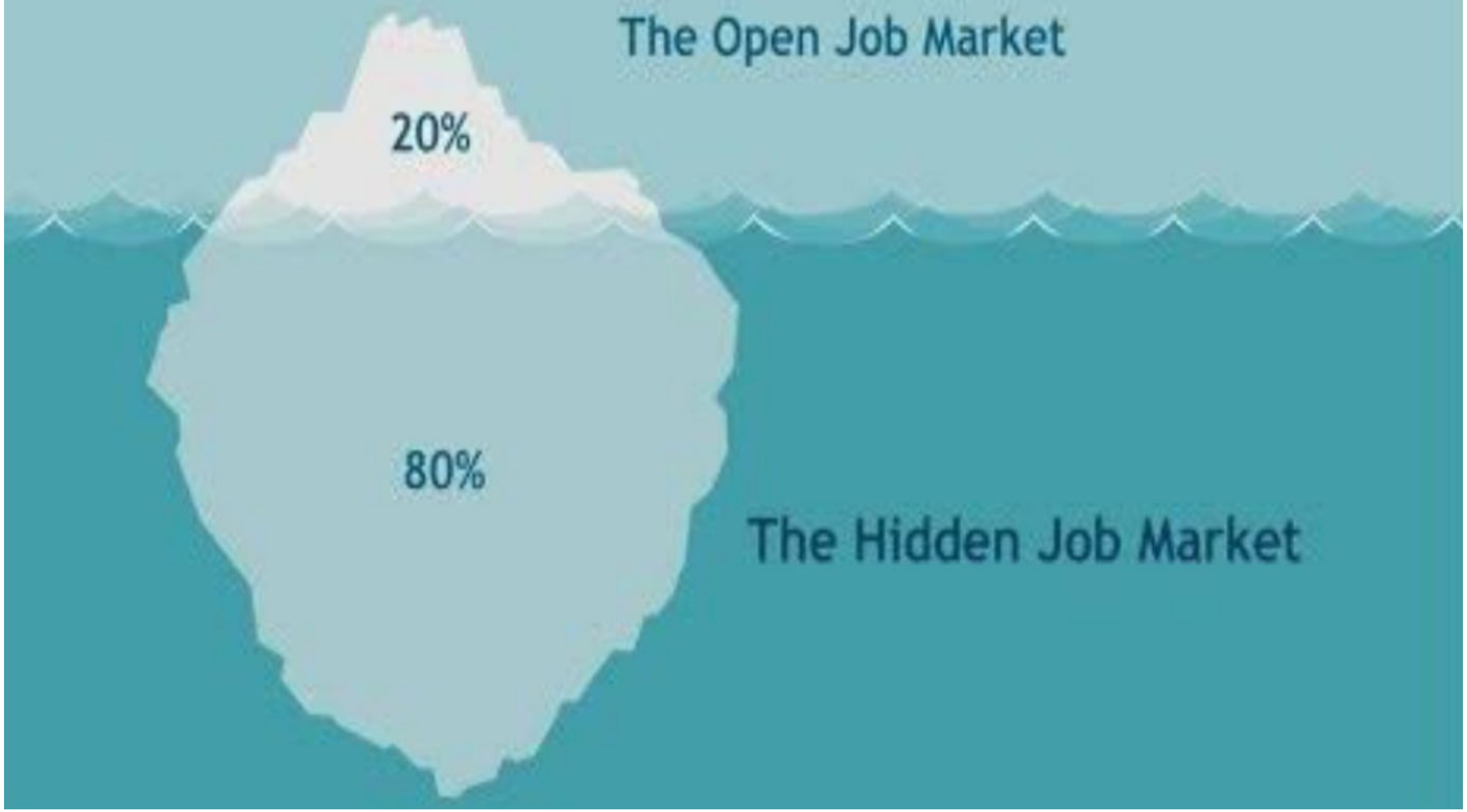

Uncertainty…


Tough competition...


Often unfair…


…you need to differentiate!

Because in a downturn…



Benefits of Smarter Professional Online Networking

- Access to quick conversations, expert opinions, issue or system scan
- Leads to new ideas, new connections
- Get real-time insights
- Efficient way to find out what people in your network are doing and whether to reconnect
- Facilitates connections at conferences and meetings
- Open doors, build relationships with experts, influencers, or others

What Kind of Networking Animal Are You?

Turtle

- No online networking or profile locked down
- Only connects with family and personal friends
- Little benefit to your organization/professional

Jelly Fish

- Profile open to all and connects with everyone
- Share content & engage frequently with little censoring
- Potential decrease in respect

Chameleon

- Profile open or curated connections
- Networking strategy
- Helps you solve problems or reach goals

Based on "When World's Collide" Nancy Rothbard, Justin Berg, Arianne Ollier-Malaterre (2013)

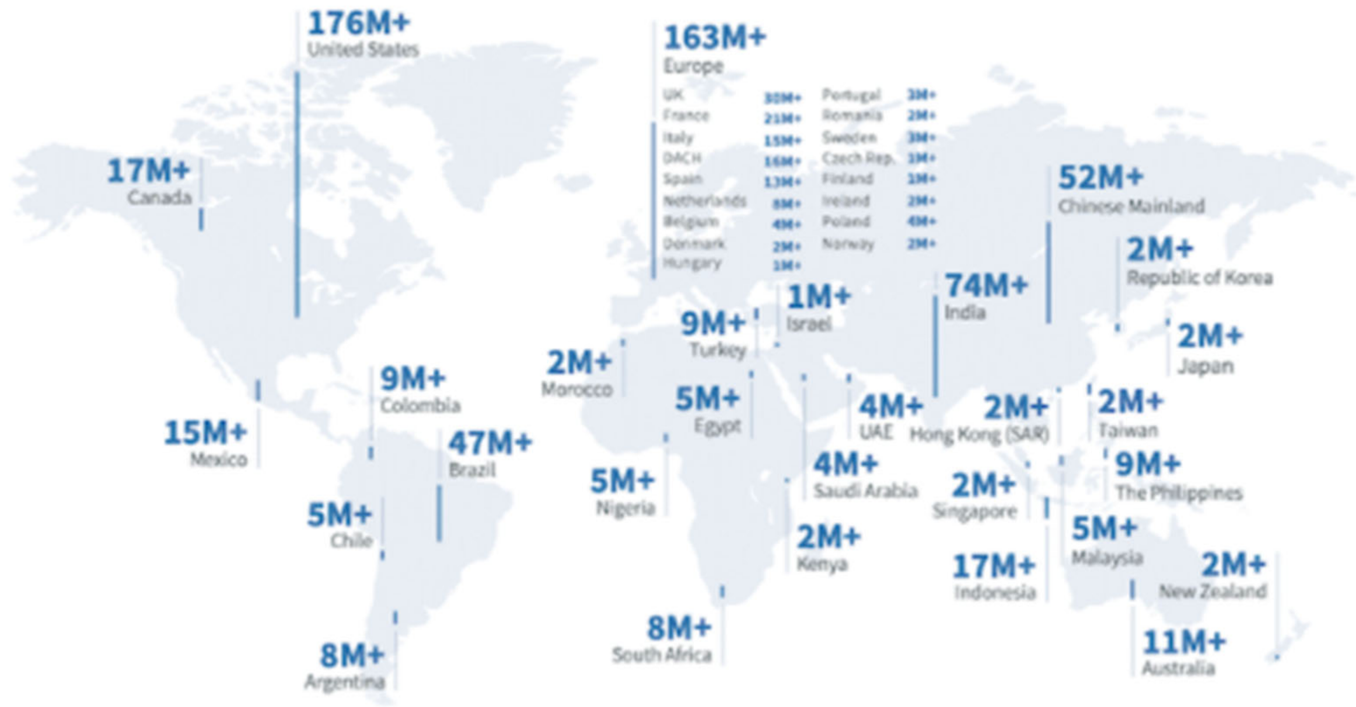

Networking is all about QUALITY!
QUANTITY
QUALITY

LinkedIn

- Do you know what is LinkedIn?

LinkedIn

Nearly 740 million members in 200 countries and regions worldwide



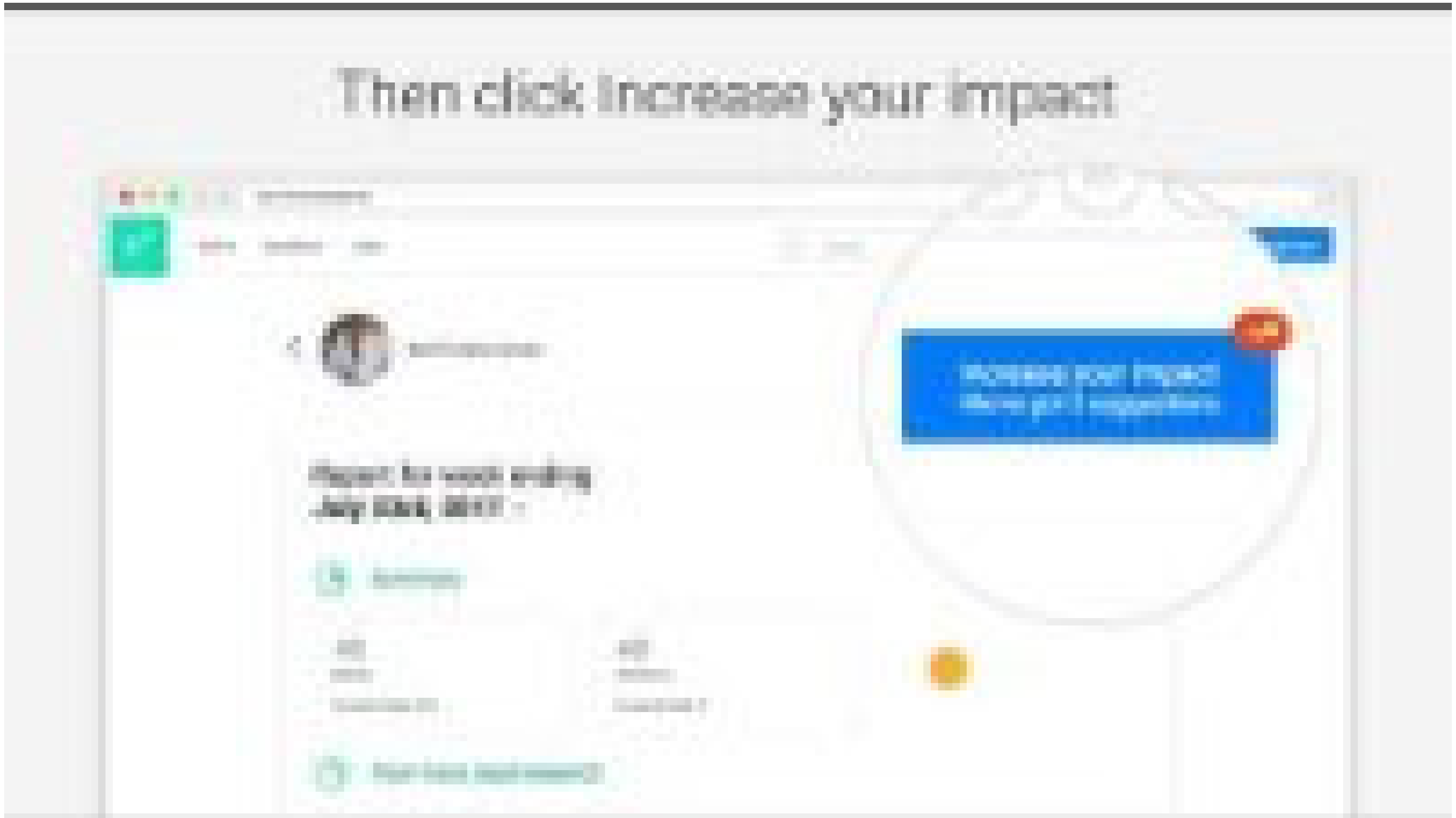
LinkedIn

- Do you have a profile in LinkedIn?
- What is the status of your profile?

Individual work

- Create or update your profiles in LinkedIn

ResearchGate



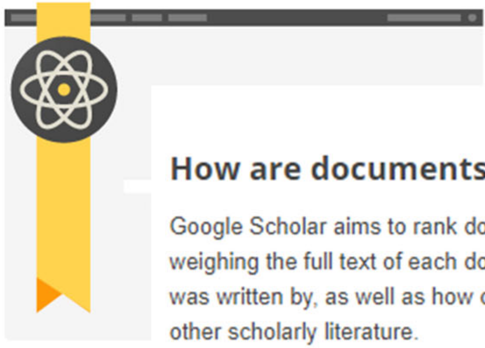
Individual work

- Create or update your profiles in ResearchGate

Google Scholar

Stand on the shoulders of giants.

Google Scholar provides a simple way to broadly search for scholarly literature. From one place, you can search across many disciplines and sources: articles, theses, books, abstracts and court opinions, from academic publishers, professional societies, online repositories, universities and other web sites. Google Scholar helps you find relevant work across the world of scholarly research.



How are documents ranked?

Google Scholar aims to rank documents the way researchers do, weighing the full text of each document, where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature.

Features of Google Scholar

- Search all scholarly literature from one convenient place
- Explore related works, citations, authors, and publications
- Locate the complete document through your library or on the web
- Keep up with recent developments in any area of research
- Check who's citing your publications, create a public author profile

Scopus

10th International Summer School on Water

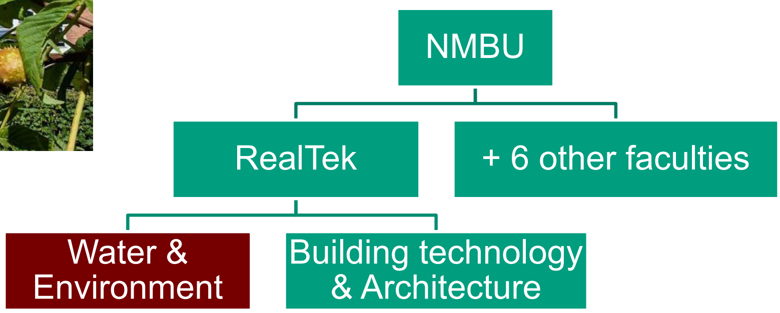
Norwegian University of Life Sciences

12 June 2021

Faculty of Science and Technology, NMBU

Norwegian University of Life Sciences

Water, Environment, Sanitation & Health – WESH Group



Additionally several other “smaller” groups at other faculties

About the Course Responsible

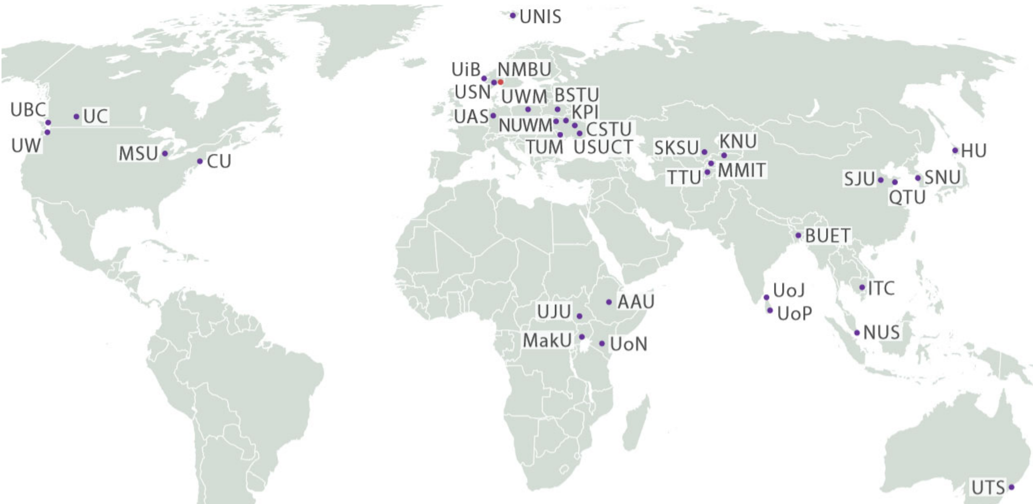
Background

- Born in Sri Lanka, lived 18 years
- MSc from NTUU-KPI, Kiev, Ukraine, in 1987, lived 7 years
- PhD from NTNU, Trondheim, Norway, in 1992
- lived 33 years in Norway; worked in several countries for NORAD, SIDA, DANIDA, UN, World Bank.

Employment

- 20 years: Director of innovation & international projects at the Norwegian Institute for Water Research
- Since 2012, fulltime professor, NMBU (2001-2011 part-time) at the Faculty of Science & Technology

WESH projects



75 universities from 45 countries
www.WaterHarmony.net

International Summer School on Water

NMBU, Ås

A tradition since 2012

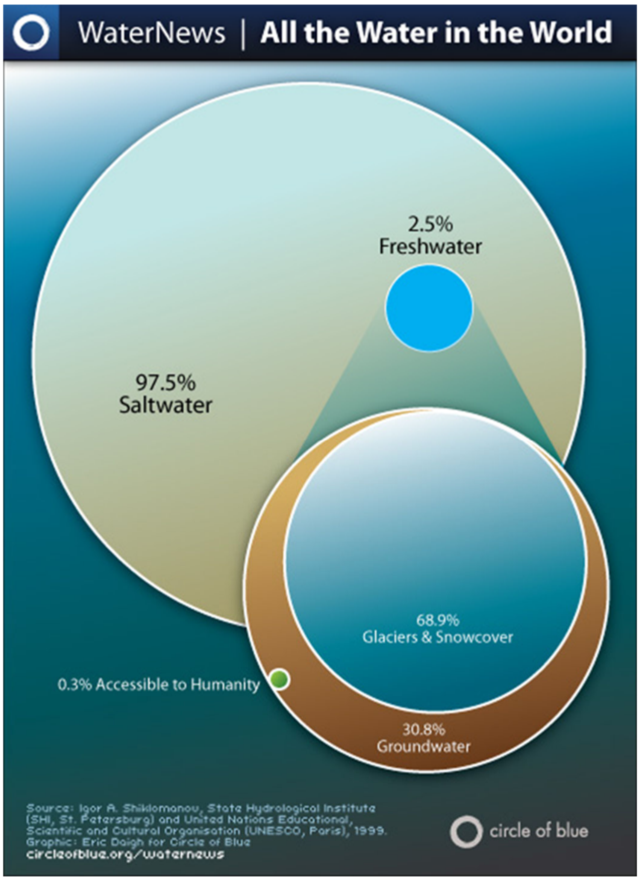
International Summer School

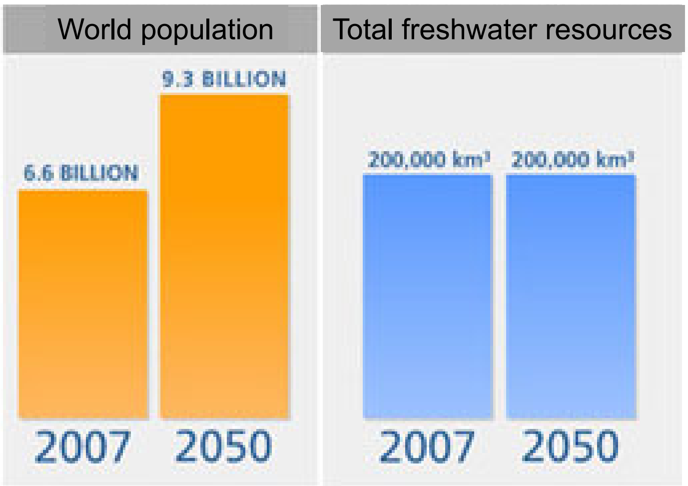
Spitsbergen

Why work with water?

Water – a scarce resource

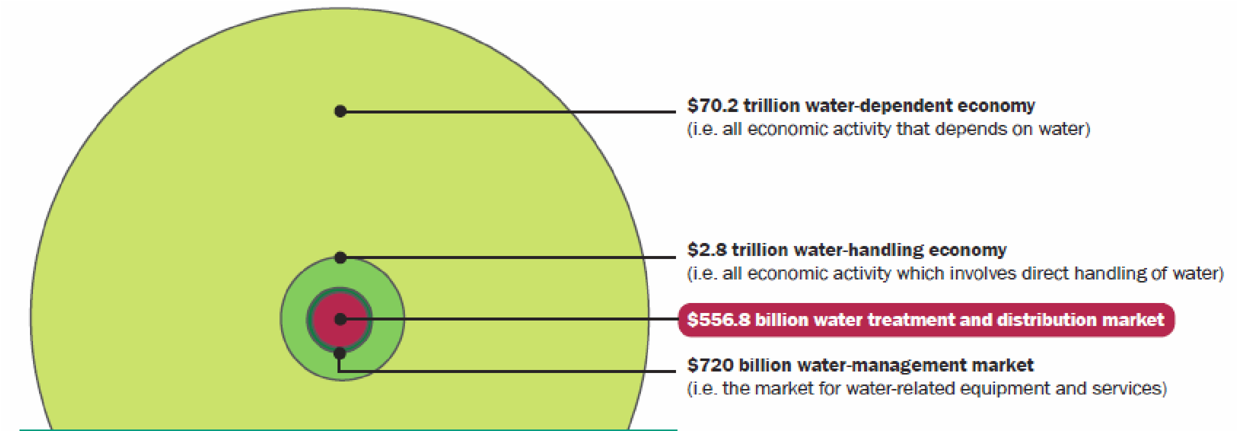
- > 70% of the earth is covered with water
- 0.007% is accessible for human
- Even that is unfairly distributed in the world creating water crises.





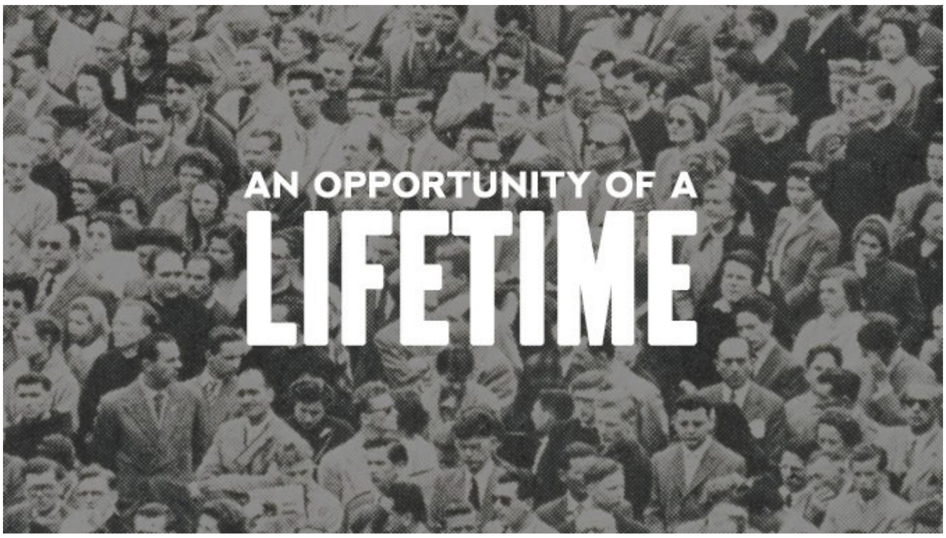
- Uneven distribution of water in the world
- Climate Change will make things worse

Global water related economy

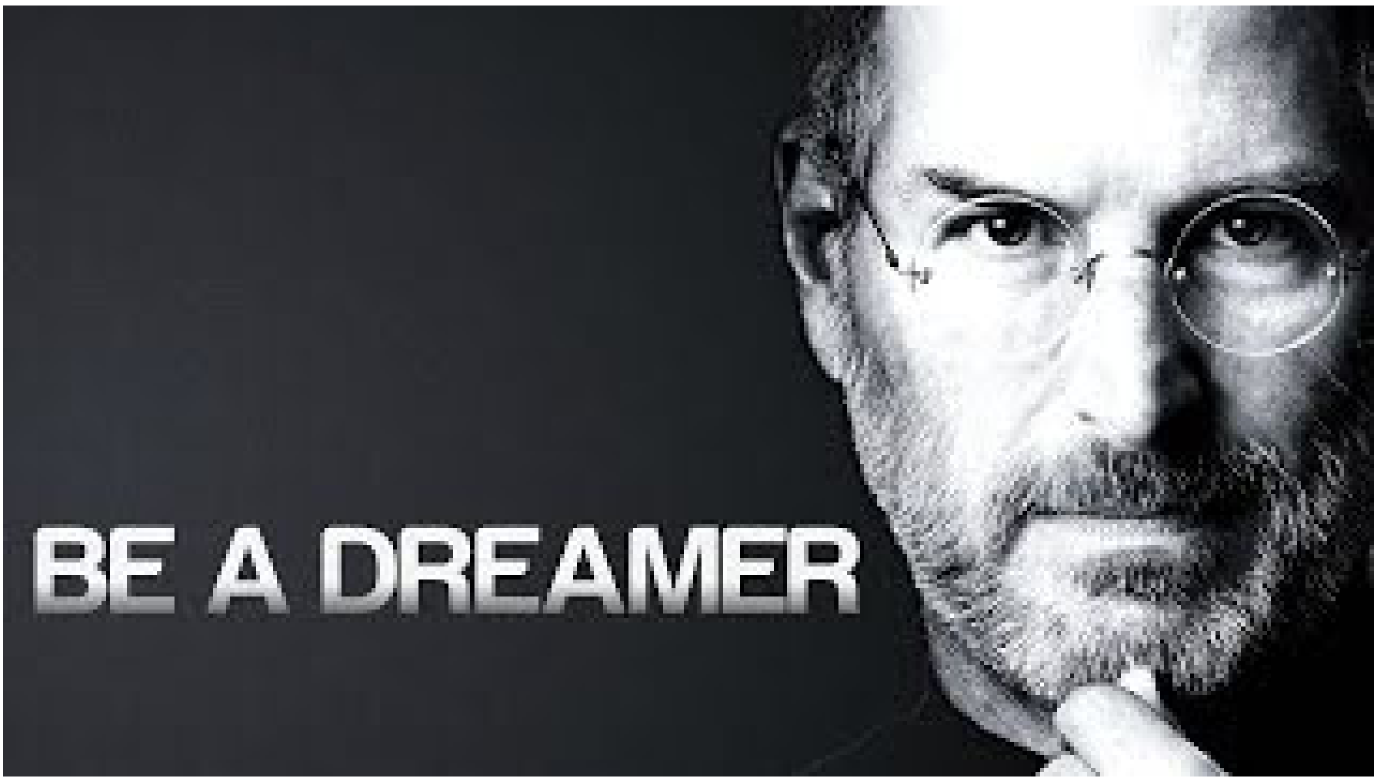


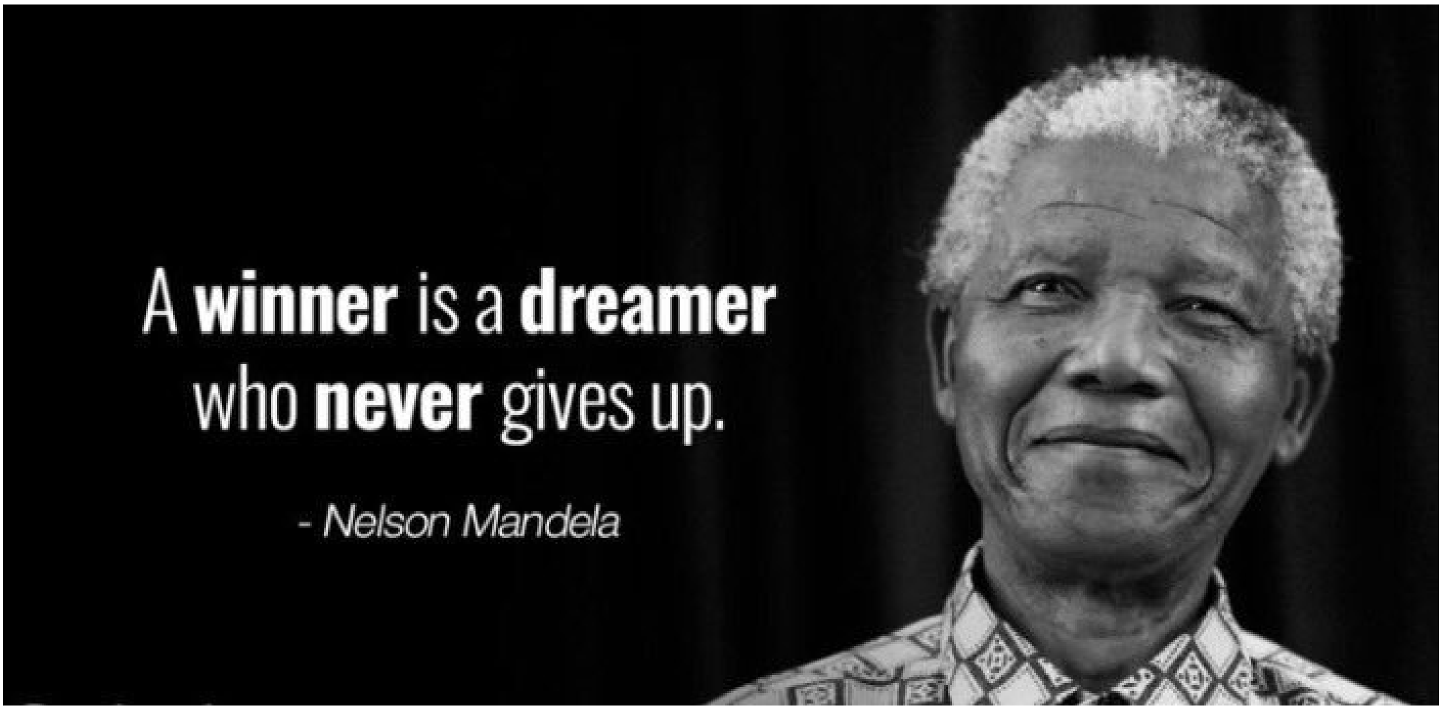
2018:
World GDP: 85 trillion USD
Water dependent: 75 trillion USD
Water treatment and distribution: 600 billion USD
The World needs water specialists!

It could be an opportunity of a lifetime, use it for form your future




WINNERS
SAY "IT MAY BE DIFFICULT BUT IT IS POSSIBLE."
SEE THE GAIN .
SEE POSSIBILITIES.
MAKE IT HAPPEN.
LOSERS
SAY "IT MAY BE POSSIBLE BUT IT IS TOO DIFFICULT."
SEE THE PAIN.
SEE PROBLEMS.
LET IT HAPPEN.
believe-toachieve.tumblr.com


BE A DREAMER


A winner is a dreamer who never gives up.
- Nelson Mandela


WHO WILL YOU BE
INTERVARSITY

Physical unit processes in water and wastewater treatment:
Screening, sedimentation, flotation and (filtration)

THT311
Harsha Ratnaweera
Professor, RealTek

Classification of treatment processes

Drinking water treatment

- Physical and Chemical processes
  - Removal of particles, NOM, metals and toxic matter
  - Removal or inactivation of pathogens
  - Softening
- Biological processes:
  - contaminants in polluted raw water
    - heavy metals,
    - natural organic matter,
    - inorganic non-metallic matter,
    - disinfection by-products,
    - endocrine disrupting
    - microbial contaminants.

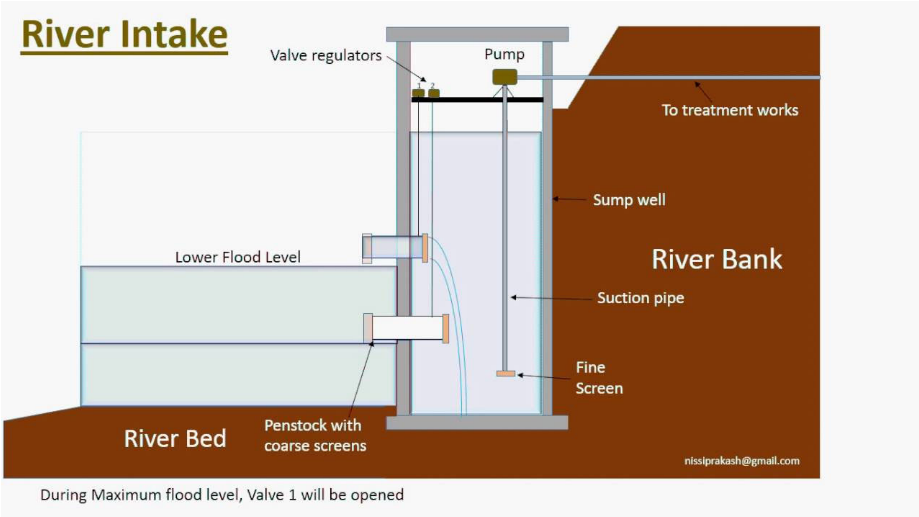
Wastewater treatment

- Sequential order of treatment
  - preliminary, primary, secondary, tertiary, advanced
- Main process mechanisms
  - physical, biological, chemical

Physical processes – water intakes

- Removal of large materials at the water intake
  - Leaves, algae
  - Small fish
  - Other debris

Water hyacinth at Lake Victoria



Screen types – (waste)water treatment

Type	Pore opening
Coarse screens	>10mm
Fine screens	10mm-2mm
Coarse micro- screens	2mm-0.5mm
Micro-screens	0.5-0.1mm
Fine micro-screens	<0.1mm

Preliminary treatment

To protect downstream treatment process

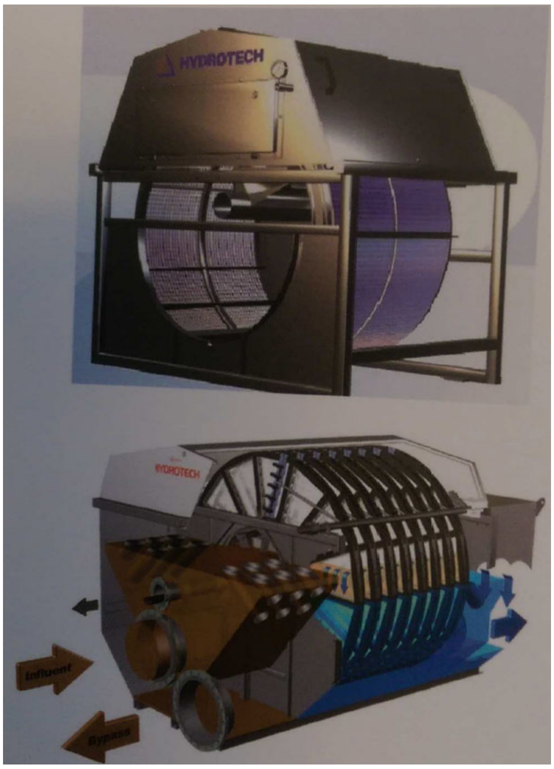
- Screening and comminution (physical)
  - timber, stones, rags, paper

>0.6m/s at Qdim to avoid sedimetation

  - bar screens and rotating screens (0:28)

Screens are often closed… (why?)

Fine micro screens



Fine Sieves / Fine screens:

- *40-60% of organic fraction of TSS are from toilet paper tissues*
- *Majority can be removed with sieves >500 microns.*
- *Combination of sieves with chemicals*

Salsnes/Trojan: 50% TSS & 20% BOD removal

Grit and sand removal /Fett- og sandfang

- Grit removal (physical)
  - sand and grit
  - Aerated sand traps (luftet sandfang)

Grit and sand removal

Grit and sand removal /Fett- og sandfang

- Grit removal (physical)
  - sand and grit

Sand from sand-traps

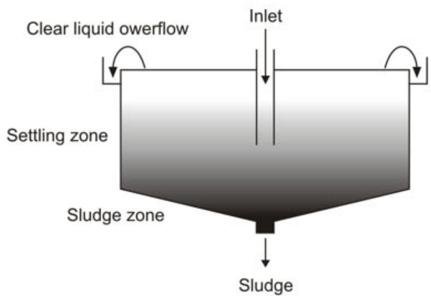
- Washed sand can be deposited (considered not hazardous)

Separation processes

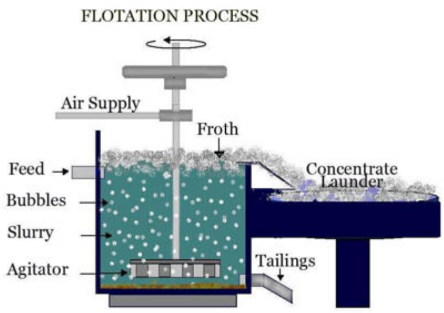
To produce
- clarified water
- effluents to reduce the pollution load to secondary processes or to/and recipients

A natural part of after many other unit processes

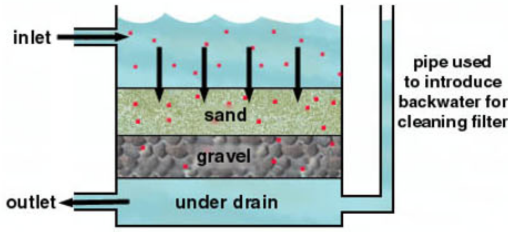
Sedimentation



Flotation

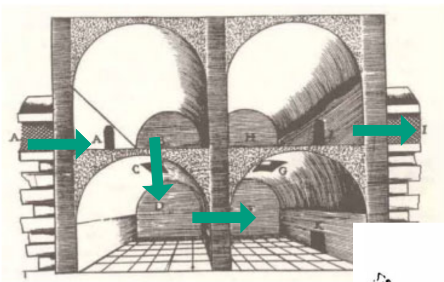


Filtration

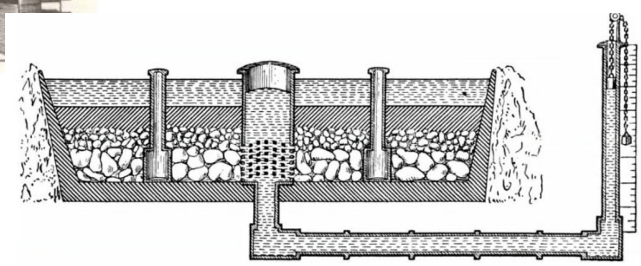


History of sedimentation

Egypt, 1450 BC
Syphoning of water or wine

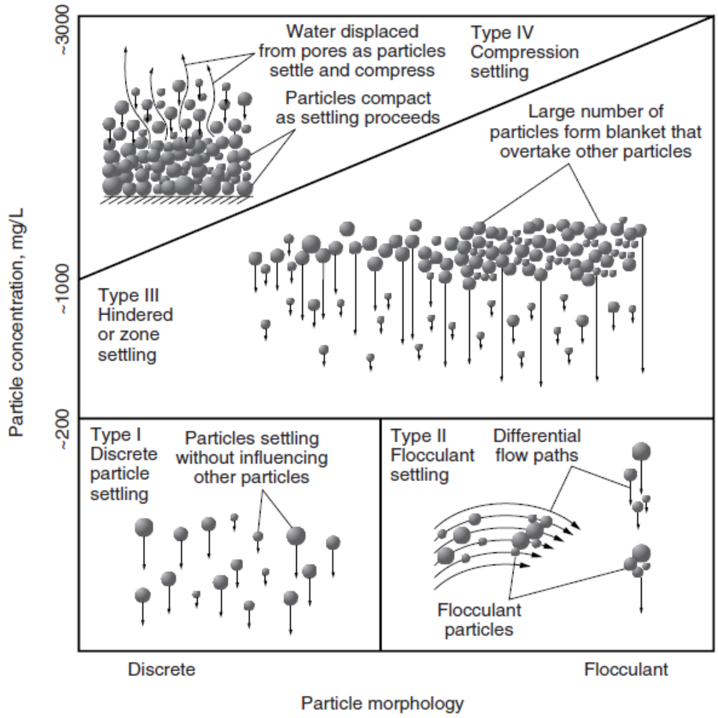


Rome, 1680, Water to aqueducts

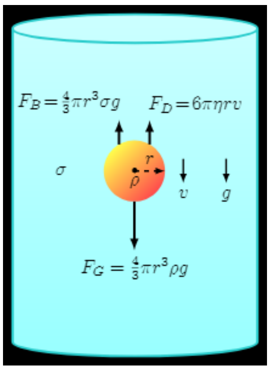


UK, 1790, Lancashire filter

Classification of particle settling: 4 types



Stokes law and terminal velocity (V_T)

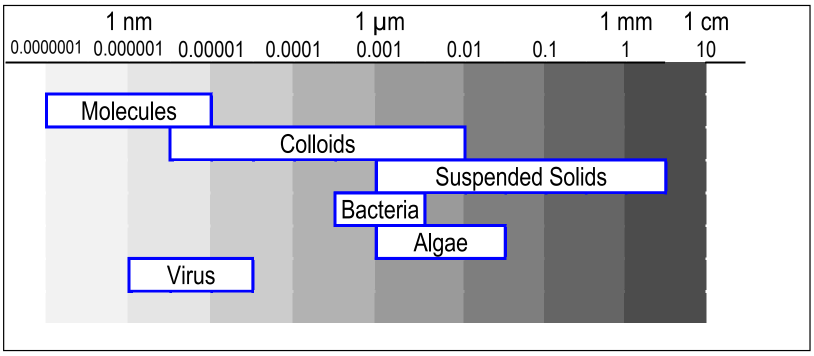


- Drag force (Stokes law), $F_D = 6\pi\eta r v$ (η= viscosity, r = radius, v= velocity)
- Buoyance force (Newtons law) $F_B = \frac{4}{3}\pi r^3 \sigma g$ (σ= fluid density, g = gravity)
- Gravity force $F_G = \frac{4}{3}\pi r^3 \rho g$ (ρ =particle density)
- $F_G = F_D + F_B$
- $\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v + \frac{4}{3}\pi r^3 \sigma g$
- $\frac{4}{3} r^2 \rho g = 6\eta v + \frac{4}{3} r^2 \sigma g$
- $6\eta v = \frac{4}{3} r^2 \rho g - \frac{4}{3} r^2 \sigma g = \frac{4}{3} r^2 (\rho - \sigma) g$
- $V_T = \frac{2r^2(\rho - \sigma)g}{9\eta}$

Approximate sedimentation times of particles in water

Diameter, µm	type	sed.tid pr 1m
1000	sand	10 sec
100	Fine sand	2 minutes
10	Clay	2 hours
1	Bacteria	8 days
0,1	colloid	2 years
0,01	colloid	20 years
0,001	colloid	200 years

Physical methods



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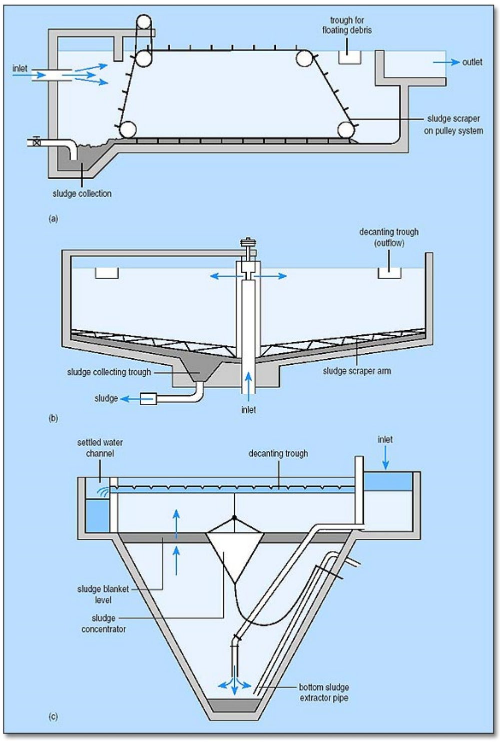
0,01	colloid	20 years
0,001	colloid	200 years

Typical removal rates	Mechanical
SS	60%
COD	30%
Tot-P	15%
Tot-N	15%

Primary treatment

- Primary sedimentation: suspended matter settles under gravity.
- Rectangular (horizontal flow), circular (radial flow), upward flow

Sedimentation tanks

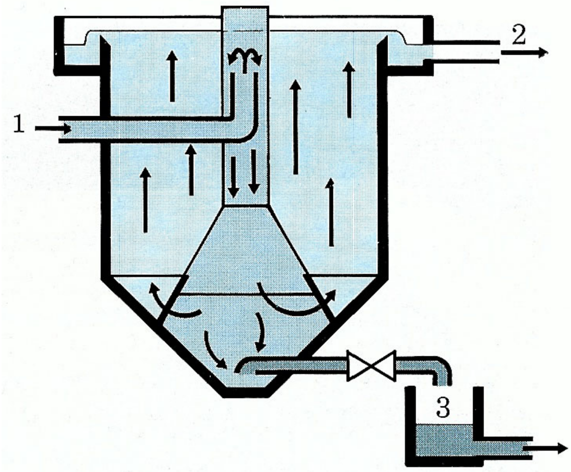


(a) rectangular horizontal flow tank;

(b) circular, radial-flow tank;

(c) hopper-bottomed, upward flow tank

Sedimentation



1 – Raw water.
2 – Treated water.
3 – Drain.

Surface load, m/s

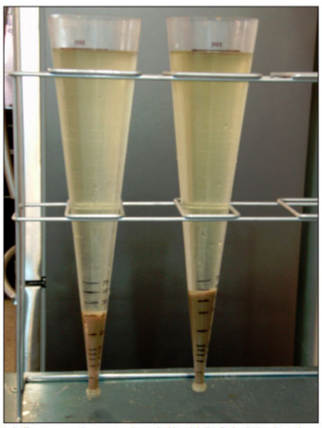
$$\text{Flow/area} = Q/A = \frac{m^3}{s} / m^2$$

Dimensioning of sedimentation tanks

- Key parameter: surface load (Q/A, m/s), 1.0-2.5
- Pre-sedimentation: Q/A: 2.0-2.5
- Secondary sedimentation in activated sludge (AS), 0.8-1.3
  - in addition to the surface load the sludge concentration, SVI, basin geometry and water depth are important
- Water depth >2.5 m (AS: >3.5m)

Dimensioning guidelines – secondary sedimentation after AS

- Sludge volume SV (ml/l) = SVI (ml/g SS) · X (g SS/l)
  - SVI: sludge volume index; X: sludge concentration
  - SVI should be between 100-150 for WW without much industrial input

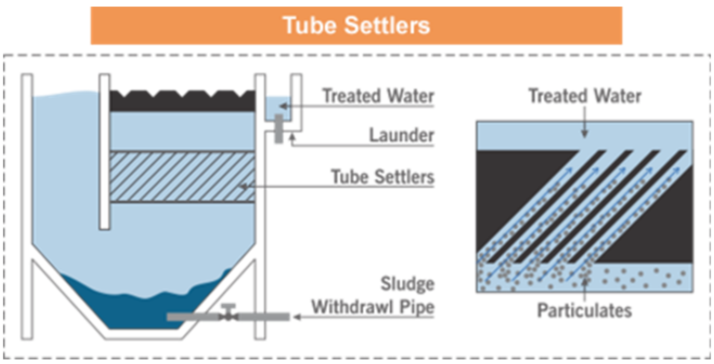


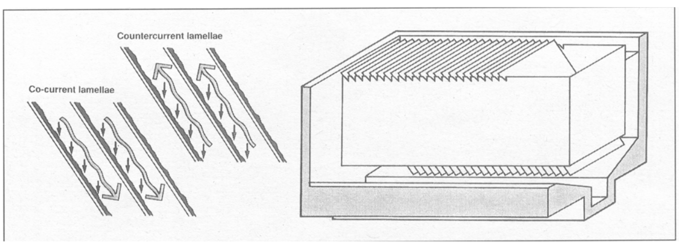
Imhoff cones are used to measure the settleable solids (biofloc), which indicate the quantity of biofloc in the tank.

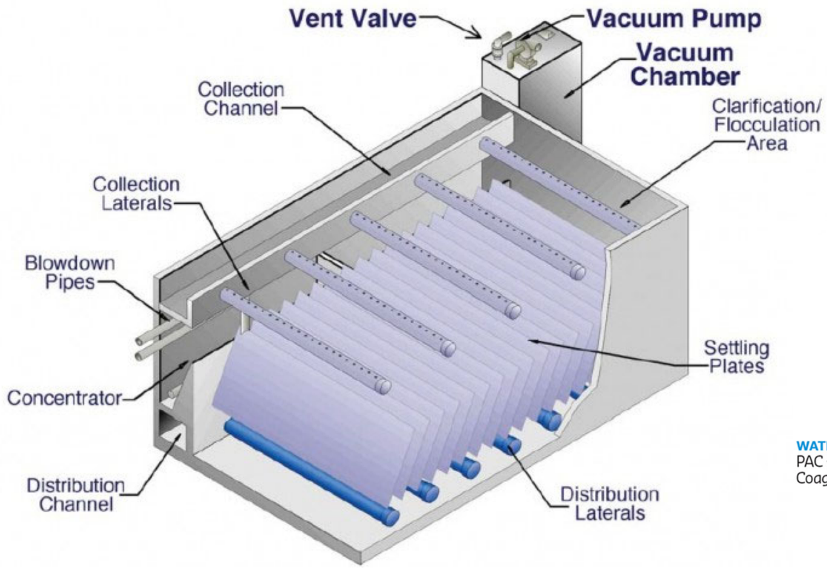
Construction guidelines

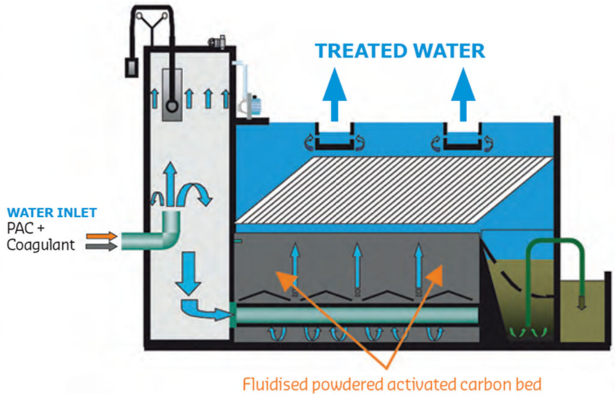
- Flow rate of inlet in sedtanks after AS or coagulation should be < 0.4 m/s and < 0.2 m/s at Q_{maxdim}
- For bigger horizontal tanks L/W ≥ 6
- For quadratic and circular tanks, the slope of sludge bottom > 60°

Lamella plate and tube settlers



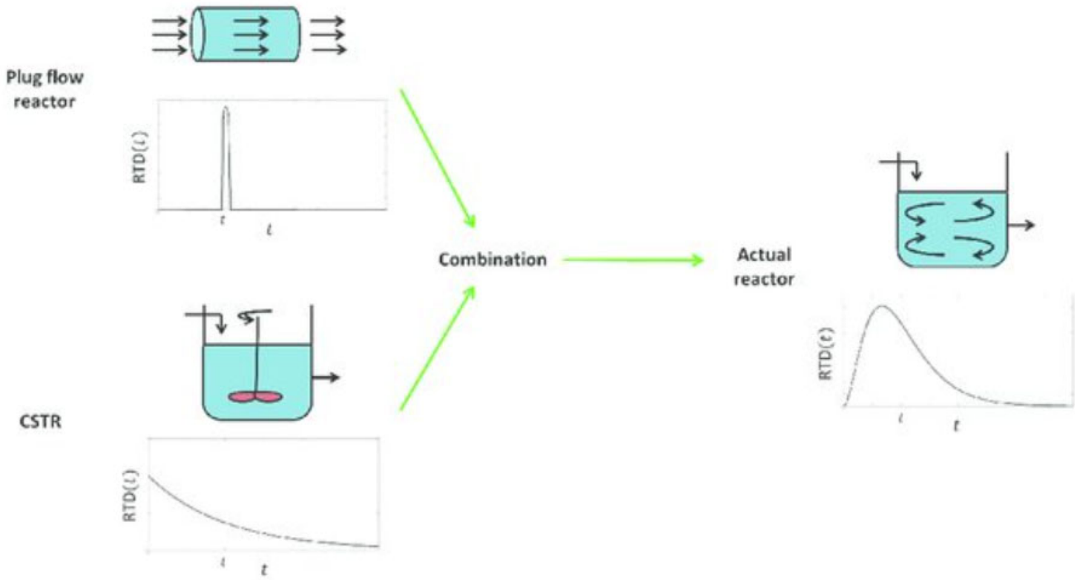




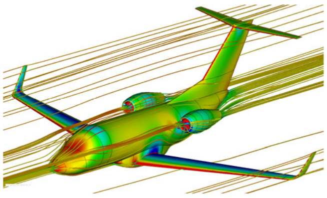


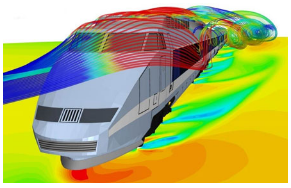
Operating principle of Pulsazur

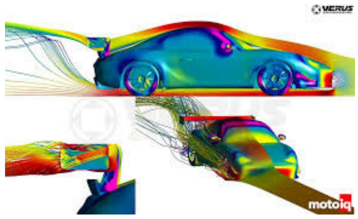
Plug Flow Reactor vs Continuous Stirred-Tank Reactor

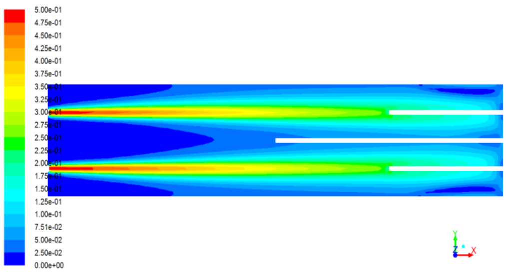


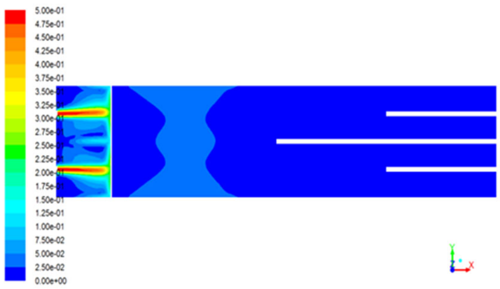
Optimising sedimentation tank hydraulics:
CFD: Computational Fluid Dynamics



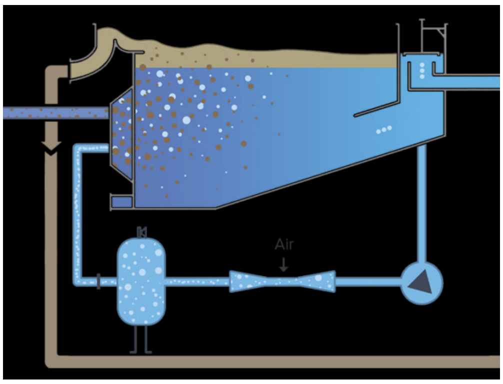


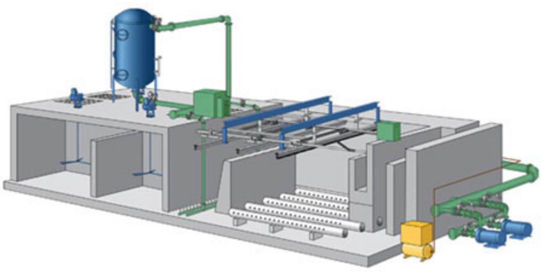


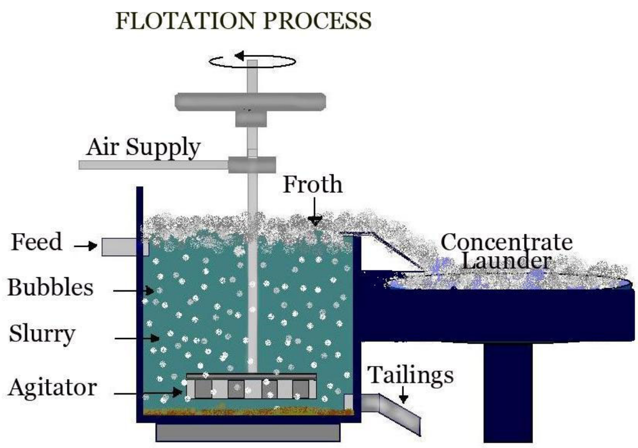




Flotation with DAF (Dissolved Air Flotation)

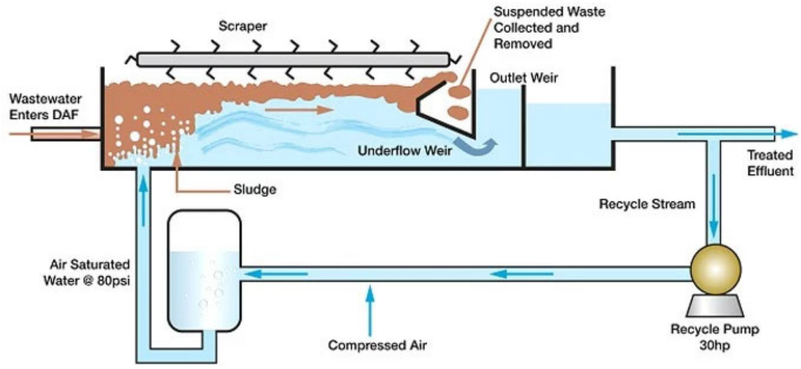


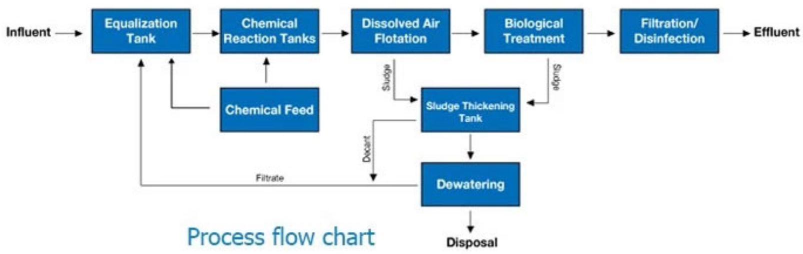




DAF

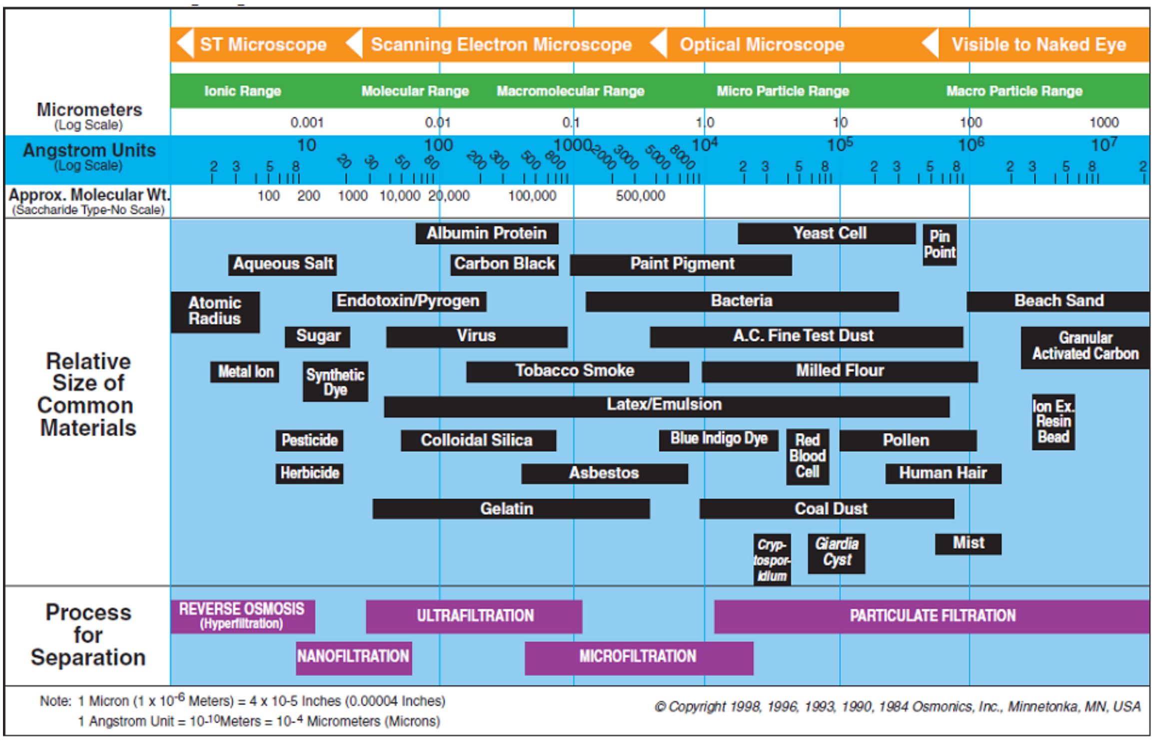
Dissolved Air Flotation System



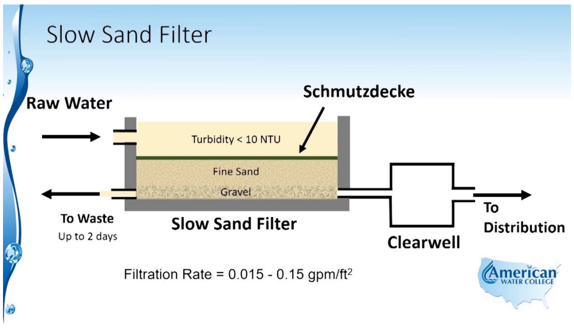


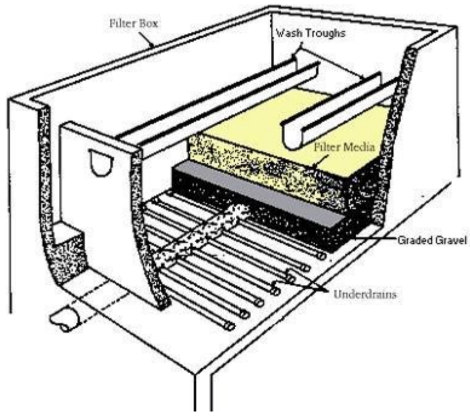
Process flow chart

Filtration



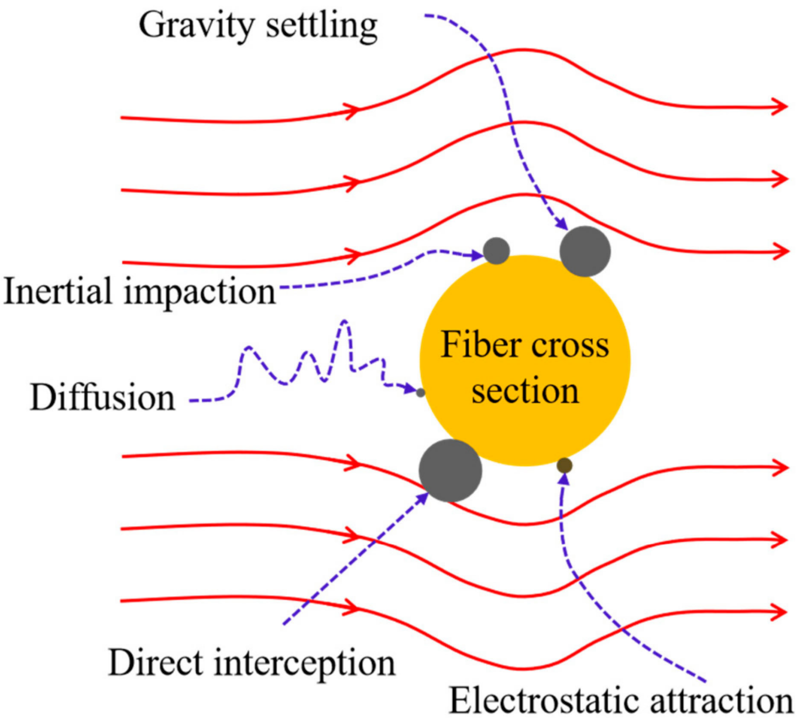
Slow and rapid sand filters



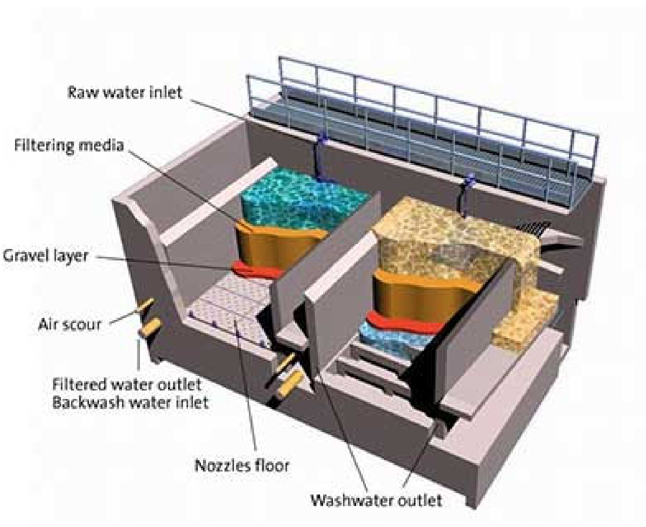


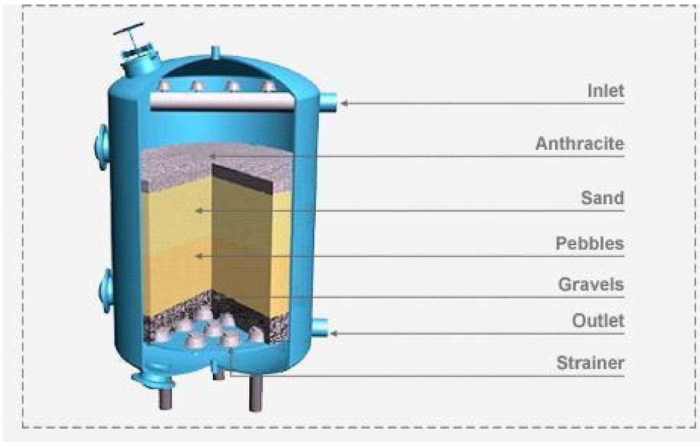
Properties	Rapid sand filter	Slow sand filter
Area	Small area	Large area
Rate of filtration(L/m2/hr)	200 mgad	2 mgad
Sand size (diameter)	0.4-0.7 mm	0.2-0.3 mm
Pretreatment	Coagulation & sedimentation	Sedimentation
Filter cleaning	Backwashing	Scraping
Operation	More skilled	Less skilled
Removal of colour	Good	Better
Removal of bacteria	98-99%	99.9%-99.99%

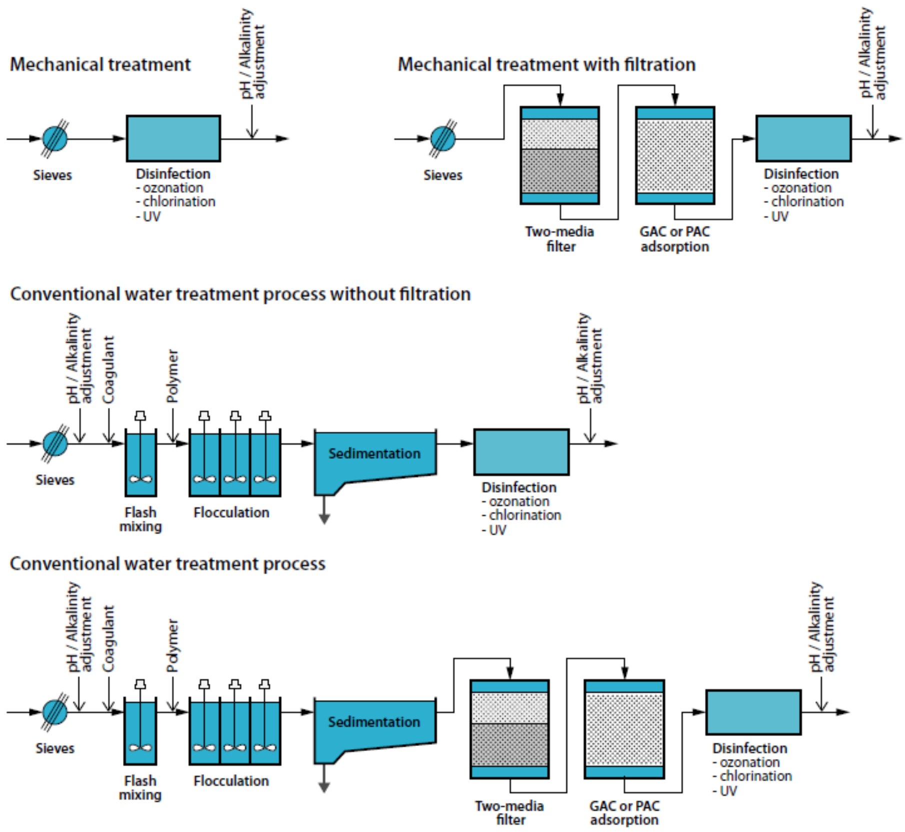
Filtration mechanisms



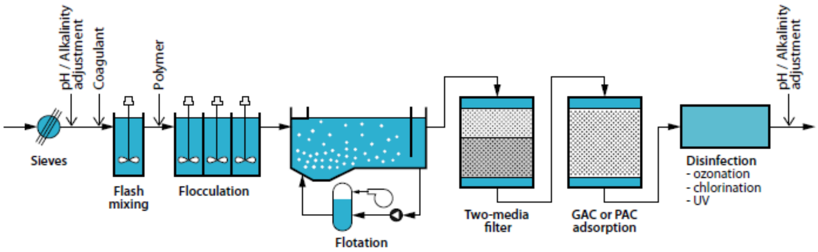
Dual media filters



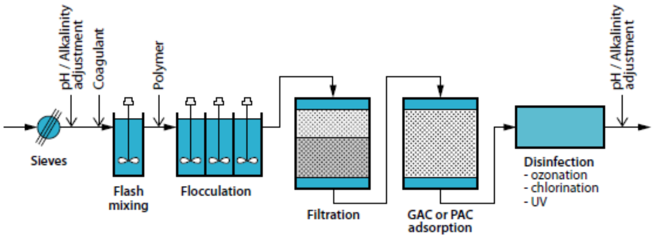




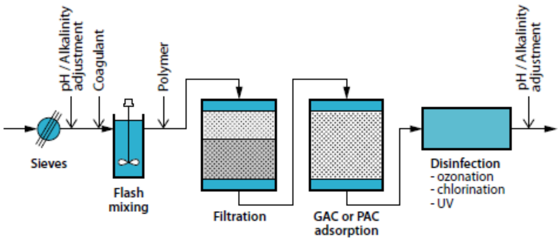
Water treatment process with flotation



Direct filtration process



Contact filtration



Physical unit processes in water and wastewater treatment:
Screening, sedimentation, flotation and (filtration)

THT311

Harsha Ratnaweera
Professor, RealTek

Classification of treatment processes

Drinking water treatment

- Physical and Chemical processes
  - Removal of particles, NOM, metals and toxic matter
  - Removal or inactivation of pathogens
  - Softening
- Biological processes:
  - contaminants in polluted raw water
    - heavy metals,
    - natural organic matter,
    - inorganic non-metallic matter,
    - disinfection by-products,
    - endocrine disrupting
    - microbial contaminants.

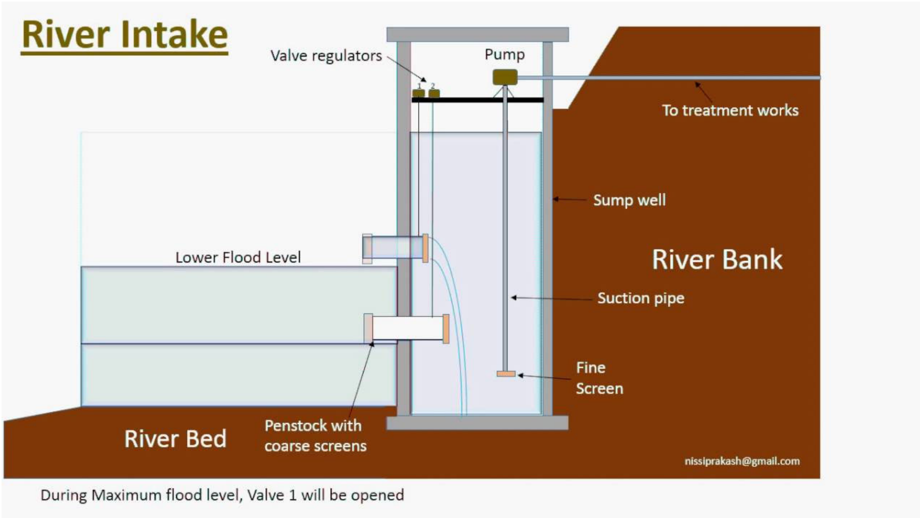
Wastewater treatment

- Sequential order of treatment
  - preliminary, primary, secondary, tertiary, advanced
- Main process mechanisms
  - physical, biological, chemical

Physical processes – water intakes

- Removal of large materials at the water intake
  - Leaves, algae
  - Small fish
  - Other debris


Water hyacinth at Lake Victoria



Screen types – (waste)water treatment

Type	Pore opening
Coarse screens	>10mm
Fine screens	10mm-2mm
Coarse micro- screens	2mm-0.5mm
Micro-screens	0.5-0.1mm
Fine micro-screens	<0.1mm

Preliminary treatment
To protect downstream treatment process

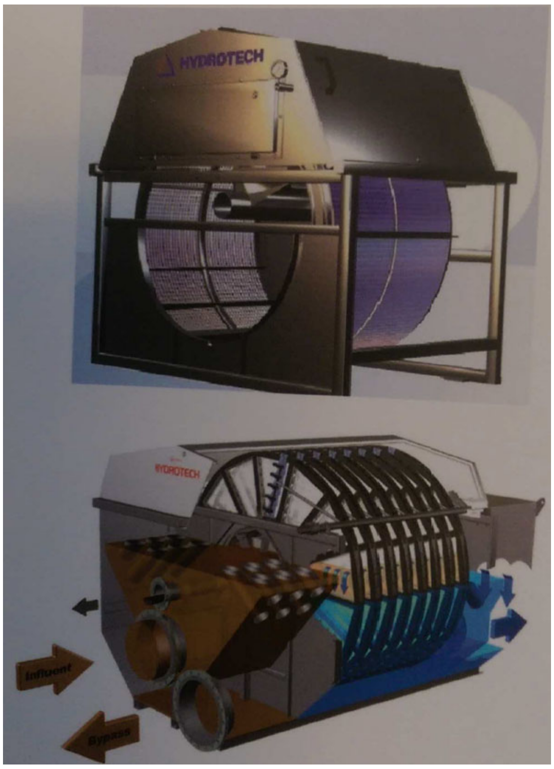
- Screening and comminution (physical)
  - timber, stones, rags, paper

>0.6m/s at Qdim to avoid sedimetation

  - bar screens and rotating screens (0:28)

Screens are often closed… (why?)

Fine micro screens



Fine Sieves / Fine screens:

- *40-60% of organic fraction of TSS are from toilet paper tissues*
- *Majority can be removed with sieves >500 microns.*
- *Combination of sieves with chemicals*

Salsnes/Trojan: 50% TSS & 20% BOD removal

Grit and sand removal /Fett- og sandfang

- Grit removal (physical)
  - sand and grit
  - Aerated sand traps (luftet sandfang)

Grit and sand removal

Grit and sand removal /Fett- og sandfang

- Grit removal (physical)
  - sand and grit

Sand from sand-traps

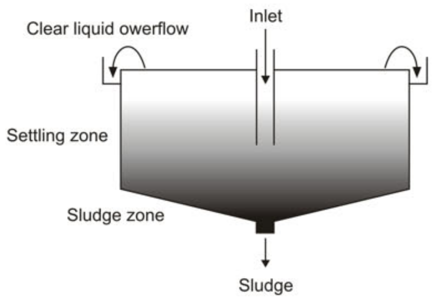
- Washed sand can be deposited (considered not hazardous)

Separation processes

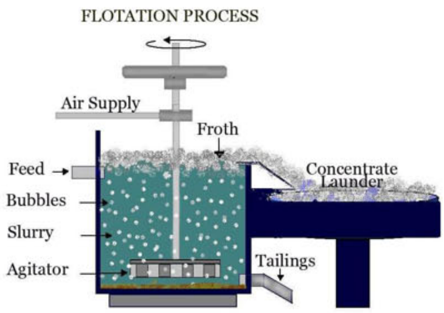
To produce
- clarified water
- effluents to reduce the pollution load to secondary processes or to/and recipients

A natural part of after many other unit processes

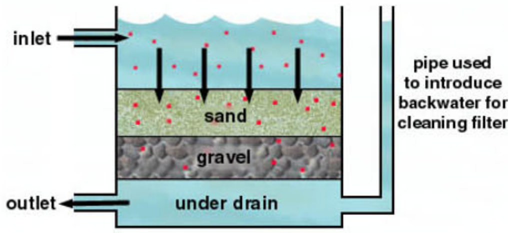
Sedimentation



Flotation

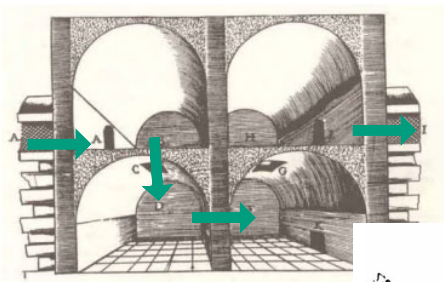


Filtration

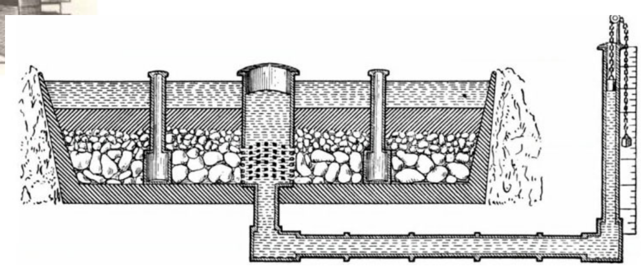


History of sedimentation

Egypt, 1450 BC
Syphoning of water or wine

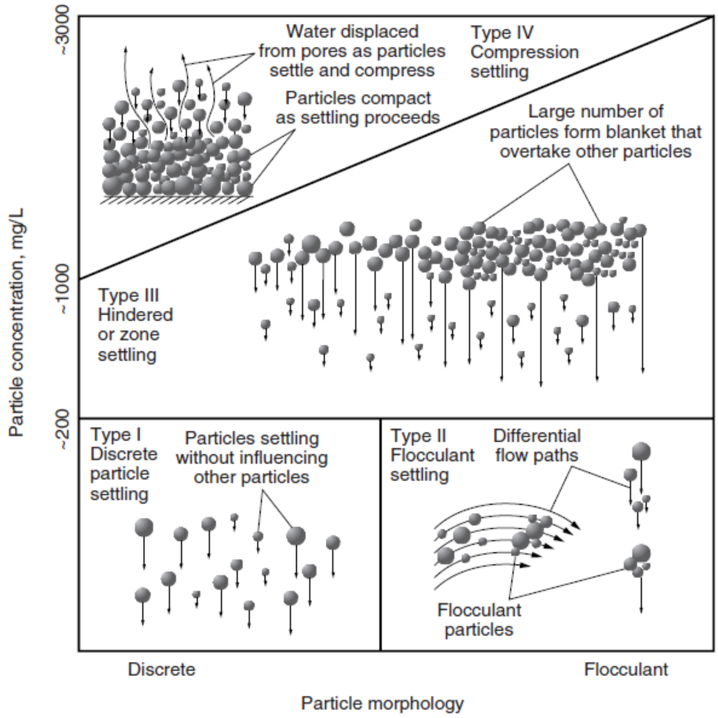


Rome, 1680, Water to aqueducts

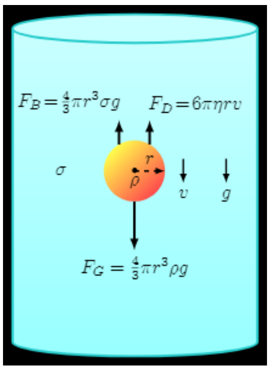


UK, 1790, Lancashire filter

Classification of particle settling: 4 types



Stokes law and terminal velocity (V_T)

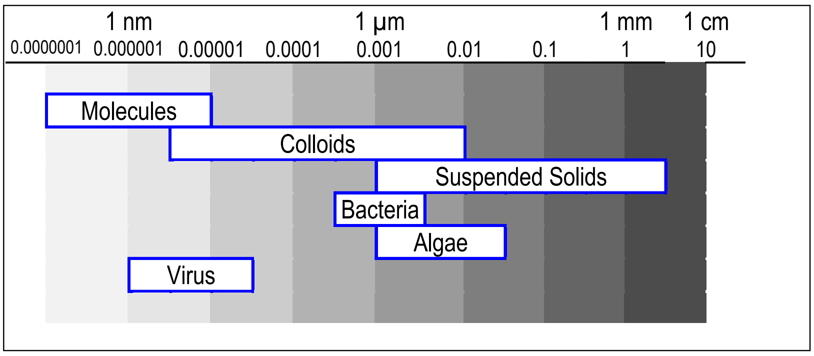


- Drag force (Stokes law), $F_D = 6\pi\eta r v$ (η= viscosity, r = radius, v= velocity)
- Buoyance force (Newtons law) $F_B = \frac{4}{3}\pi r^3 \sigma g$ (σ= fluid density, g = gravity)
- Gravity force $F_G = \frac{4}{3}\pi r^3 \rho g$ (ρ =particle density)
- $F_G = F_D + F_B$
- $\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v + \frac{4}{3}\pi r^3 \sigma g$
- $\frac{4}{3} r^2 \rho g = 6\eta v + \frac{4}{3} r^2 \sigma g$
- $6\eta v = \frac{4}{3} r^2 \rho g - \frac{4}{3} r^2 \sigma g = \frac{4}{3} r^2 (\rho - \sigma) g$
- $V_T = \frac{2r^2(\rho - \sigma)g}{9\eta}$

Approximate sedimentation times of particles in water

Diameter, µm	type	sed.tid pr 1m
1000	sand	10 sec
100	Fine sand	2 minutes
10	Clay	2 hours
1	Bacteria	8 days
0,1	colloid	2 years
0,01	colloid	20 years
0,001	colloid	200 years

Physical methods



Diameter, µm	type	sed.tid pr 1m
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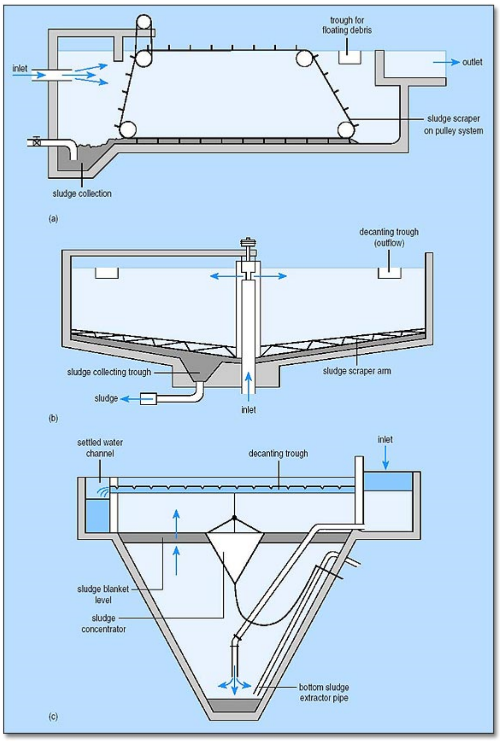
10	Clay	2 hours
1	Bacteria	8 days
0,1	colloid	2 years
0,01	colloid	20 years
0,001	colloid	200 years

Typical removal rates	Mechanical
SS	60%
COD	30%
Tot-P	15%
Tot-N	15%

Primary treatment

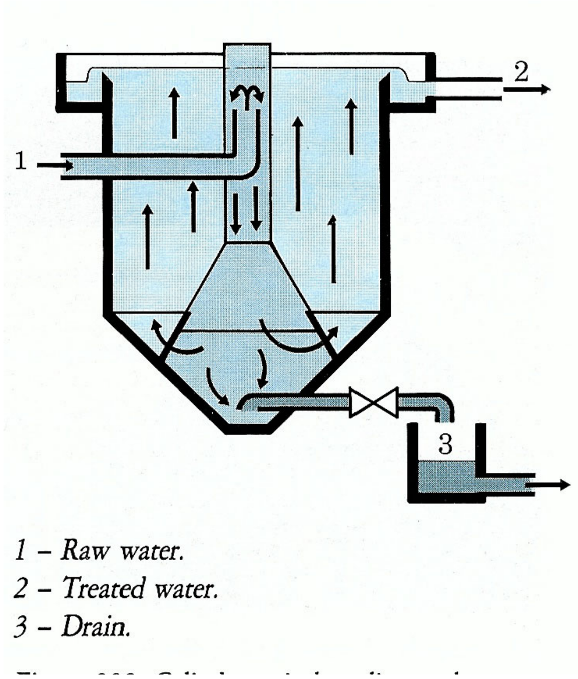

- Primary sedimentation: suspended matter settles under gravity.
- Rectangular (horizontal flow), circular (radial flow), upward flow

Sedimentation tanks



(a) rectangular horizontal flow tank;
(b) circular, radial-flow tank;
(c) hopper-bottomed, upward flow tank

Sedimentation



Surface load, m/s

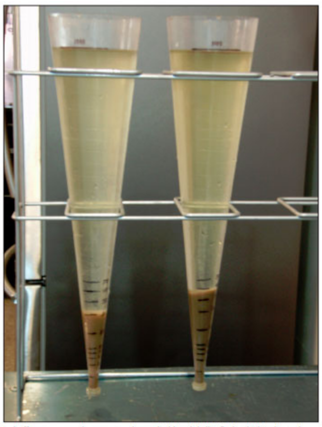
$$\text{Flow/area} = Q/A = \frac{m^3}{s}/m^2$$

Dimensioning of sedimentation tanks

- Key parameter: surface load (Q/A, m/s), 1.0-2.5
- Pre-sedimentation: Q/A: 2.0-2.5
- Secondary sedimentation in activated sludge (AS), 0.8-1.3
  - in addition to the surface load the sludge concentration, SVI, basin geometry and water depth are important
- Water depth >2.5 m (AS: >3.5m)

Dimensioning guidelines – secondary sedimentation after AS

- Sludge volume SV (ml/l) = SVI (ml/g SS) · X (g SS/l)
  - SVI: sludge volume index; X: sludge concentration
  - SVI should be between 100-150 for WW without much industrial input

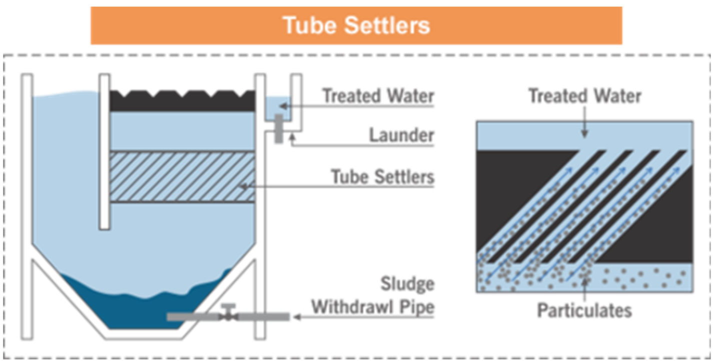


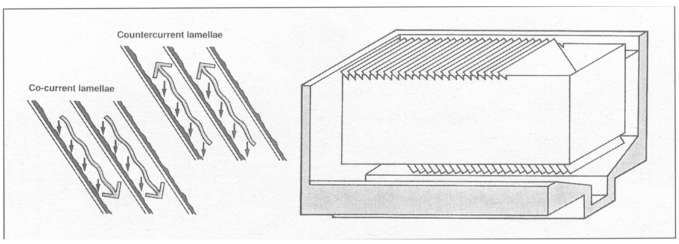
Imhoff cones are used to measure the settleable solids (biofloc), which indicate the quantity of biofloc in the tank.

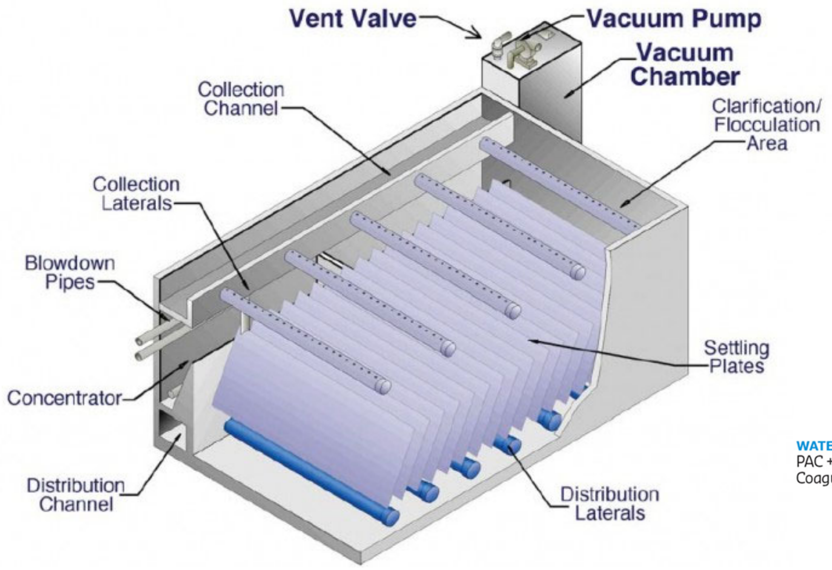
Construction guidelines

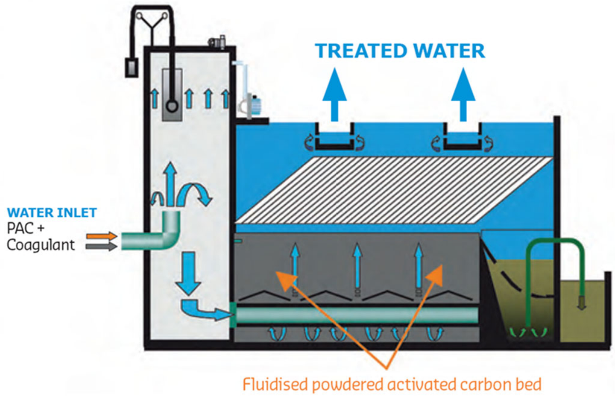
- Flow rate of inlet in sedtanks after AS or coagulation should be < 0.4 m/s and < 0.2 m/s at Q_{maxdim}
- For bigger horizontal tanks L/W ≥ 6
- For quadratic and circular tanks, the slope of sludge bottom > 60°

Lamella plate and tube settlers



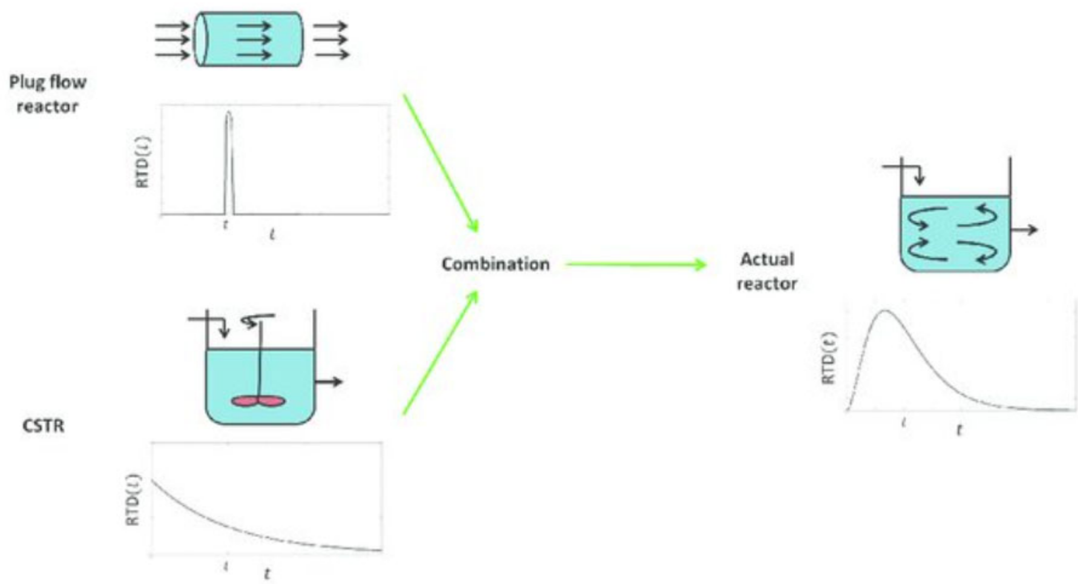






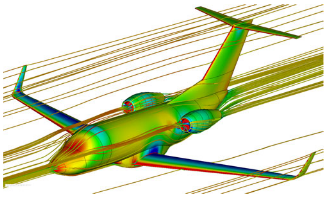
Operating principle of Pulsazur

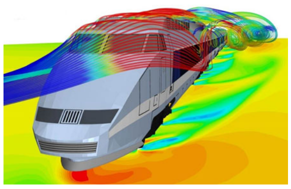
Plug Flow Reactor vs Continuous Stirred-Tank Reactor

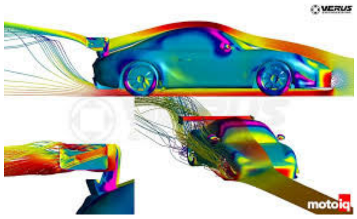


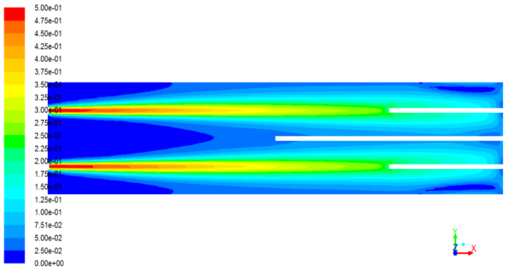
Optimising sedimentation tank hydraulics:

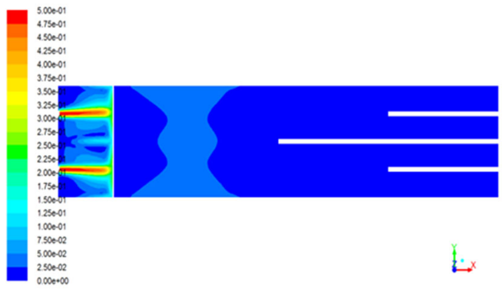
CFD: Computational Fluid Dynamics



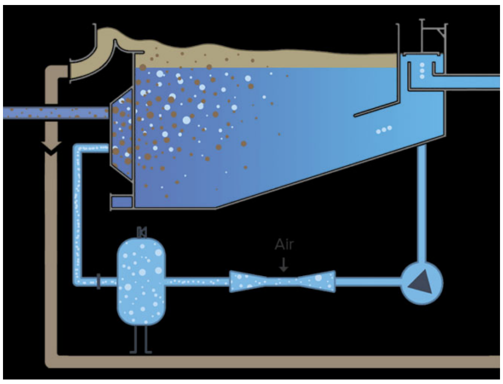


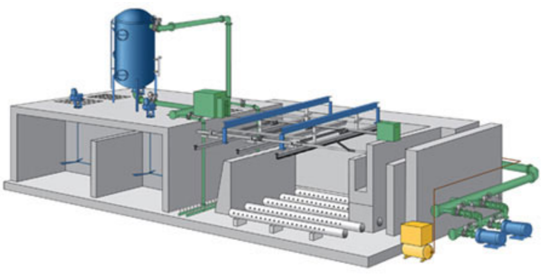


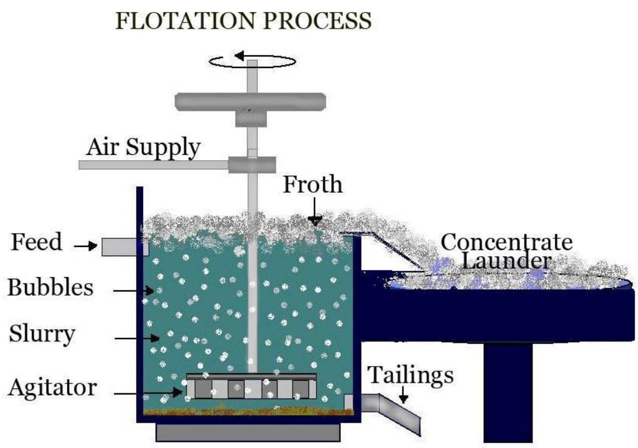




Flotation with DAF (Dissolved Air Flotation)

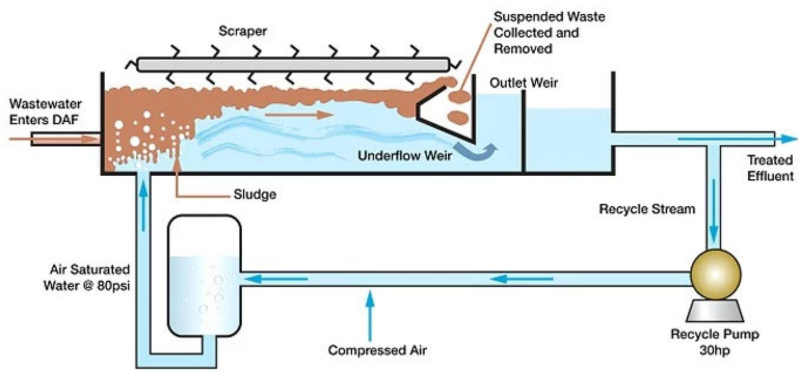


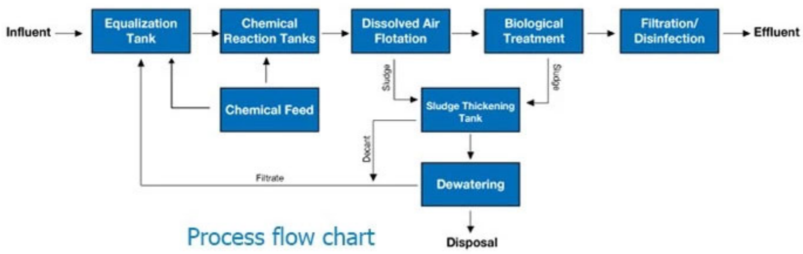




DAF

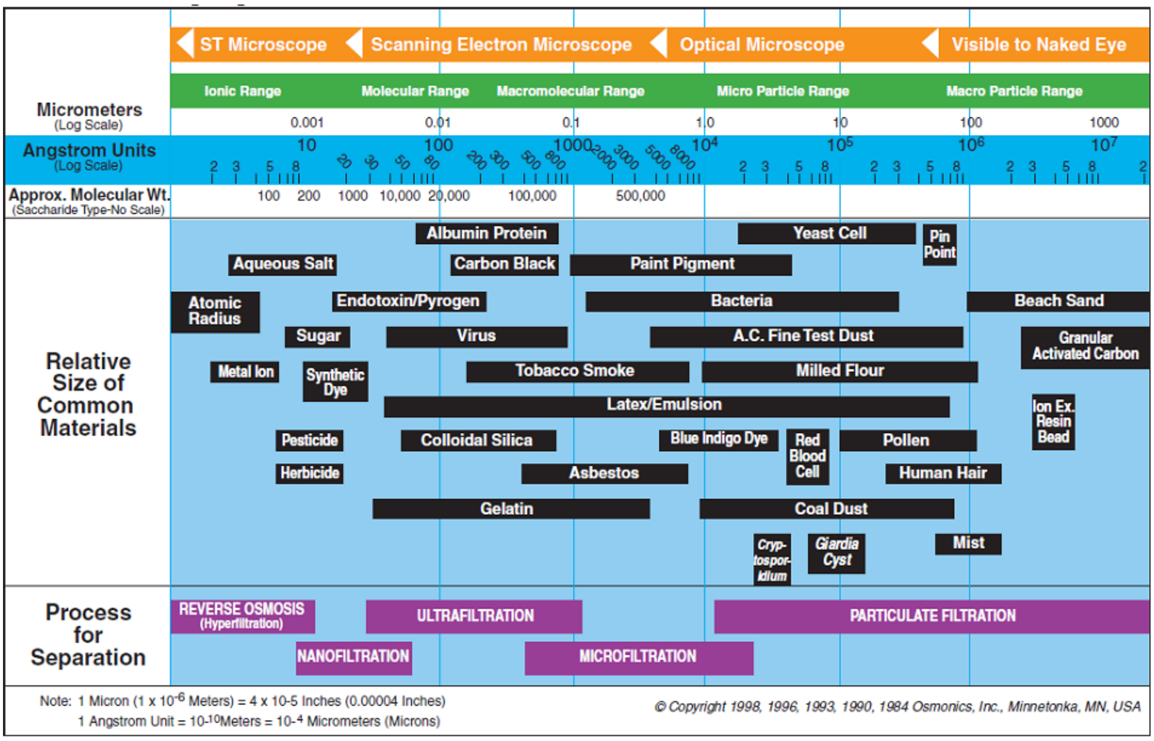
Dissolved Air Flotation System



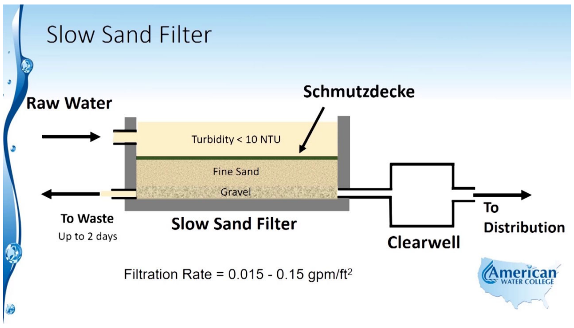


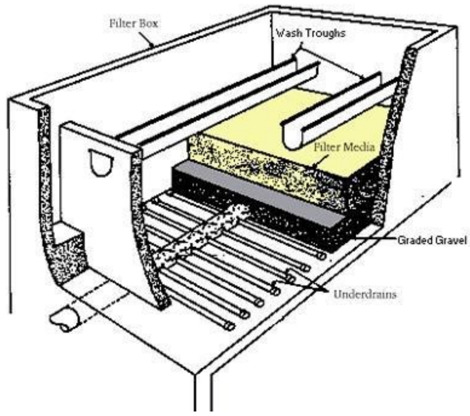
Process flow chart

Filtration



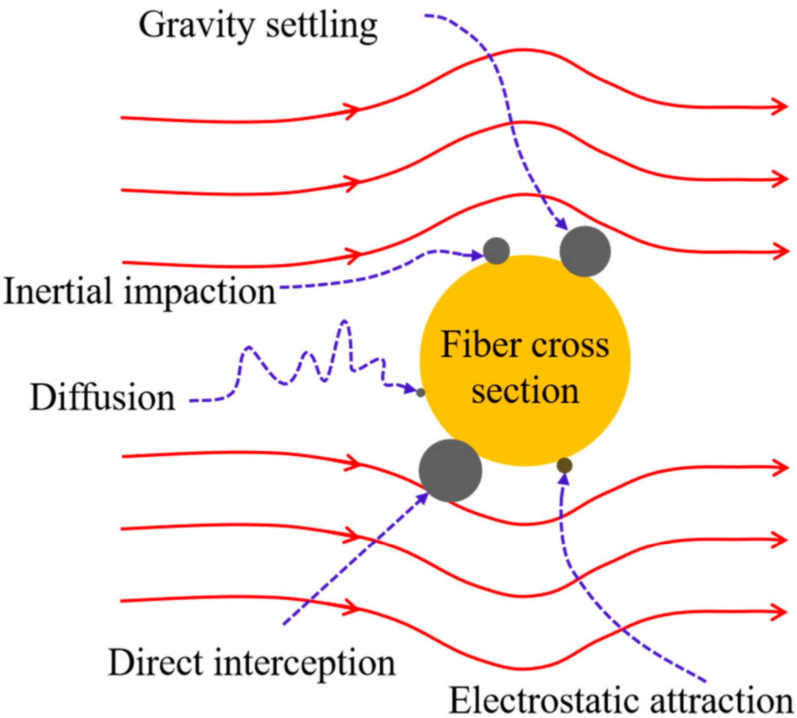
Slow and rapid sand filters



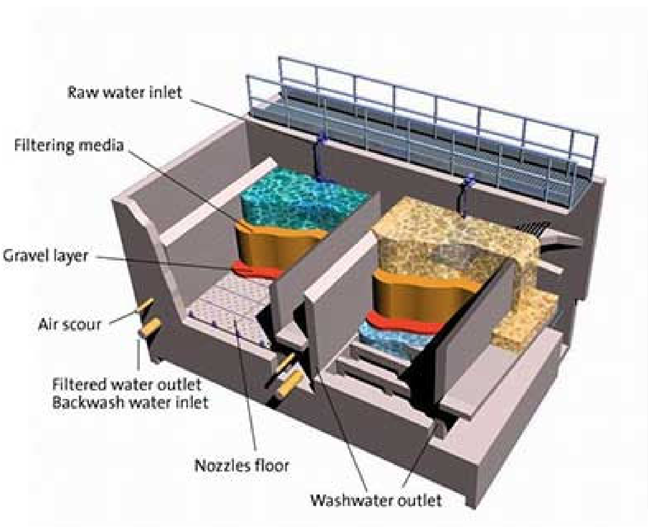


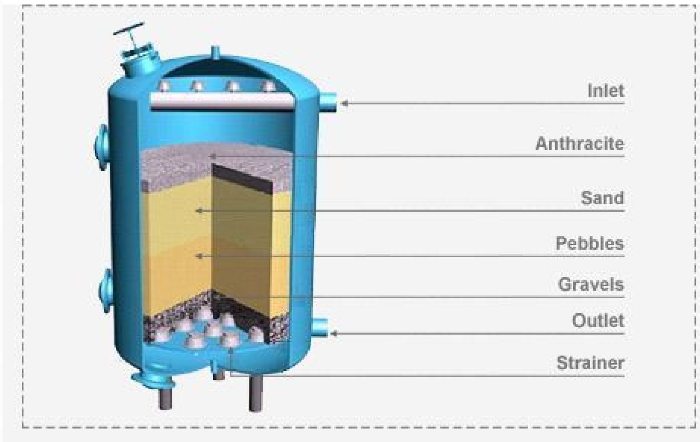
Properties	Rapid sand filter	Slow sand filter
Area	Small area	Large area
Rate of filtration(L/m2/hr)	200 mgad	2 mgad
Sand size (diameter)	0.4-0.7 mm	0.2-0.3 mm
Pretreatment	Coagulation & sedimentation	Sedimentation
Filter cleaning	Backwashing	Scraping
Operation	More skilled	Less skilled
Removal of colour	Good	Better
Removal of bacteria	98-99%	99.9%-99.99%

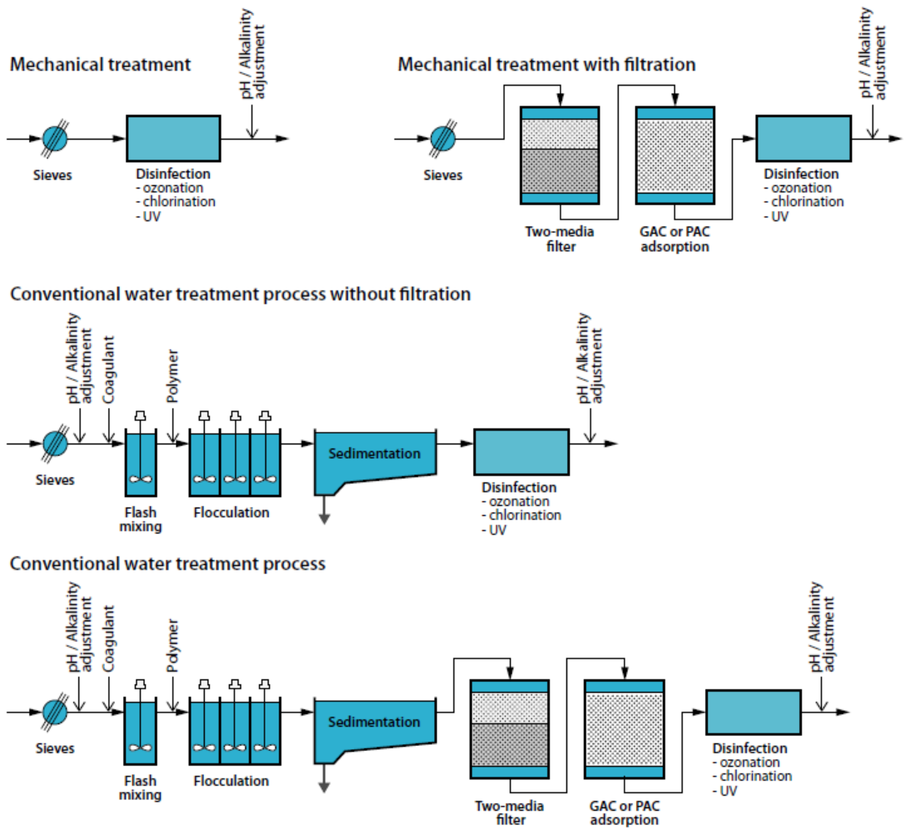
Filtration mechanisms



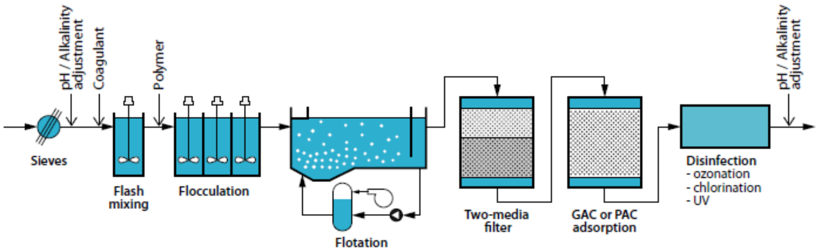
Dual media filters



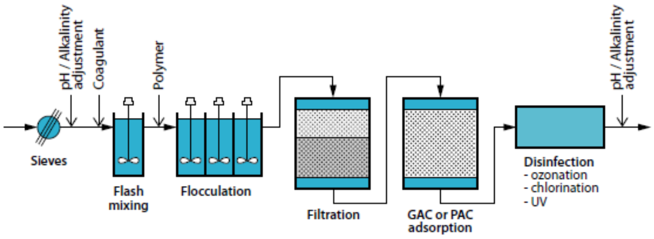




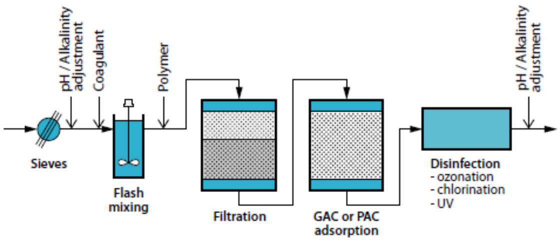
Water treatment process with flotation



Direct filtration process

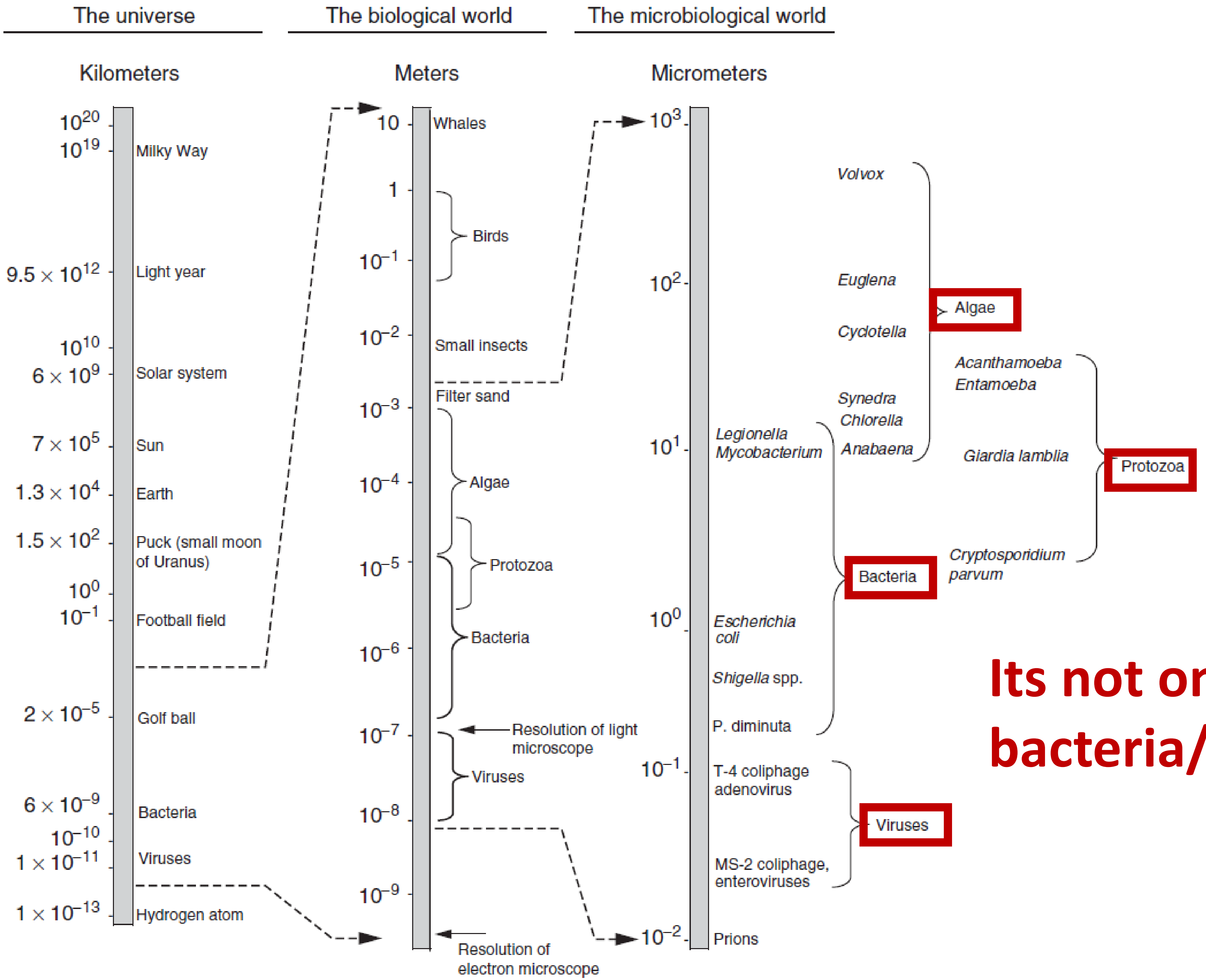


Contact filtration



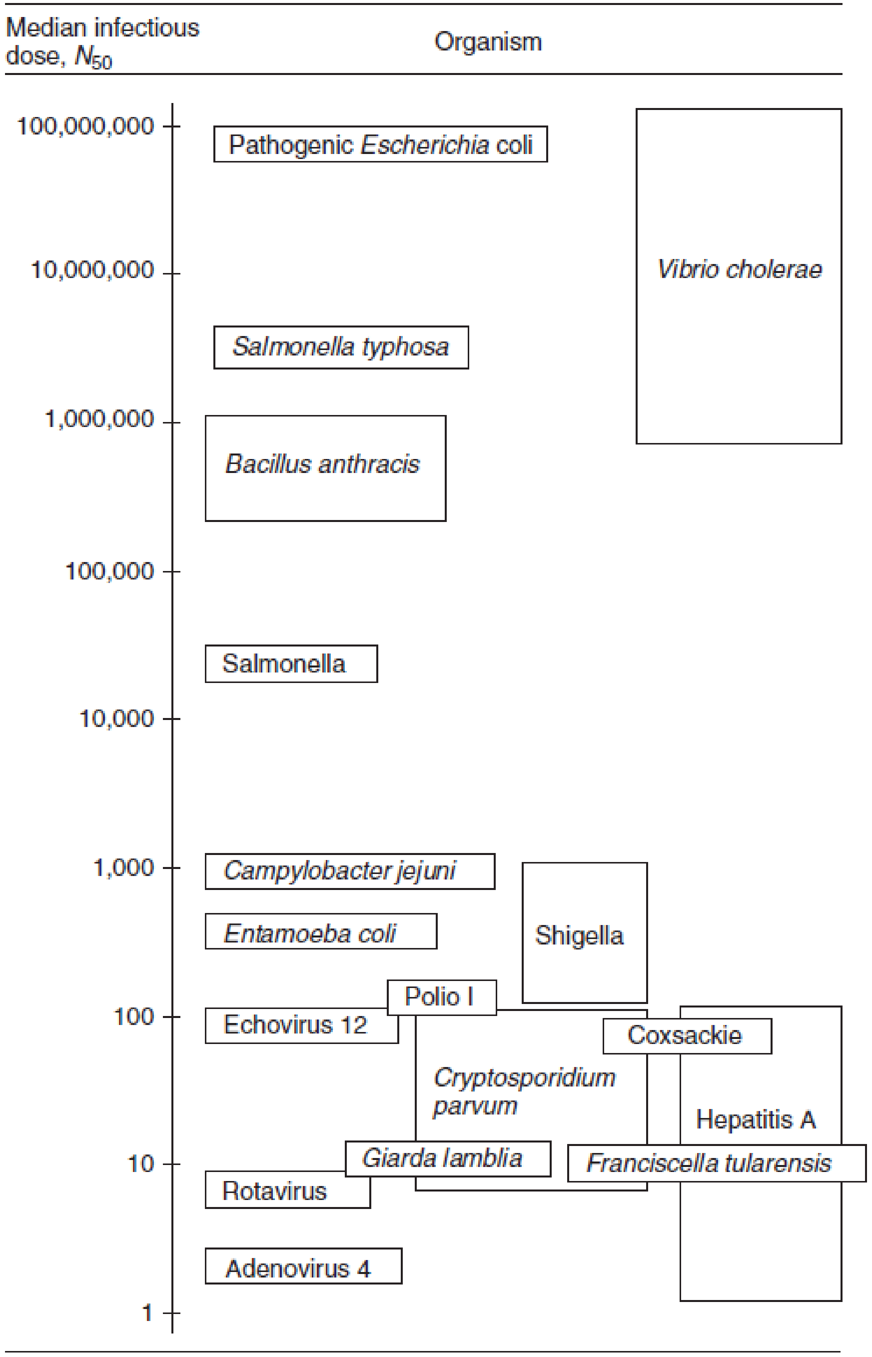
Microbiological parameters

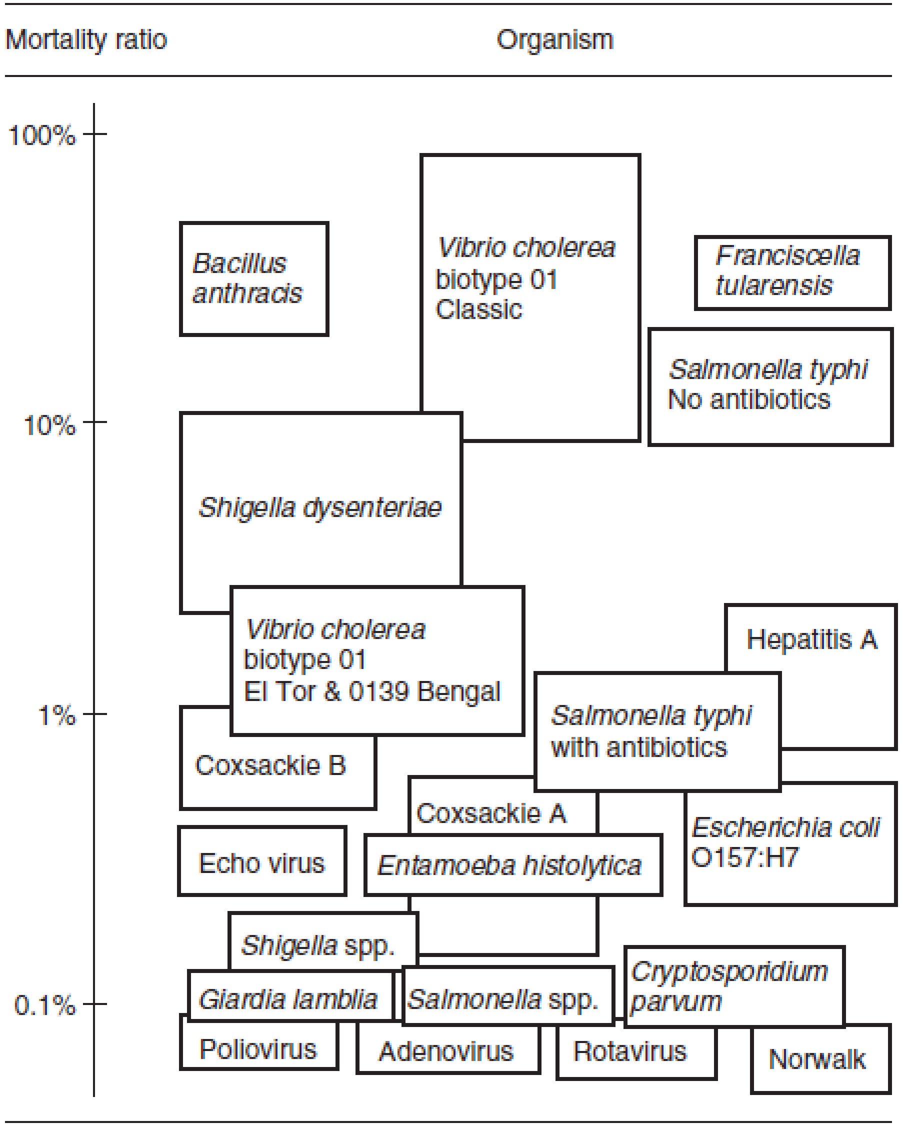
Water microbiology

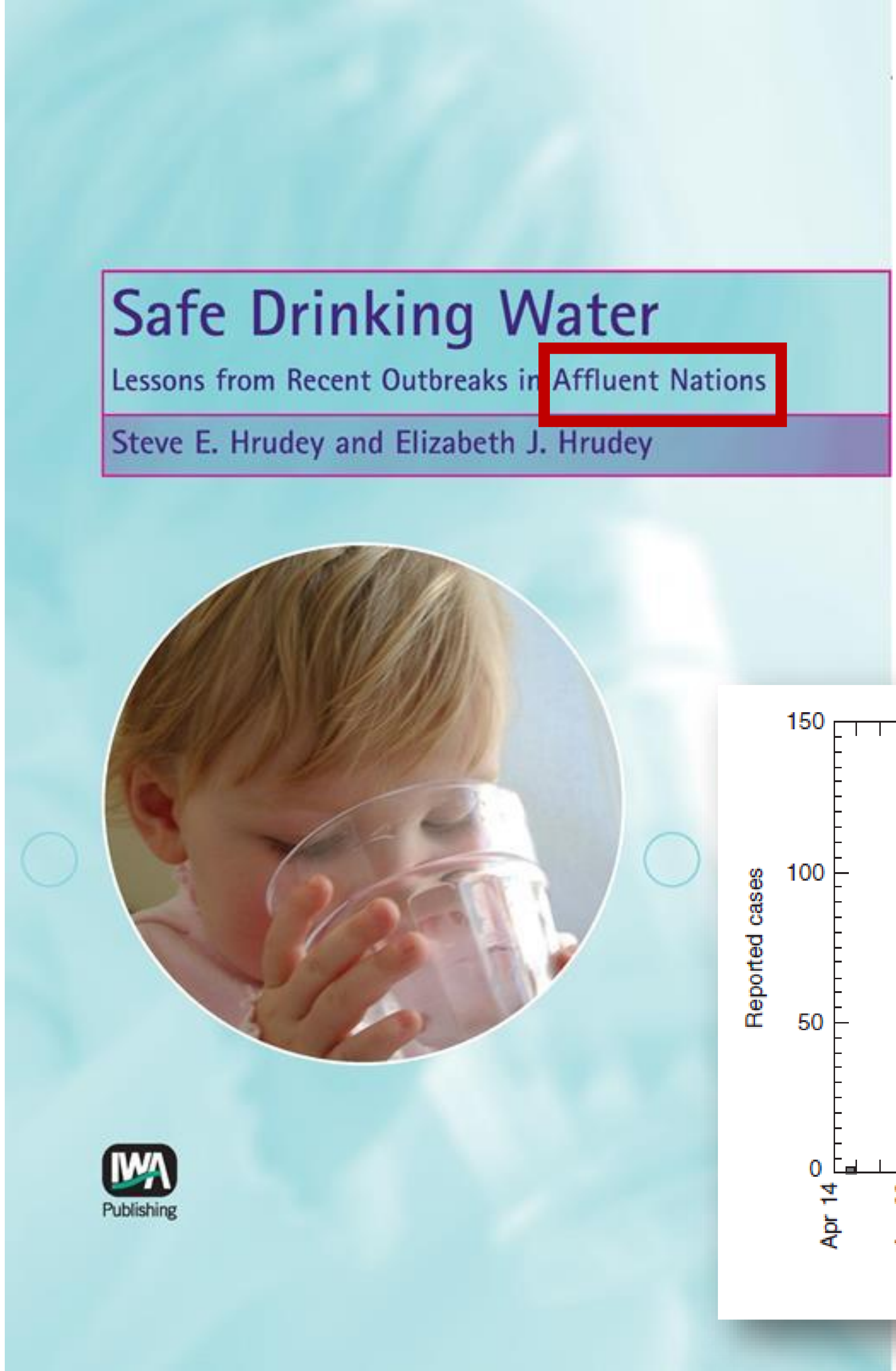


Its not only bacteria/viruses…

Pathogens in drinking water







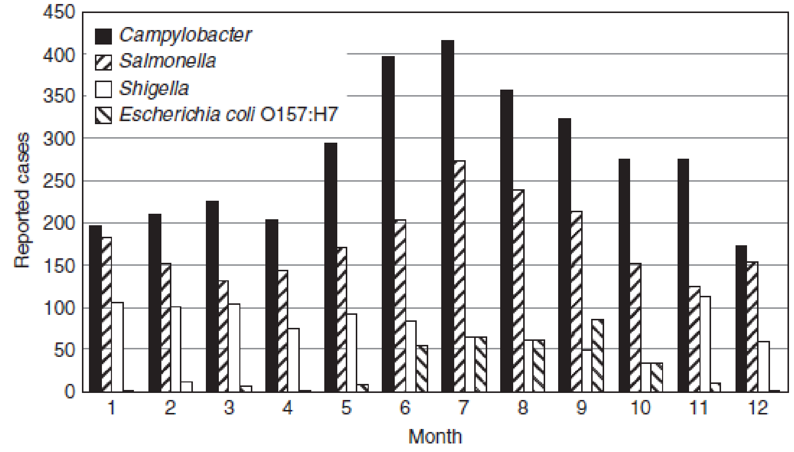


Figure 3-11
Cases of foodborne gastroenteritis in the United States in 1996. (Adapted from Altekruse et al., 1999.)

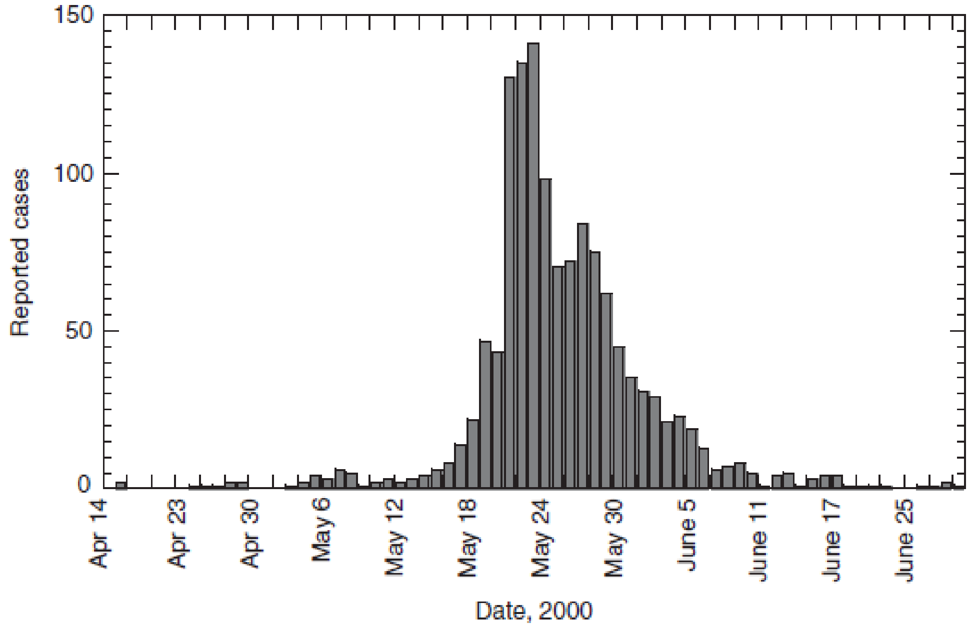
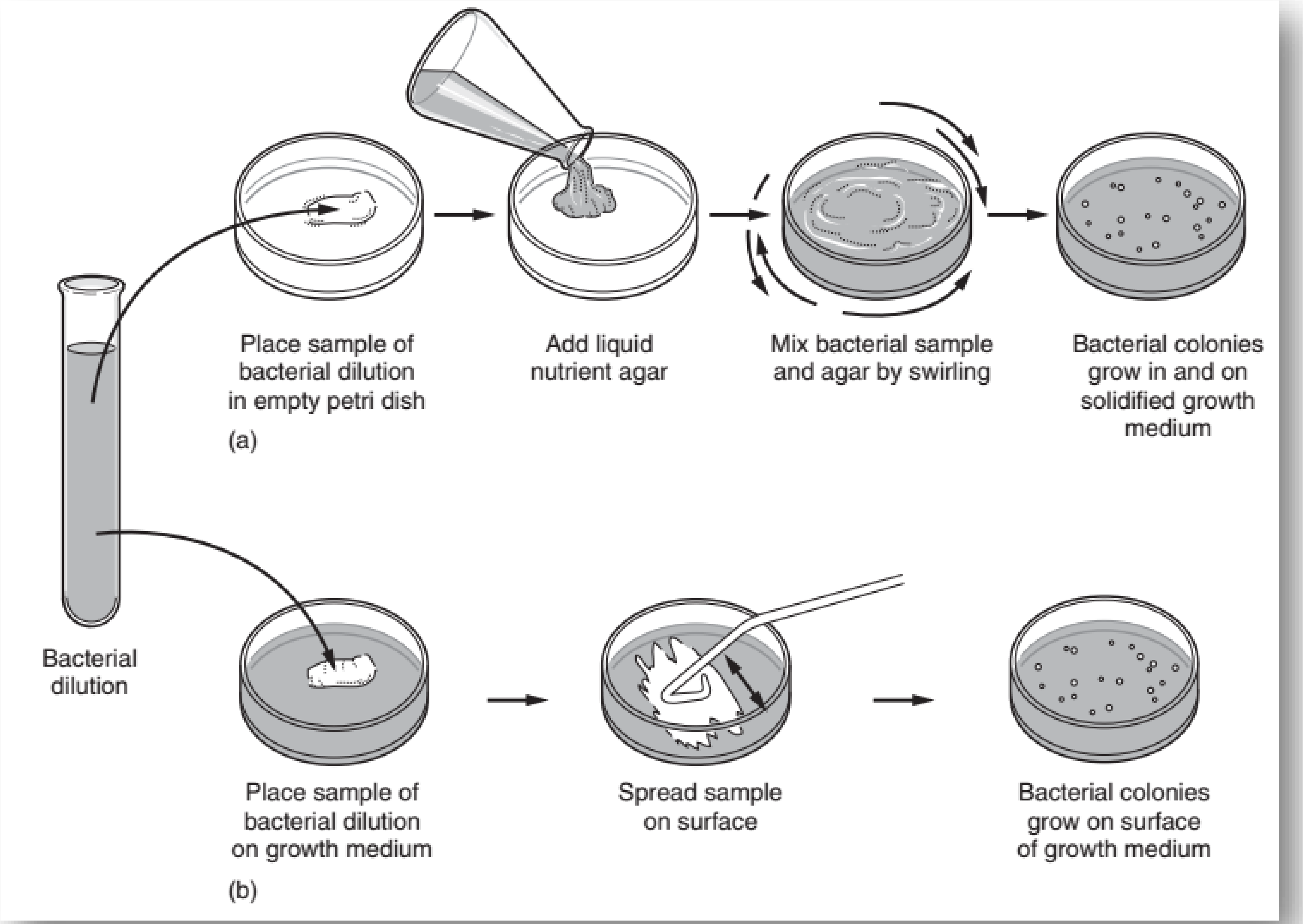


Figure 3-10
Number of illness cases reported during Walkerton, Ontario, disease outbreak of 2000. (Data from Bruce–Grey–Owen Sound Health Unit, 2000.)

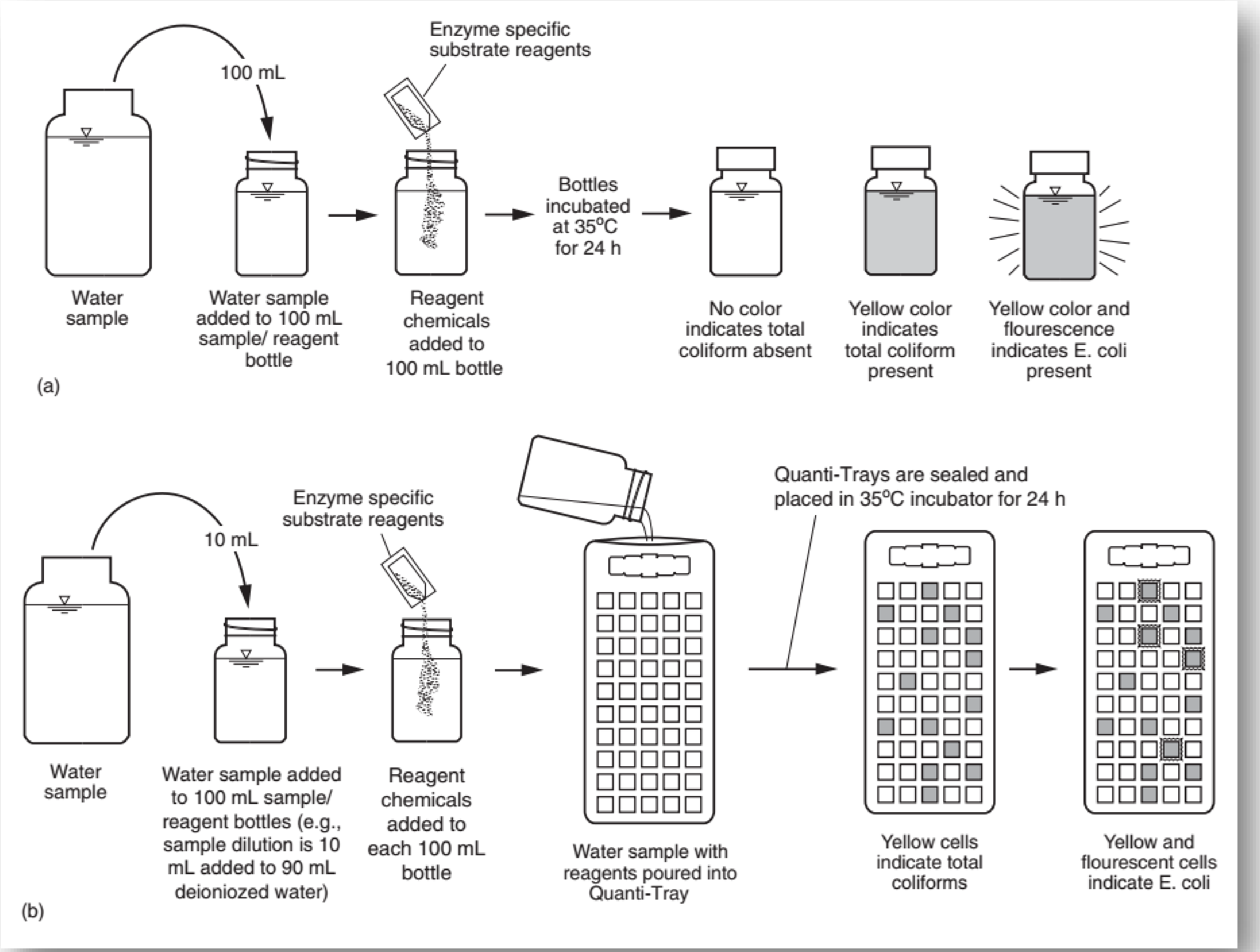
Microbiological methods

- Plate culture



Microbiological methods

- Enzyme-specific tests



Discussion session

- What surprised you in this course, and why?
- What’s the most important thing you learned? Why do you think so?
- What do you want to learn more about, and why?

Chemical methods and application

THT311

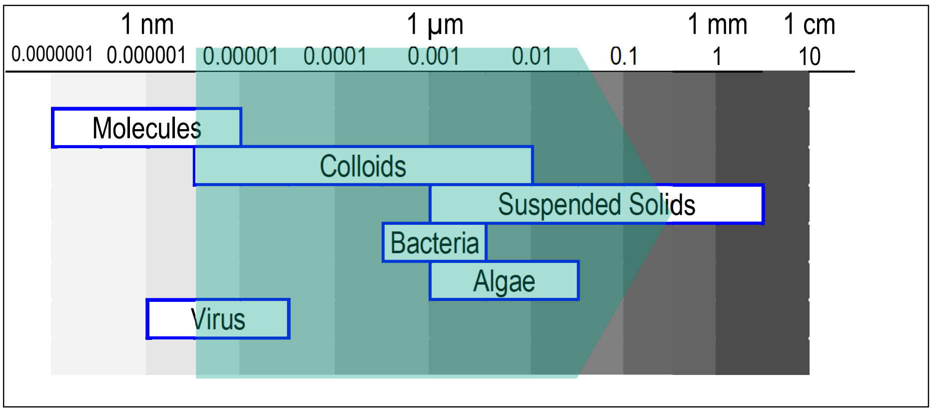
Harsha Ratnaweera

Coagulation

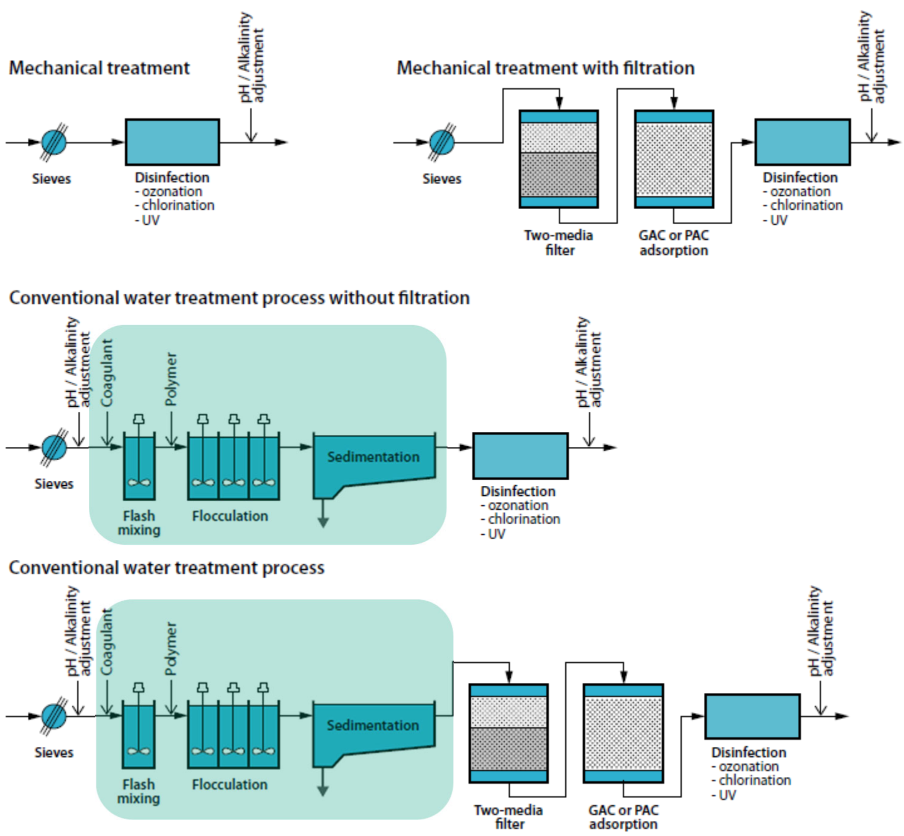
- Main objectives:
  - Remove particles
  - Remove NOM (in DWT)
  - Remove phosphates (in WWT)

Mechanical vs chemical treatment

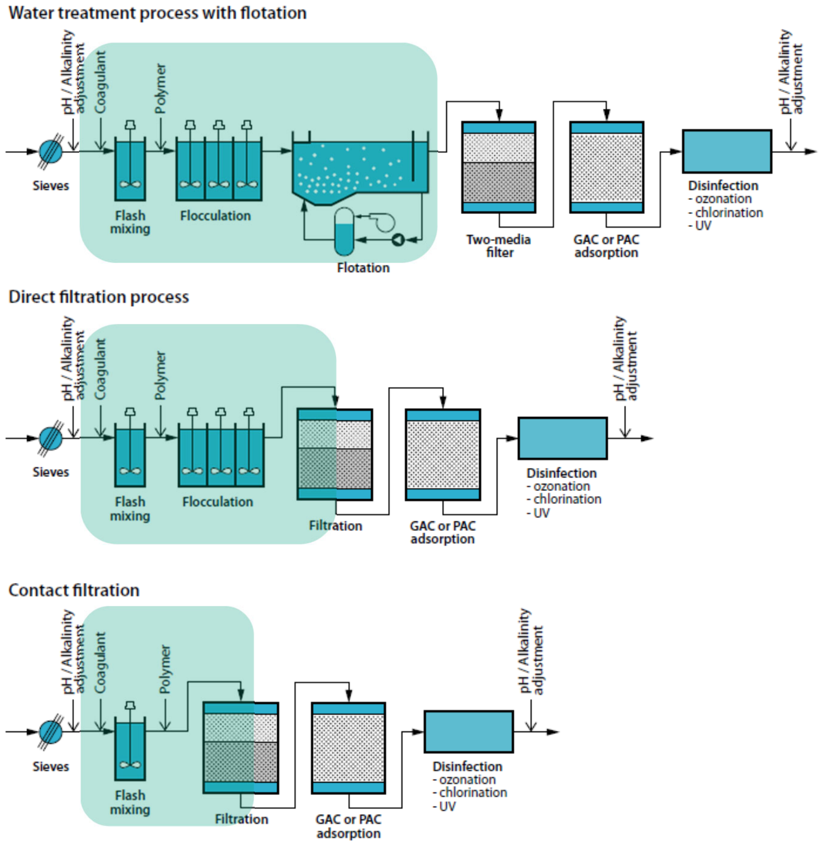
Typical removal rates	Mechanical	Chemical
SS	60%	80-90%
COD	30%	50-70%
Tot-P	15%	70-90%
Tot-N	15%	25-30%



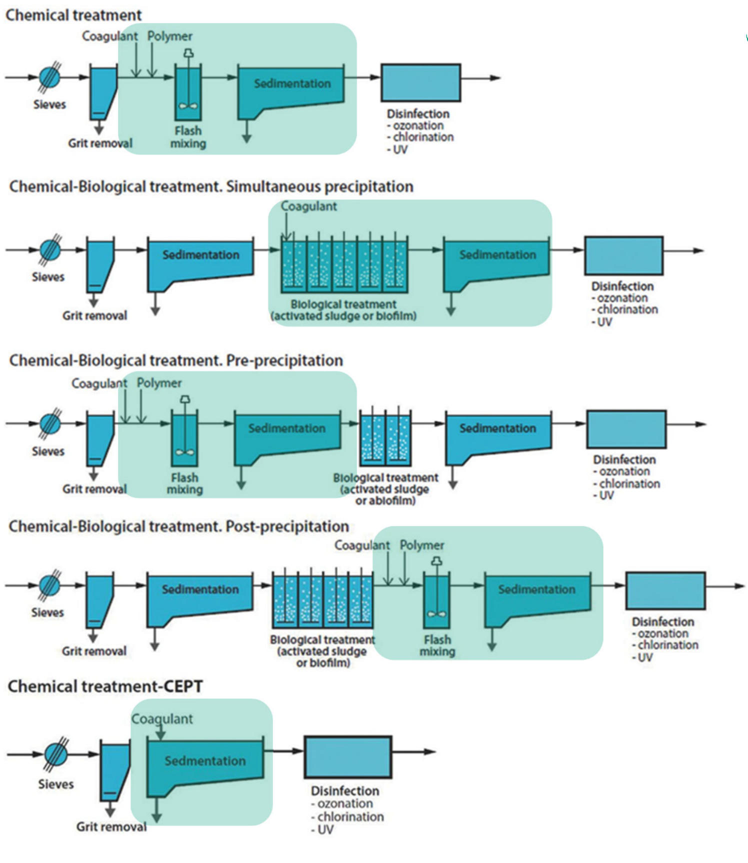
DWTP



DWTP


Water treatment process with flotation
pH / Alkalinity adjustment
Coagulant
Polymer
Sieves
Flash mixing
Flocculation
Flotation
Two-media filter
GAC or PAC adsorption
Disinfection
- ozonation
- chlorination
- UV
pH / Alkalinity adjustment
Direct filtration process
pH / Alkalinity adjustment
Coagulant
Polymer
Sieves
Flash mixing
Flocculation
Filtration
GAC or PAC adsorption
Disinfection
- ozonation
- chlorination
- UV
pH / Alkalinity adjustment
Contact filtration
pH / Alkalinity adjustment
Coagulant
Polymer
Sieves
Flash mixing
Filtration
GAC or PAC adsorption
Disinfection
- ozonation
- chlorination
- UV
pH / Alkalinity adjustment

WWTP


Chemical treatment
Coagulant
Polymer
Sieves
Grit removal
Flash mixing
Sedimentation
Disinfection
- ozonation
- chlorination
- UV
Chemical-Biological treatment. Simultaneous precipitation
Coagulant
Sieves
Grit removal
Sedimentation
Biological treatment (activated sludge or biofilm)
Sedimentation
Disinfection
- ozonation
- chlorination
- UV
Chemical-Biological treatment. Pre-precipitation
Coagulant
Polymer
Sieves
Grit removal
Flash mixing
Sedimentation
Biological treatment (activated sludge or abiofilm)
Sedimentation
Disinfection
- ozonation
- chlorination
- UV
Chemical-Biological treatment. Post-precipitation
Coagulant
Polymer
Sieves
Grit removal
Sedimentation
Biological treatment (activated sludge or biofilm)
Flash mixing
Sedimentation
Disinfection
- ozonation
- chlorination
- UV
Chemical treatment-CEPT
Coagulant
Sieves
Grit removal
Sedimentation
Disinfection
- ozonation
- chlorination
- UV

Particle removal mechanisms
(The 4 coagulation mechanisms)

- Compression of Double Layer
- Adsorption-charge neutralization
- Bridging
- Sweep floc

Colloidal stability
Potential energy

Derjaguin–Landau–Verwey–Overbeek

$VT = VA+VR+VS$

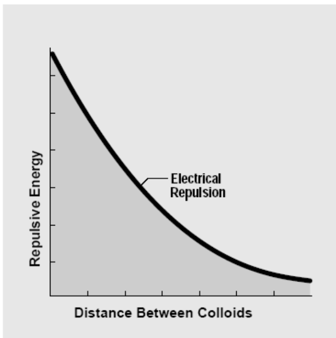
Attractive force: $VA = -A/(12\pi D^2)$

Repulsive force: $VR = 2\pi\varepsilon a\zeta^2 \exp^{(-\kappa D)}$

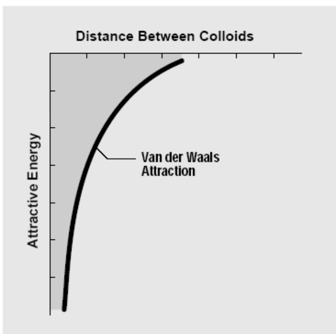
Solvent potential VS = negligible

A is the Hamaker constant and *D* is the distance between the particles

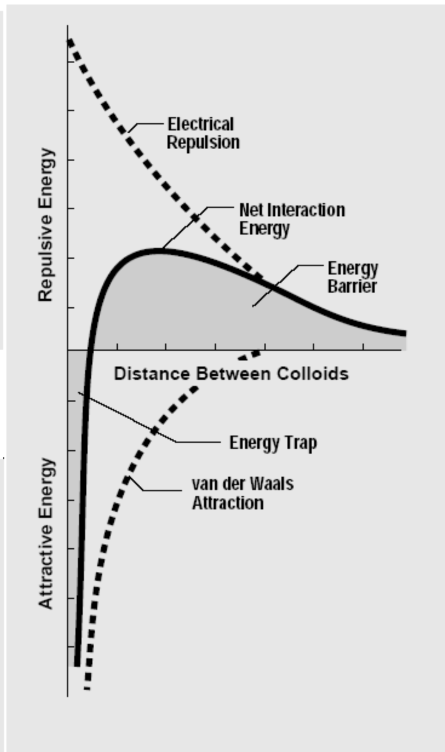
where *a* is the particle radius, ϵ is the solvent permeability, κ is a function of the ionic composition, and ζ is the zeta potential.



Electrostatic repulsion is always shown as a positive curve.



Van der Waals attraction is shown as a negative curve.



Interaction
The net interaction curve is formed by subtracting the attraction curve from the repulsion curve.

Shulze-Hardy rule

An empirical rule summarizing the general tendency of the critical coagulation concentration to vary inversely with the sixth power of the counter ion charge number of added electrolyte, without specific absorption (or chemical reactions)

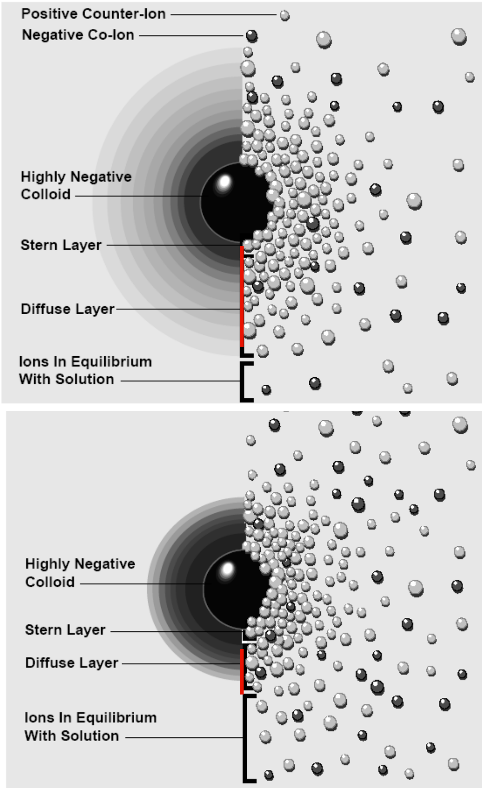
$$M^{I} : M^{II} : M^{III} = \left(\frac{1}{1}\right)^{6} : \left(\frac{1}{2}\right)^{6} : \left(\frac{1}{3}\right)^{6} = 100 : 1.6 : 0.3$$

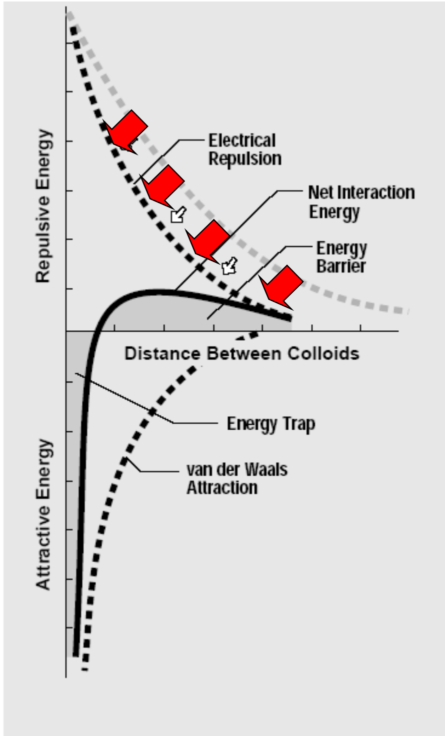
Can be derived from the DLVO theory

Sea water addition to ww

- Seawtaer has Ca^{2+} and Mg^{2+} which positively infleunce coagulation
- Several WWTPs along the coast add upto 8% seawater.

Double layer compression





S
C

Compression
Double layer compression squeezes the repulsive energy curve reducing its influence. Further compression would completely eliminate the energy barrier.

Hydrolysis

$Al^{3+} + H_20 \rightarrow Al(OH)^{2+} + H^+$

$Al(OH)^{2+} + H_20 \rightarrow Al(OH)_2^{\ +} + H^+$

$Al(OH)_2^{\ +} + H_20 \rightarrow Al(OH)_3\downarrow + H^+$

Release of H+ : pH reduces

Aquo Al ion — $Al(H_2O)_6^{3+}$

↓↑ → Hydrogen ion

Mononuclear species — $Al(OH)(H_2O)_5^{2+}$

↓↑ → Hydrogen ion

Polynuclear species — $Al_{13}O_4(OH)_{24}^{7+}$

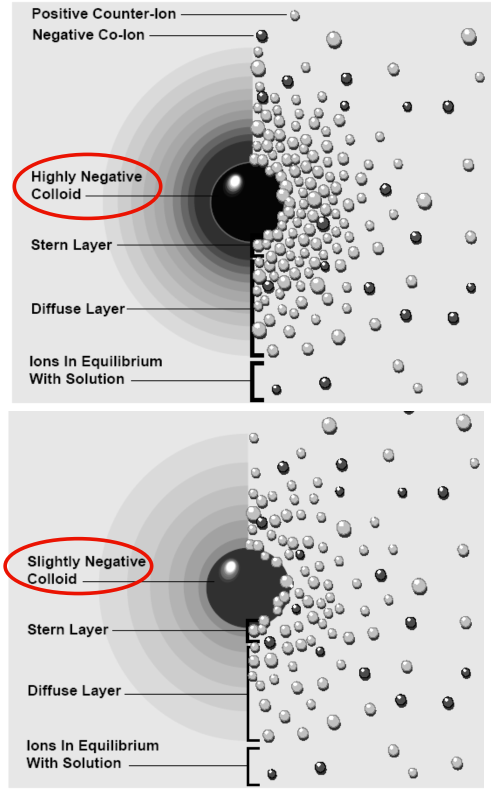
↓↑ → Hydrogen ion

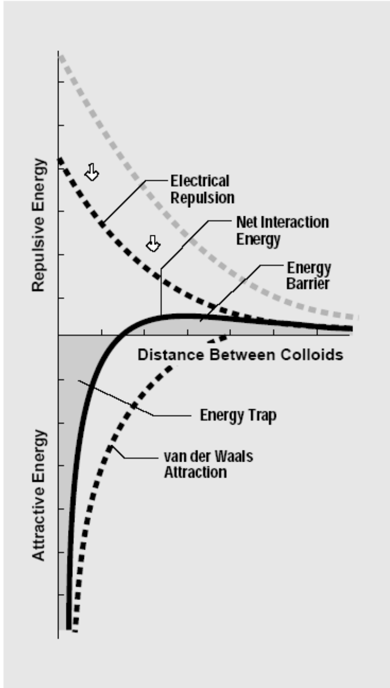
Precipitate — $Al(OH)_3(s)$

↓↑ → Hydrogen ion

Aluminate ion — $Al(OH)_4^-$

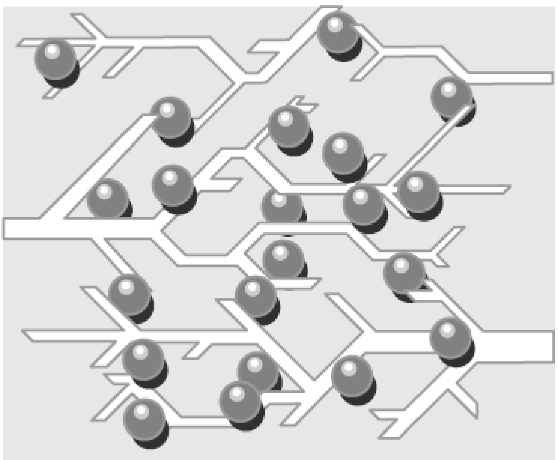
Adsorption- Charge Neutralization





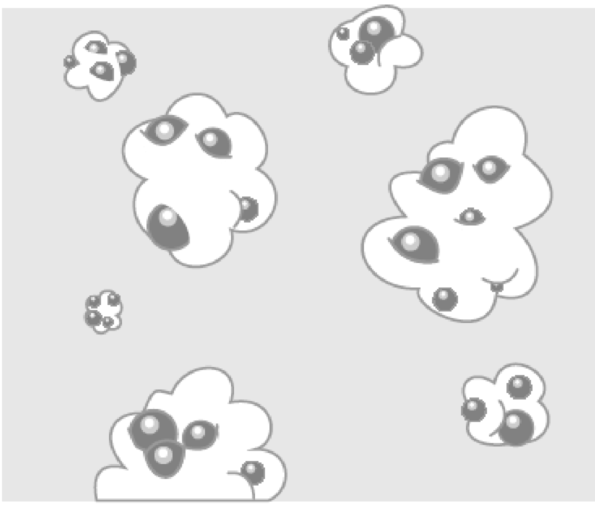
Charge Reduction
Coagulant addition lowers the surface charge and drops the repulsive energy curve. More coagulant can be added to completely eliminate the energy barrier.

Bridging



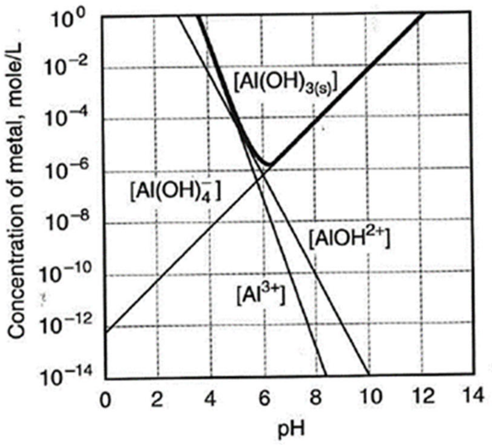
Bridging
Each polymer chain attaches to many colloids.

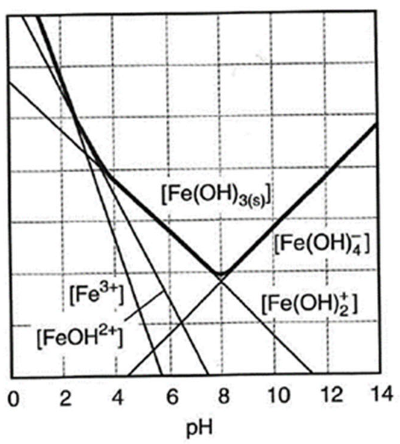
Sweep floc



Sweep Floc
Colloids become enmeshed in the growing precipitate.

Solubility diagrams

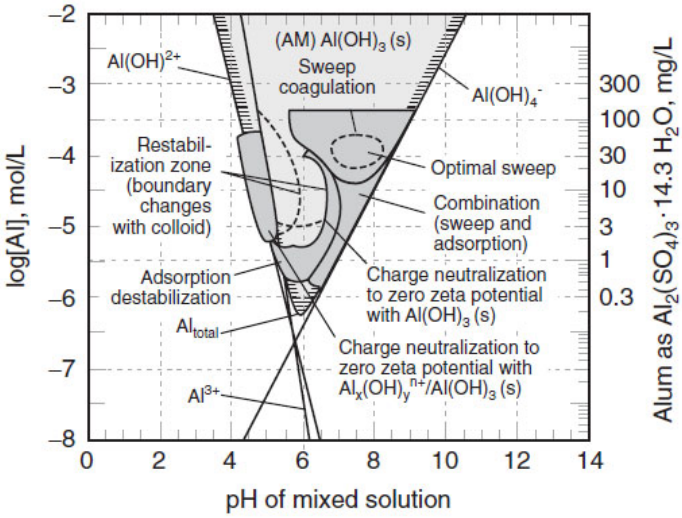


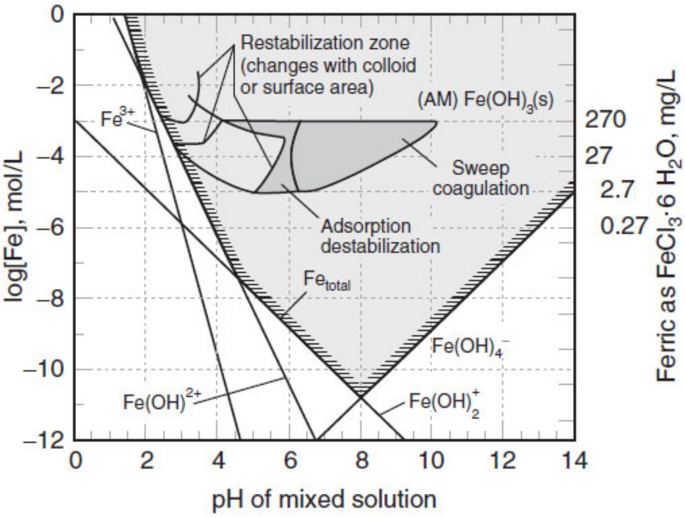


$\log[Al^{3+}] = 10.8 - 3pH$
$\log[AlOH^{2+}] = 5.8 - 2pH$
$\log[Al(OH)_4^-] = -12.2 + pH$
$C_T = [Al^{3+}] + [AlOH^{2+}] + [Al(OH)_4^-]$

$\log[Fe^{3+}] = 3.2 - 3pH$
$\log[FeOH^{2+}] = 1.0 - 2pH$
$\log[Fe(OH)_2^+] = -2.5 - pH$
$\log[Fe(OH)_4^-] = -18.4 + pH$
$C_T = [Fe^{3+}] + [FeOH^{2+}] + [Fe(OH)_2^+] + [Fe(OH)_4^-]$

Coagulation diagrams





Average dosing

Coagulant	Optimal pH	Normal dosage, mg-Me/l
Al3+	6.0-7.0	1.5-3.0 mg Al/l
Fe3+	4.5-5.5	3.0-6.0 mg Fe/l
PAX	6.5-7.5	1.0-2.5 mg Al/l

- Why is it necessary to add almost twice Al for Fe?
- If you have a hard water with high pH, which coagulant?
- If you have soft water and pre precipitation, which coagulant?

Colloids & coagulation

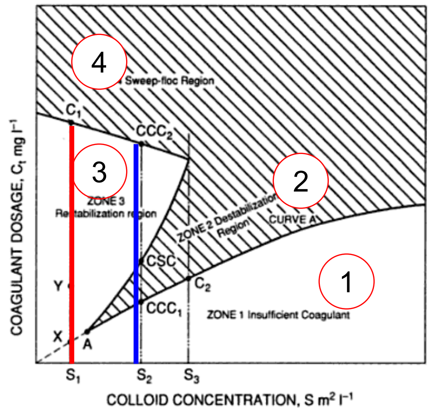


Figure 4.3 Zones of destabilization and restabilization at a given pH value as related to colloid concentration, *S* and coagulant dosage, C_T. (Adapted from Stumm and O'Melia, 1968).

- **Zone 1** indicates that insufficient coagulant has been applied to the colloidal suspension and that destabilization does not take place.
- **Zone 2** refers to the region in which destabilization has taken place.
- **Zone 3** is that region where destabilization and then, restabilization has taken place, due to excessive coagulant addition.
- **Zone 4** is the region where the coagulant dosage is high enough for oversaturation, and precipitation of metal hydroxide species to occur.

THT271-272

Phosphate removal mechanisms

- Chemical reactions with Al, Fe, Ca with P resulting in MeP-complexes
- Adsorption or sweep floc of MeP, complex and various ions to particles which separates.

- $Me^{3+} + PO_4^{3-} \rightarrow MePO_4$ $(MePO_4)_x (OH)_{3-3x}$
- $Al^{3+} + PO_4^{3-} \rightarrow Al(PO)_4$

Coagulants and mechanisms

Water type	Drinking water coagulation		Wastewater coagulation	
Mechanism and coagulant type	Inorganic coagulants	Organic coagulants	Inorganic coagulants	Organic coagulants
Double-layer compression	Occasionally	Not applicable	Used when seawater is available	Not applicable
Adsorption-charge neutralisation	Dominant	Occurs with cationic polymers	Occurs frequently	Occurs with cationic polymers
Inter-particle bridging	Not applicable	Dominant	Not applicable	Dominant
Colloidal entrapment (Sweep floc)	Occasionally	Not applicable	Dominant	Not applicable

Selection of coagulants

- **Traditional**
  - Al3+ (Aluminiumsulphate, Aluminiumchloride)
  - Fe3+ (Iron Chlorode, Iron chloride suplpahte)
  - Ca2+ (Calcium hydroxide)
  - Fe2+ (Iron Sulphate)
- **New (innovative)**
  - Prepolymerized (PAX, PIX)
  - With Slica/water glass
  - With Ca2+
  - With flocculants
  - Chitosan
  - Ti^{4+} & Zr^{4+}

Challenges

- Too little P after pre-precipitation
- Too low pH after pre precipitation
- Too strong binding of P to Al/Me so poor accessibility of P to plants
- Too much sludge?
- Sludge too difficult to process?
- Working pH range vary
- Price Fe^{2+} vs Fe^{3+}

Influence of Prepolymerisation

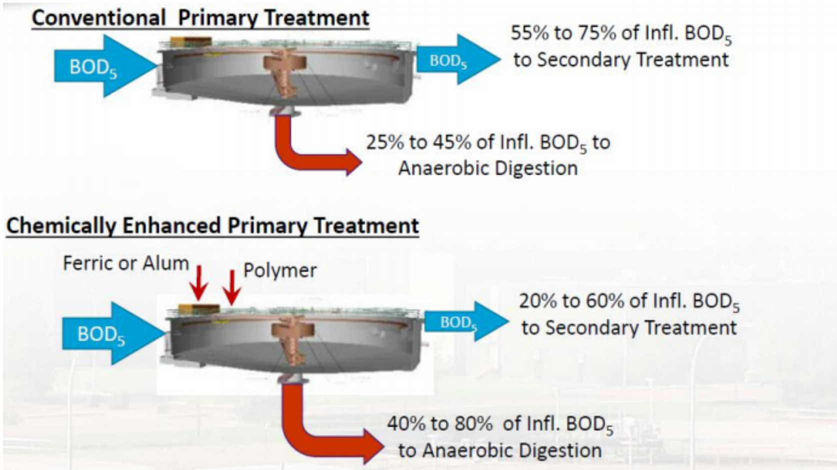
Coagulant	OH/Me	Me[PO], %
Aluminium sulphate	0	57
Iron Chloride	0	56
Poly-Aluminium Chloride I	1.1	43
Poly-Aluminium Chloride II	1.7	35
Poly-Aluminium Chloride III	1.9	25

OH/Al ↑ Al[PA] ↑ ⇨ Al[PO]↓

CEPT- Chemically Enhanced Primary Treatment

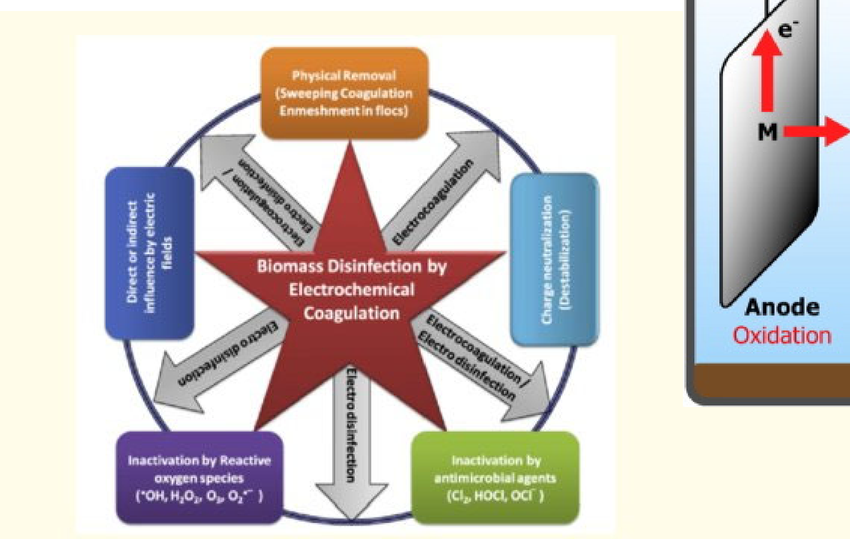
- Using external chemical addition to increase particle capture within primary treatment
- External chemicals:
  - Coagulant – typically a metal salt like alum or ferric chloride
  - Polymer – “tie it all together”

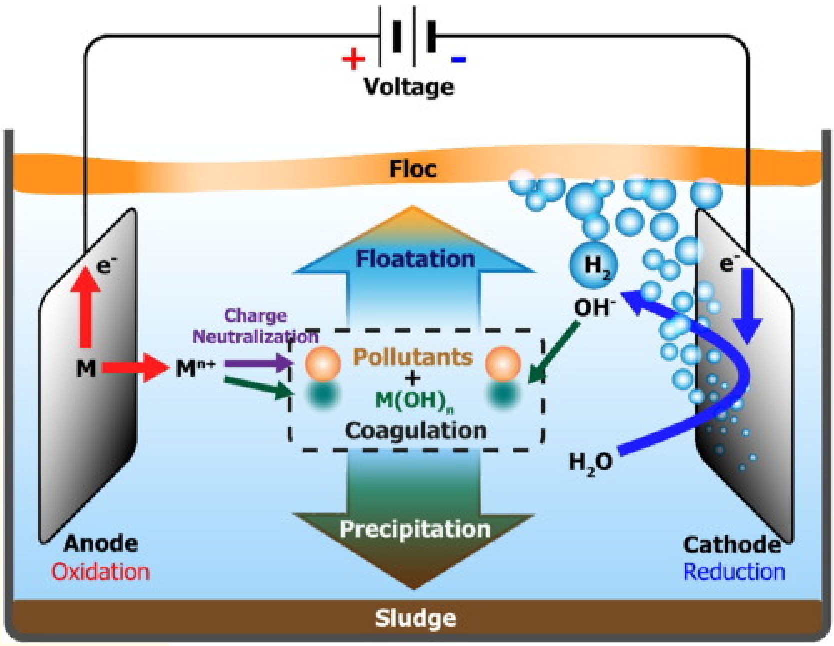
How can CEPT increase energy production?



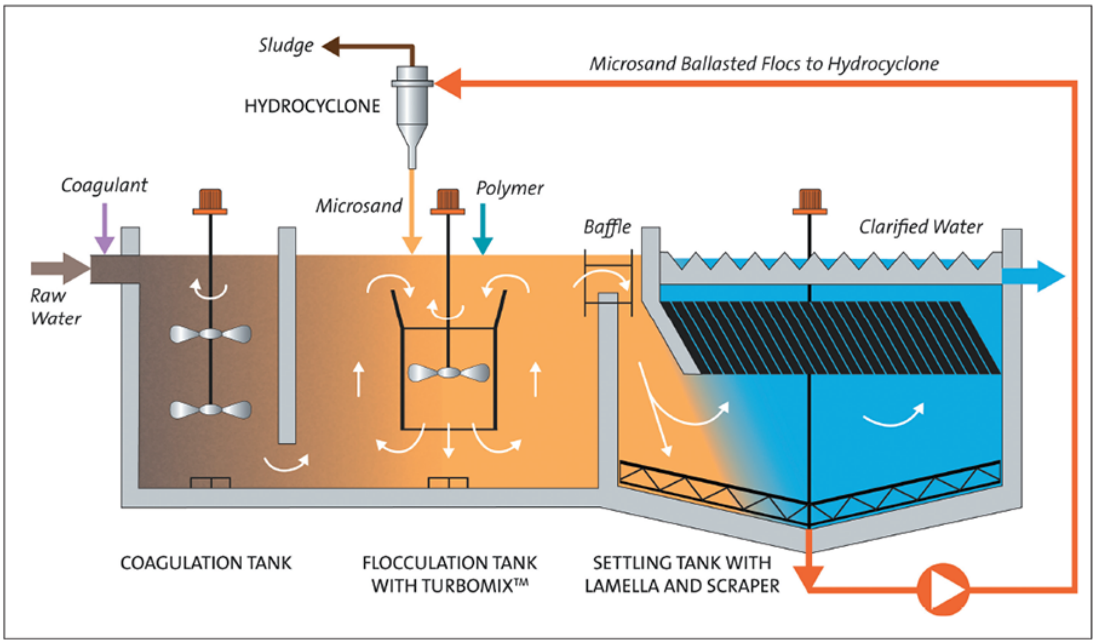
Electro coagulation

- Advantages?

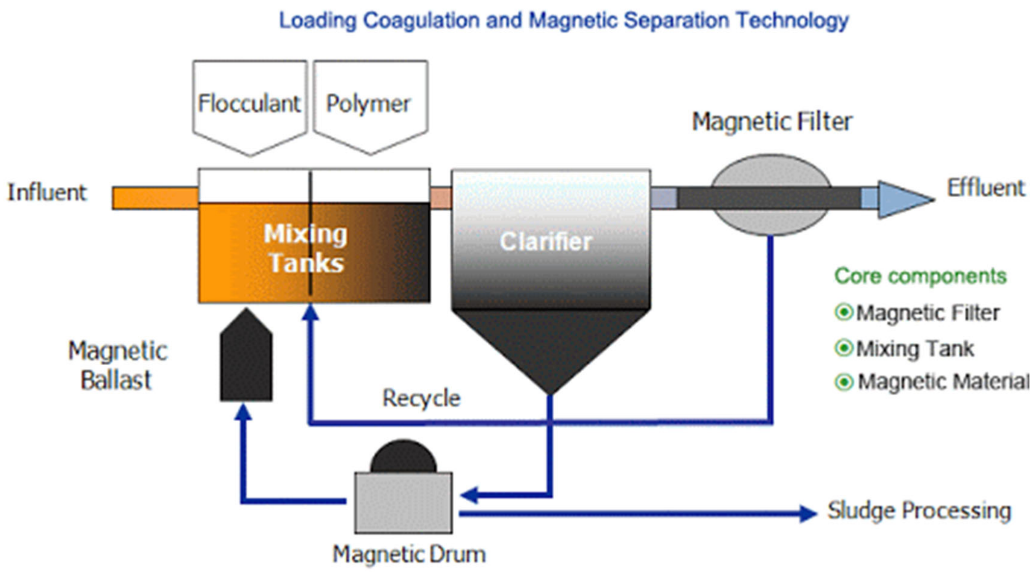




Ballasted coagulation – micro sand

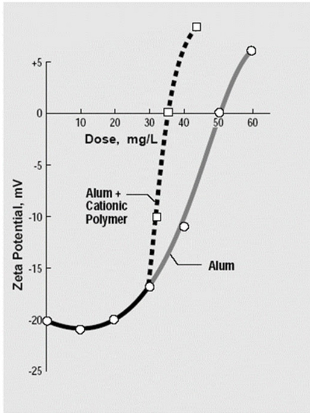


Ballasted coagulation – magnetic particles



Flocculation

- Organic flocculants
  - PAA, very low dosages (1-2% of coagulants), 15-25 costly as coagulants
- Can reduce the sludge volume considerably
  - surface loads can increase from 0.5-3.0 to 3-10 m/h
- Construction
  - Pedal flocculators
  - Tube-flocculators



Cationic Coagulant Aid
Zeta potential curves can be used to evaluate the charge neutralizing properties of cationic polymers.

Flocculation - advantages

- **Increase of process stability**
  - Stronger and heavier flocs
  - Less floc brekage undre transport
  - (somewhat) less infleunced by over- and under dosage
  - More compact slidge

Flocculators

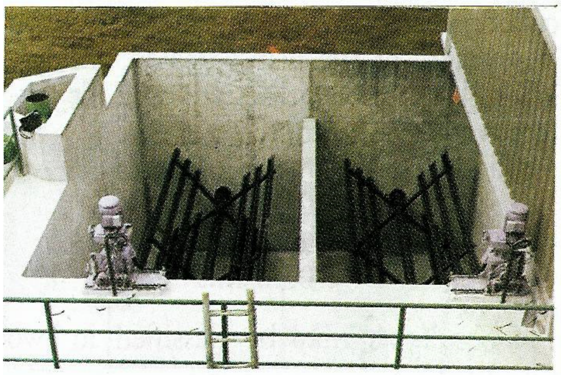


Figure 300. Paddle type flocculator.

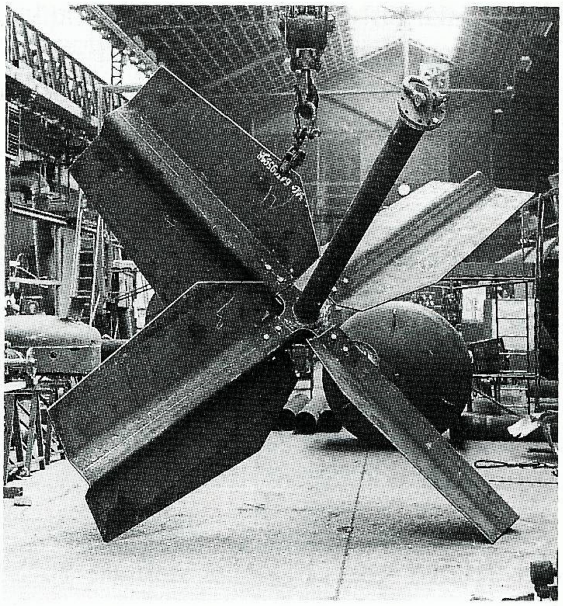
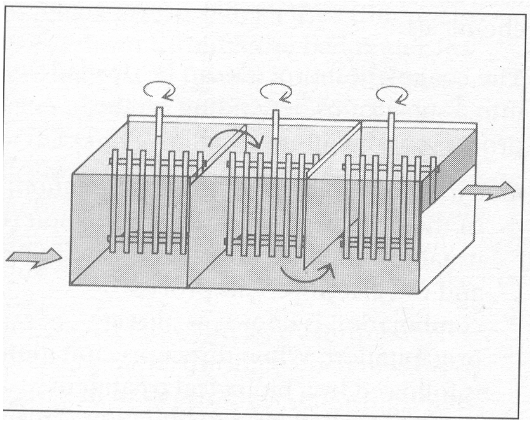
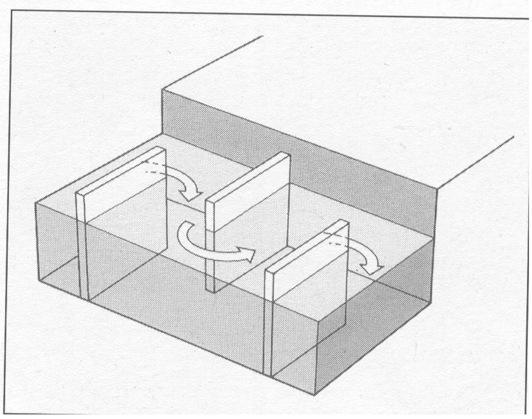


Figure 301. Propeller type flocculator.

Flocculation chambers





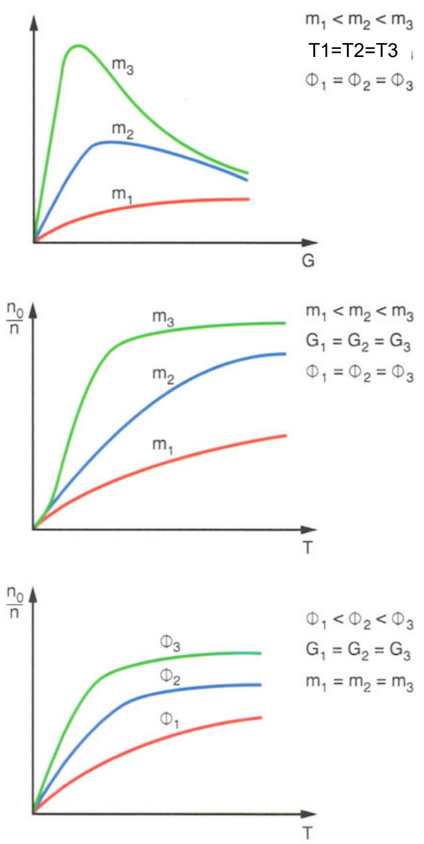
Advantages and disadvantages?

Flocculation intensity

- Rate of aggregation ($\frac{n_o}{n}$) of smaller particles to flocks (aggregates) is a function of
  - Velocity gradient, G
  - Mixing time (duration), T (reactor volume/Q)
  - Concentration of particles, ϕ

G =$(\frac{W}{\mu_a})^{-1/2}$ or in a pipe: G= $\frac{(f.v^3)^{0.5}}{2.d.v}$

- W=added energy per volume, watt/m2
- μ_a = absolute viscosity, kg/m.sec
- f= coefficient of resistance, f=100Re$^{-0.25}$, where R=v d/θ; v= flow m/sec; d= diam, m; θ=kinetic viscosity, m^2/sec

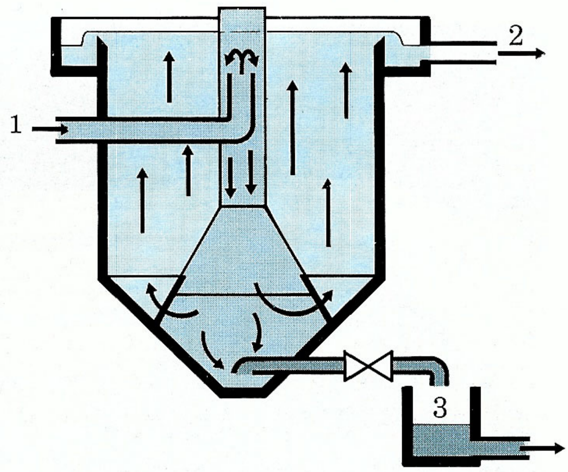


G-value (Velocity gradient)

- M= number of chambers
- ϕ = concentration of particles
- T = retention time
  - Sedimentation needs big and heavy flocs (lowering G)
  - Flotation needs light and smaller flocs (high & even G)

Separation

- Sedimentation
- Flotation
- Filtration



1 – Raw water.
2 – Treated water.
3 – Drain.

Figure 303. Cylindroconical settling tank.

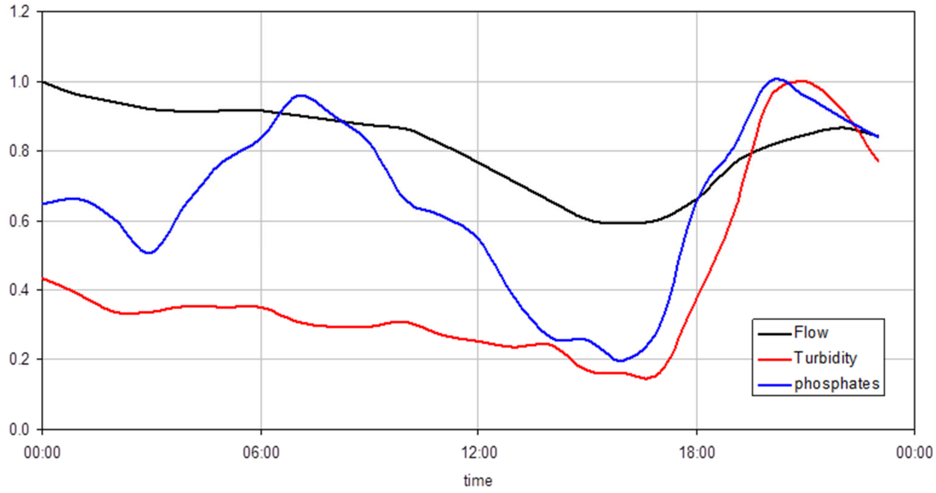
Design parameters

Effluent concentration: 2-3 g P/m^3	Biological phosphorus removal Simultaneous precipitation, Fe^{++} or Al^{+++}, MR = 0.8 Preprecipitation, Al^{+++}, MR = 1.
Effluent concentration: 1-2 g P/m^3	Simultaneous precipitation, Fe^{++} or Al^{+++}, MR = 1 Preprecipitation, Ca^{++} + Fe^{++}, pH 8-9, MR (Fe) = 1 Direct precipitation, Ca^{++}, pH 10-11 Direct precipitation, Al^{+++}, MR = 1.5 Post precipitation, Al^{+++}, pH 6.5-7.2, MR = 1
Effluent concentration: 0,5-1 g P/m^3	Simultaneous precipitation, Fe^{++} or Al^{+++}, MR = 1.5 Simultaneous precipitation + preprecipitation or soil ponds, Fe^{++} or Al^{+++}, MR = 1.5 Post precipitation, Al^{+++}, pH 5.5-6.5, MR = 2 Direct precipitation, Ca^{++}, pH 10-11 + sea water Preprecipitation, Ca^{++} + Fe^{++}, pH 9-10, MR (Fe) = 1.5
Effluent concentration: 0.3-0.5 g P/m^3	Simultaneous precipitation, Fe^{++} or Al^{+++} + contact filtration Fe^{++} or Fe^{+++}, MR both processes = 2. Post precipitation, Al^{+++}, pH 5.5-6.0, MR = 2, + contact filtration, Fe^{+++}, MR = 2.

Table 10.2
Example of processes of technical-financial relevance to obtain given effluent concentrations for total phosphorus.
The abbreviation MR (molar ratio) means: Number of moles of metal ions added per mole of total phosphorus in the influent.

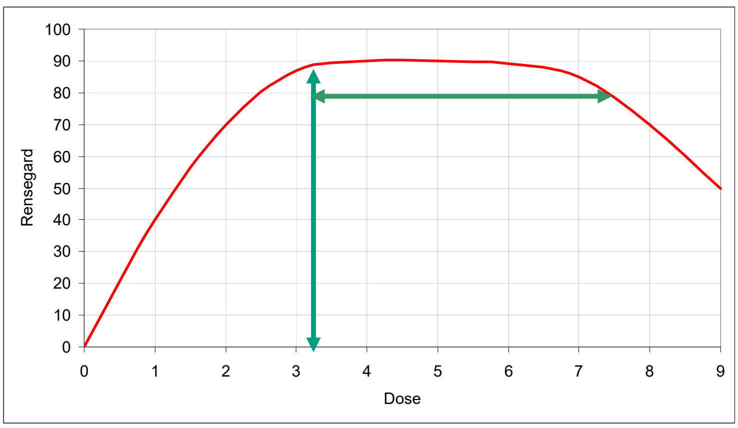
Dosing control

- Optimal dosage = f(Q, SS, P, pH)
- Common dosing strategy : D=f(Q)



Waste of coagulants?

- Optimal dosage = minimum dosage needed to achieve the required treatment efficiency



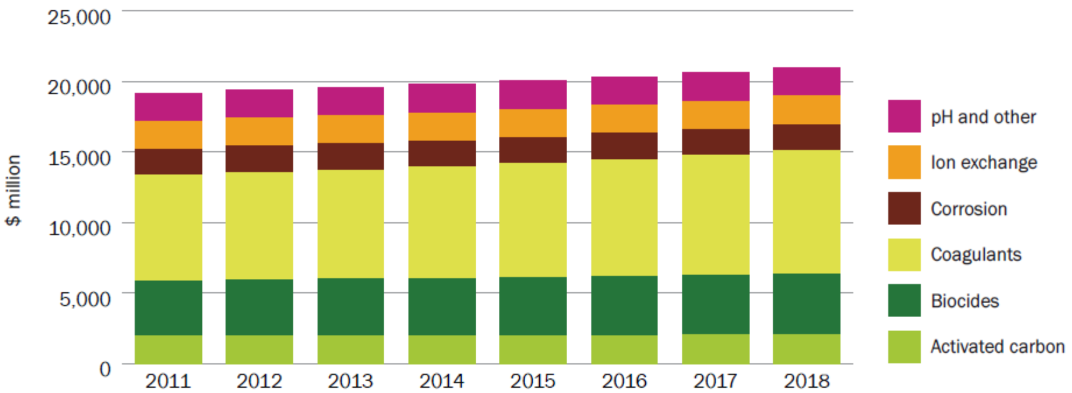
Jar-test





Coagulant production - Global

Figure 1.114 Municipal and industrial chemicals forecast, 2011-2018



$ million	2011	2012	2013	2014	2015	2016	2017	2018
Activated carbon	1,974.0	1,979.8	1,985.8	1,992.4	2,000.1	2,008.7	2,018.4	2,029.5
Biocides	3,898.6	3,946.6	3,995.6	4,050.6	4,113.8	4,185.0	4,264.7	4,356.4
Coagulants	7,485.7	7,613.4	7,744.1	7,890.5	8,059.0	8,248.4	8,460.7	8,705.0
Corrosion	1,870.9	1,871.8	1,872.9	1,874.0	1,875.3	1,876.8	1,878.4	1,880.3
Ion exchange	1,978.5	1,980.7	1,982.9	1,985.4	1,988.3	1,991.6	1,995.2	1,999.4
pH and other	1,992.3	1,996.8	2,001.4	2,006.6	2,012.6	2,019.4	2,026.9	2,035.6
Total	**19,200.0**	**19,389.1**	**19,582.7**	**19,799.7**	**20,049.2**	**20,329.7**	**20,644.2**	**21,006.1**

Source: GWI

Wastewater management
Needs, challenges and legislation: EU and WHO

Harsha Ratnaweera

THT311-2021

Outline

- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

What is wastewater?

Wastewater is…

Combination of the liquid or water-carried wastes

Wastewater types…

Household and municipal wastewater

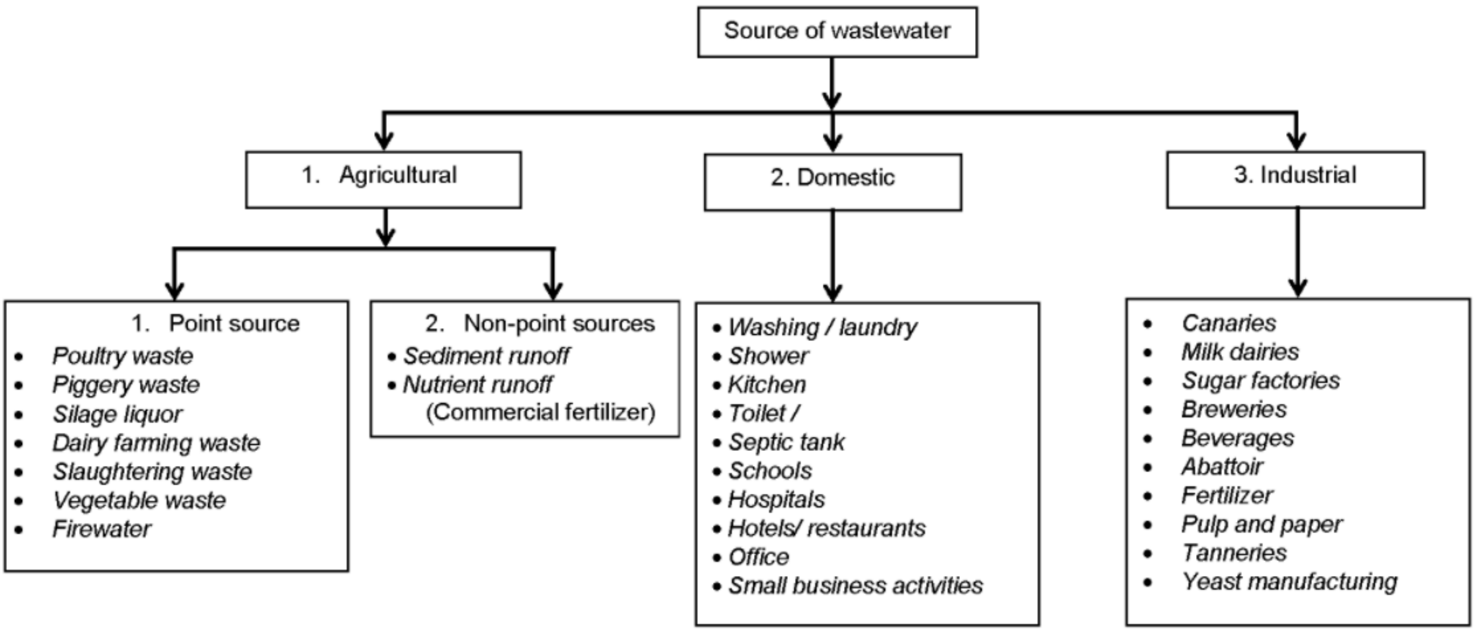
Industrial wastewater (cooling and process water)

Agricultural wastewater

Rainwater overflows

Infiltrated water

Sources of wastewater



Wastewater constituents

Nutrients

Nitrogen N, phosphorus P and carbon C

Heavy metals

Industrial/commercial wastewater (Zn, Cu, Cr etc.)

Suspended solids

Solid particles in suspension

Biodegradable organics

Mostly carbohydrates, fats and proteins

Wastewater constituents

Pathogens

Viruses, bacteria, protozoa

Priority pollutants

Proved or suspected to be carcinogenic, mutagenic, toxic or teratogenicity compounds

Refractory organics

Not easily removed during conventional treatment pollutants (phenols, pesticides, surfactants etc.)

Dissolved inorganics

Pollutants from household activities (Ca, Na, sulphate etc.)

Definitions in UWWTD

One population equivalent 1 p.e.

"The organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day"

Generated load = "size" of agglomeration expressed in p.e.

1 p.e. means pollution load produced by **1 person** within 24 hours and takes into account

- Resident and non-resident population
- Industries covered by Art.11 UWWTD
- Industrial wastewater from small and medium enterprises
- All remaining urban wastewater

Open www.menti.com code 43 67 558

Some wastewater related problems

Human and wildlife acute and chronic health risks

- Brain and nervous system
- Endocrine system disruption
- Toxicity
- Cancer etc.

Drinking water source contamination

- Infiltrated wastewater from sewage leaks into groundwater
- Discharge of untreated wastewater into surface water

Poor ecological and chemical water status

- Eutrophication

Wastewater status in 60’s and 70’s in Norway

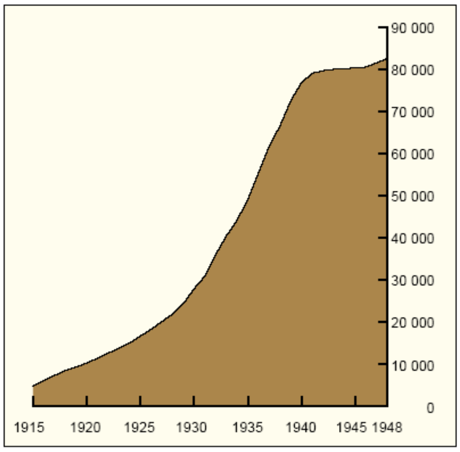
- Almost no WWTPs
- But many sewers with poor quality
- Main purpose was to transport WW from housing areas.
- ”Dillution is solution to pollution”

Massive pollution….

- Increased use of water closets
- Septic tanks as the only treatment
- Serious pollutions in rivers, lakes and fjords.
- High bacteria concentrations
- Low oxygen content in recipients
- Massive algal blooms due to N and P

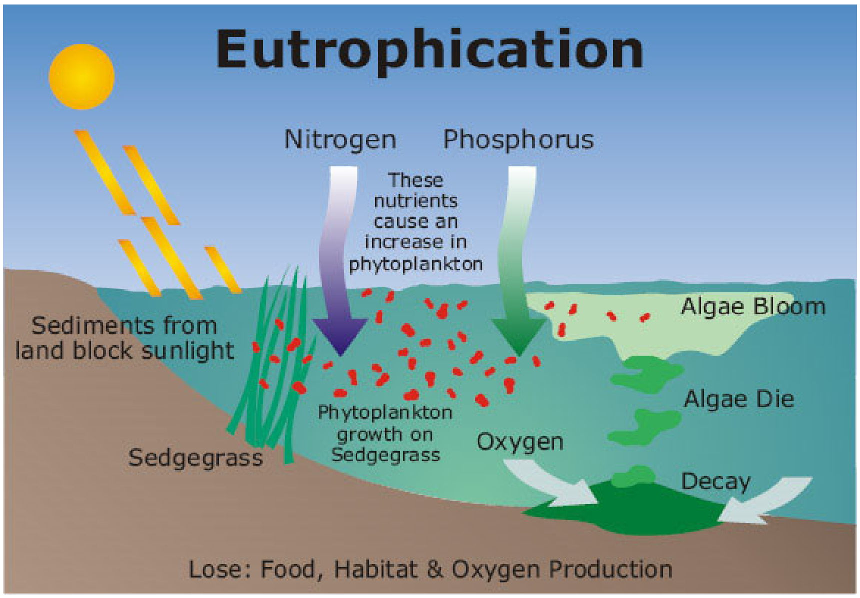
Masseforekomst av planktonalger i Bispevika og Bjørvika på 1970-tallet. (Foto: Fjellanger Widerøe VisKom).

Number of water closets in Oslo 1915-1948



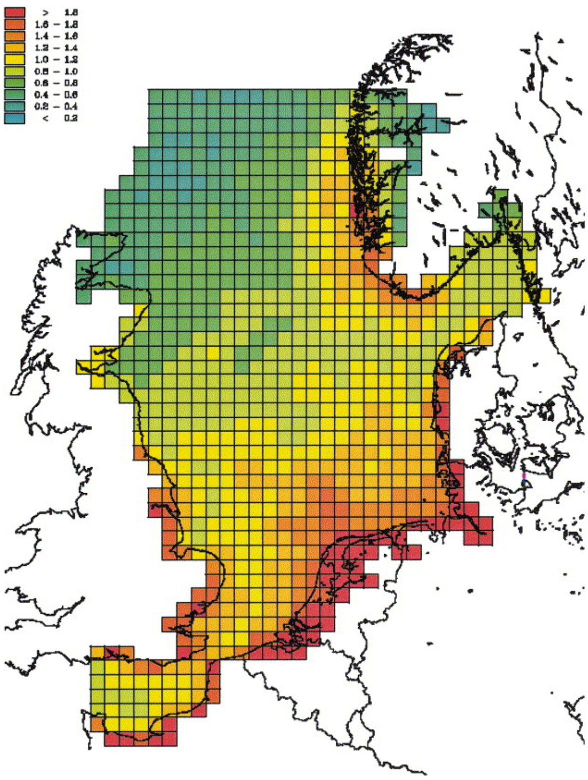
Focus on WW treatment in 1970's

- Pretreatment
- Mechanical treatment
- Biological treatment
- Chemical treatment- Mostly primary and secondary treatment without biological stage

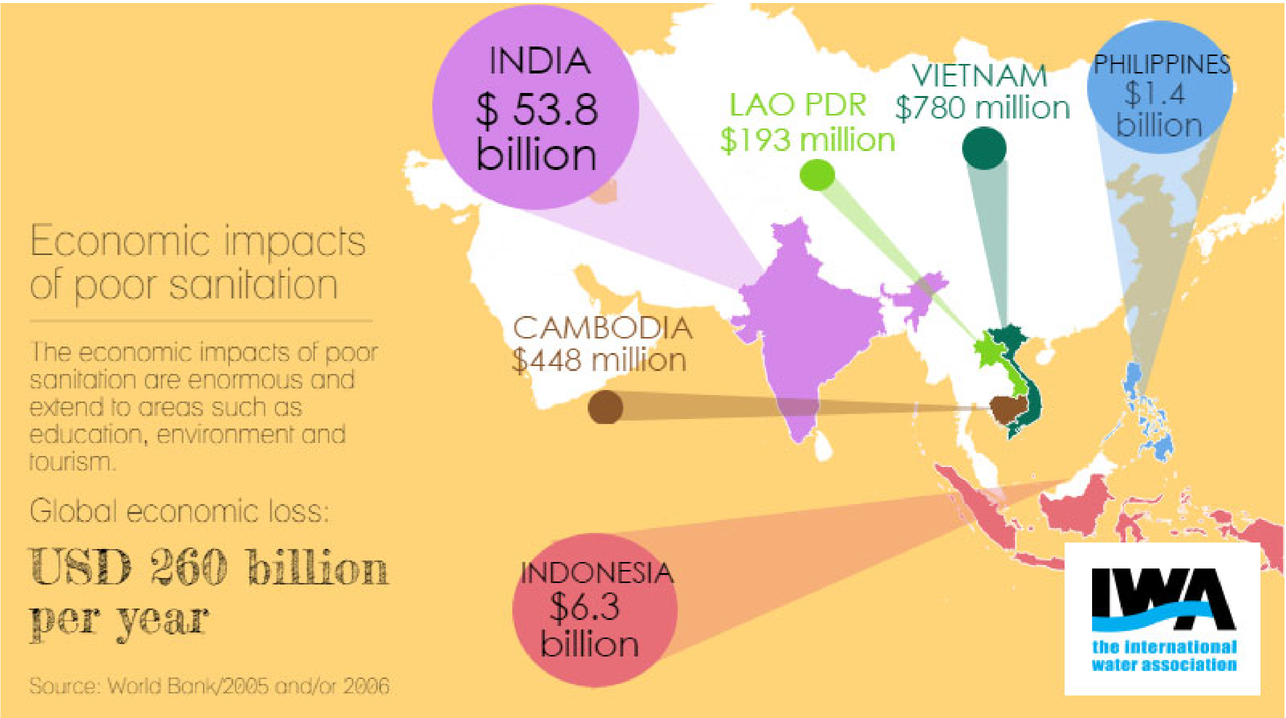


- Org-C + O_2 → CO_2
- NH_4-N + O_2 → NO_2 + O_2 → NO_3 (→ N_2)

Nitrogen in North sea 1998



Economic impact on poor sanitation



Outline

- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

Discharge permits in Norway: norskutslipp.no

level.

- Frontpage
- **Wastewater treatment plants**
- Landfills
- Households
- Industry
- Agriculture
- Offshore petroleum industry
- Products
- Transport

Choose county
Choose municipality

Wastewater treatment plants

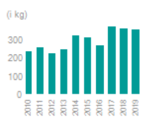
About 2,500 municipal wastewater treatment plants have been built in Norway, 400 of which have discharge permits from the County Governors. The municipalities themselves are responsible authorities for the rest, that is to say for populated areas of fewer than 2,000 person equivalents in the case of discharge to fresh water and fjord outlets, and of fewer than 10,000 for discharge into fjords and coastal waters. There are also about 350,000 treatment plants for approximately 800,000 people who either live in sparsely populated areas or have cabins. For these too, the municipality is the pollution control authority. Most wasteater treatment plants in Norway were built during the period 1970 to 1985. There are still about 500 untreated discharges, covering approximately 350,000 persons, where treatment plants have yet to be built. Two trends are that new treatment systems are being built for individual houses and cabins, while other buildings are being connected to the public sewerage system and closing down their separate treatment plants. + Read more

Pollutants

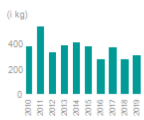
Phosphrous total (P-TOT)	Arsenic (As)	Copper (Cu)	Nickel (Ni)
Suspended solids (SS)	Lead (Pb)	Mercury (Hg)	[...]

Trends of selected pollutants (see complete list)

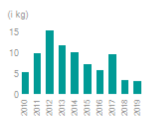
Arsenic (As)



Lead (Pb)



Mercury (Hg)



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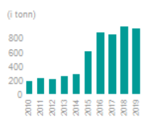

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Search for a facility

Releases to air and water as well as transfers of waste from different sectors, both aggregated and at facility level.

- Frontpage
- **Wastewater treatment plants**
- Landfills
- Households
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- Offshore petroleum industry
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- Transport

Choose county
Choose municipality

Sentralrenseanlegg Vest (VEAS)

Show facility on map

Export to Excel

Cleaning method: Kjemisk-biologisk
[Type vannforekomst for avløpsvannet]: Kystvann
Permit and control reports (Norwegian only): Permit, Control report 2011, Control report 2020
Monitoring report for the water body:
Authority: Statsforvalteren i Oslo og Viken

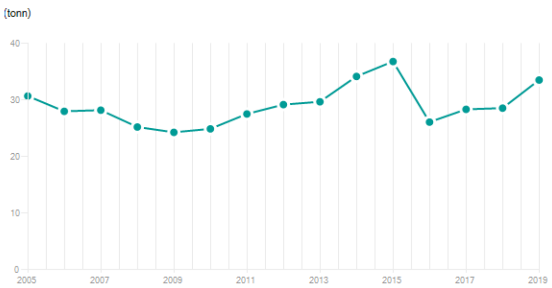
Emissions

Time interval 2005 – 2019

Compare to... wastewater treatment plants within a geographical area, or a facility.

Discharges of Phosphrous total (P-TOT) (in tonn per year)

Sentralrenseanlegg Vest (VEAS)



View
To water
Not reported

Category
- Arsenic (As)
- Biological oxygen demand (BOF5)
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- **Phosphrous total (P-TOT)**
- Suspended solids (SS)

Sentralrenseanlegg Vest (VEAS) : Discharges of Phosphrous total (P-TOT)

EU Directives

- Bathing Water Directive 1976
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In preparation

Roadmap

Feedback period

21 July 2020 - 08 September 2020

FEEDBACK: CLOSED

UPCOMING

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More about roadmaps

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Urban Wastewater Treatment Directive (91/271/EEC)

Aims to…

Protect the environment from the adverse effects of wastewater discharges

Concerns…

Collection, treatment and discharge of **urban wastewater**

Treatment and discharge of certain **industrial wastewaters**

Requires…

Certain level of **treatment** (primary, secondary or tertiary) depending on the **sensitivity** of receiving area

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Sensitive areas

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Surface freshwater used for abstraction of drinking water which **could contain 50 mg/L of nitrate** (Directive 75/440/EEC)

Areas where further treatment is necessary to **satisfy other Directives**

Sensitive areas in Nordic countries

Receiving water – agglomerations > 2000 pe Number (in red: % of total pe)

Country	Coastal waters			Fresh water and estuaries		
	Less sensitive	Normal	Sensitive	Less sensitive	Normal	Sensitive (incl. soil)
Denmark	Only sensitve areas		70 %	Only sensitve areas		30 %
Sweden	Only sensitve areas		39 58 %	Only sensitve areas		328 48%
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Norway	37 23 %	0 0 %	23 42 %	0 0 %	7 7 %	92 26 %
Iceland	Only less sensitve areas					

Ødegaard, 2017

Wastewater limit values in UWWTD

Parameter	Type of waters	
	Normal waters	Sensitive Waters
BOD5	25 mgO2/L	25 mgO2/L
Minimum % of reduction	70 - 90%	70 - 90%
COD	125 mgO2/L	125 mgO2/L
Minimum % of reduction	75%	75%
TSS	35 mg/L	35 mg/L
Minimum % of reduction	90%	90%
Total Nitrogen		
10 000 - 100 000 p.e.	-	15 mg/L (70 - 80%)
>100 000 p.e.	-	10 mg/L (70 - 80%)
Total Phosphorus		
10 000 - 100 000 p.e.	-	2 mg/L (80%)
>100 000 p.e.	-	1 mg/L (80%)

WW discharge limits in Africa and Asia

.4 Parameter	.4 Unit	Effluent Discharge Standards						
		Africa				Asia		
		Nigeria	Tanzania	Ghana	Uganda	Thailand	Malaysia	India
Temperature	°C	40	-na-	-na-	35	40	40	-na-
pH	-	6–9	6.5–8.5	6–9	6–8	5.5–9	5.5–9.0	6.5–8.5
BOD	mg O_2/L	30–50	30	50	50	20–60	50	30
COD	mg O_2/L	60–90	60	250	100	120–400	100	250
Oil and grease	mg/L	10	5	5	10	5–15	10	10
DS	mg/L	200	3000	1000	1200	3000	-na-	-na-
SS	mg/L	25	100	50	100	50	100	50–100
Total N	mg/L	10	10	-na-	10	-na-	-na-	10

WW discharge limits in China

Indicator	Integrated Wastewater Discharge Standard (GB8978–1996)		Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB 18918–2002)			Environmental Quality Standards for Surface Water (GB-3838-2002)
	Grade I	Grade II	Grade I-A	Grade I-B	Grade II	Grade IV
SS	20	30	10	20	30	–
COD	60	120	50	60	100	30
BOD_5	20	30	10	20	30	6
TN	–	–	15	20	–	1.5
TP	–	–	0.5	1	3	0.3(0.1 lake)
NH_3-N	15	25	5(8)*	8(15)*	25(30)*	1.5

* Lower than 12 °C in the bracket.

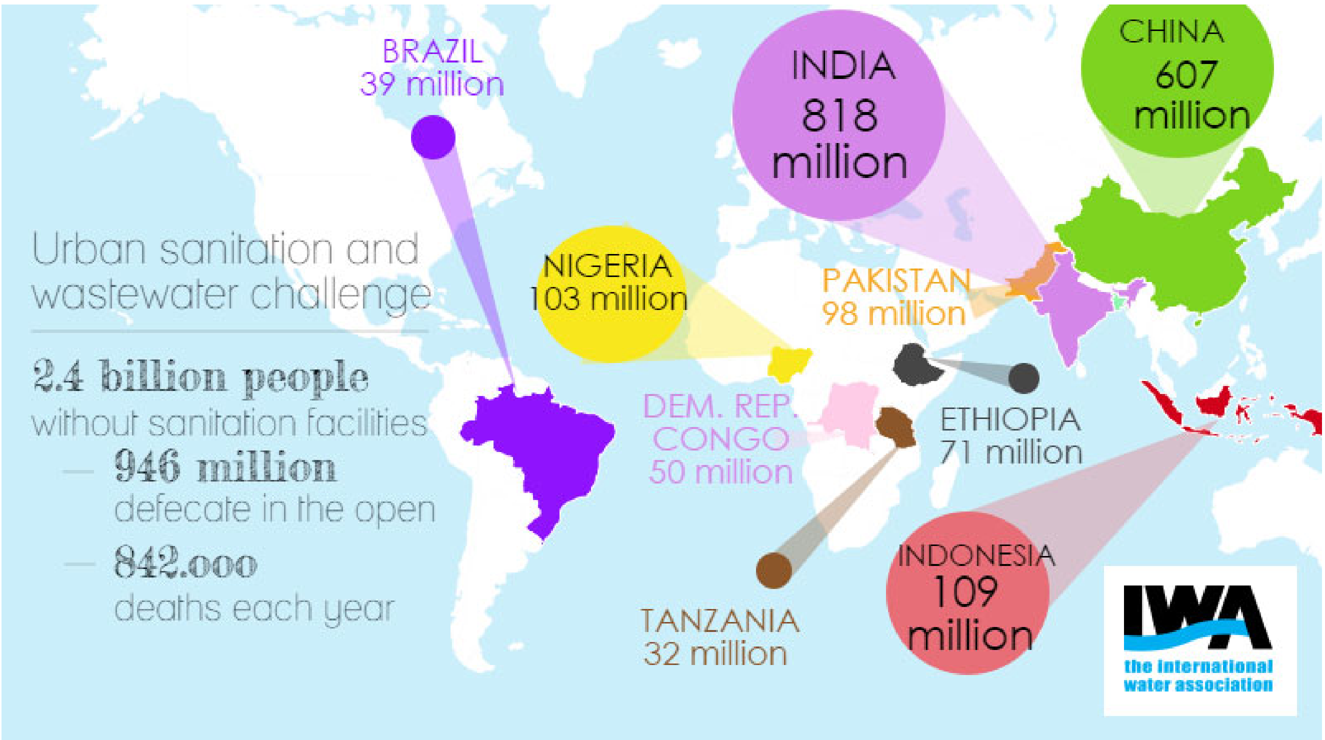
Country	PE treated	pH	t (°C)	SS (mg SS/l)	DO (mg O_2/l)	COD (mg COD/l)	BOD_5 (mg BOD_5/l)	TN (mg N/L)	Total ammonium (mg NH_4-N/l)	Total ammonia (mg NH_3-N/l)	TP (mg P/l)	Microbial indicators
EU Urban Wastewater Treatment Directive (UWWTD)[p]	>2,000			35/90% reduction		125/75% reduction	25/70-90% reduction	–			–	
	10,000 – 100,000							15			2	
	>100,000							10			1	
Ireland	≤10			30			20	5	20		2	
	>2,000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
France	<20			30			35					
	20 - 2000	6–8.5	<25	50% reduction		60% reduction	35, 60% reduction					
	>2000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
Romania	>2,000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
Ecuador		6 - 9	±3[q]	130		200	100	50 TKN	30		10	<2000 FC MPN/100 ml
Tanzania		6.5–8.5	20–35	100 TSS		60	30	15 TKN			6	<10,000 TC counts/ 100 ml
Jordan				60 TSS	>1	150	60	70			15 as T-PO_4	<1,000 *E. coli* MPN/100 ml Nematodes < 1
India 2015		6.5–9		20 TSS		50	10	10	<5			<100 FC MPN/100 ml
India 2017/18	Metro	6.5–9		50 TSS			20					<1,000 FC MPN/100 ml
	Non-metro			100 TSS			30					
India NGT 2019		5.5–9		20 TSS		50	10	10			1	<230 FC MPN/100 ml
India 1986[r] Inland water		5.5–9	<5	100		250	30	100 TKN		5 as free NH_3	5 diss. PO_4 as P	
Land irrigation				200			100					

Note to the table: Coliforms represented include E. coli, Fecal Coliforms (FC) and Total Coliforms (TC).
[o] Detail for ranges of permitted consents omitted from this version for clarity.
[p] TP and TN only considered in designated "sensitive" areas.
[q] Of the receiving water body.
[r] Total set covers a range of 40 parameters and three further application areas for discharge into public sewer, marine coastal areas.

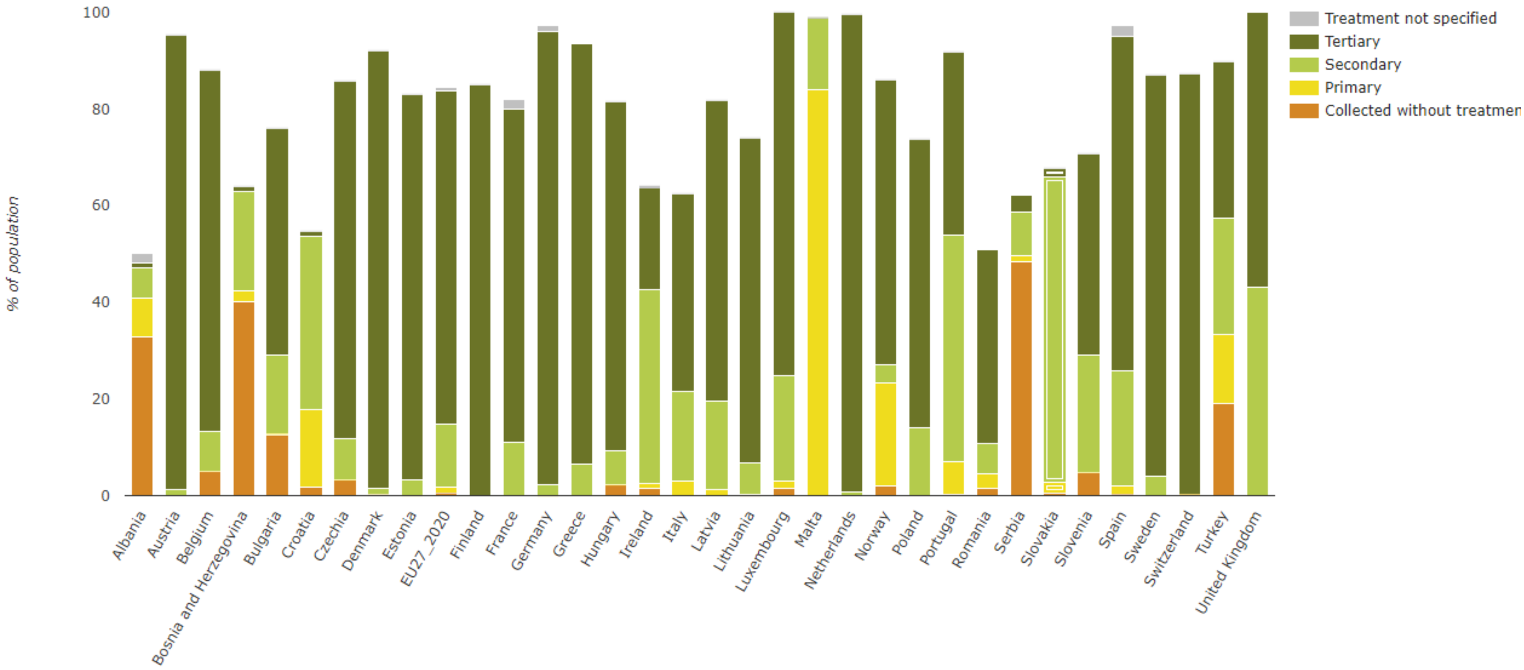
Outline

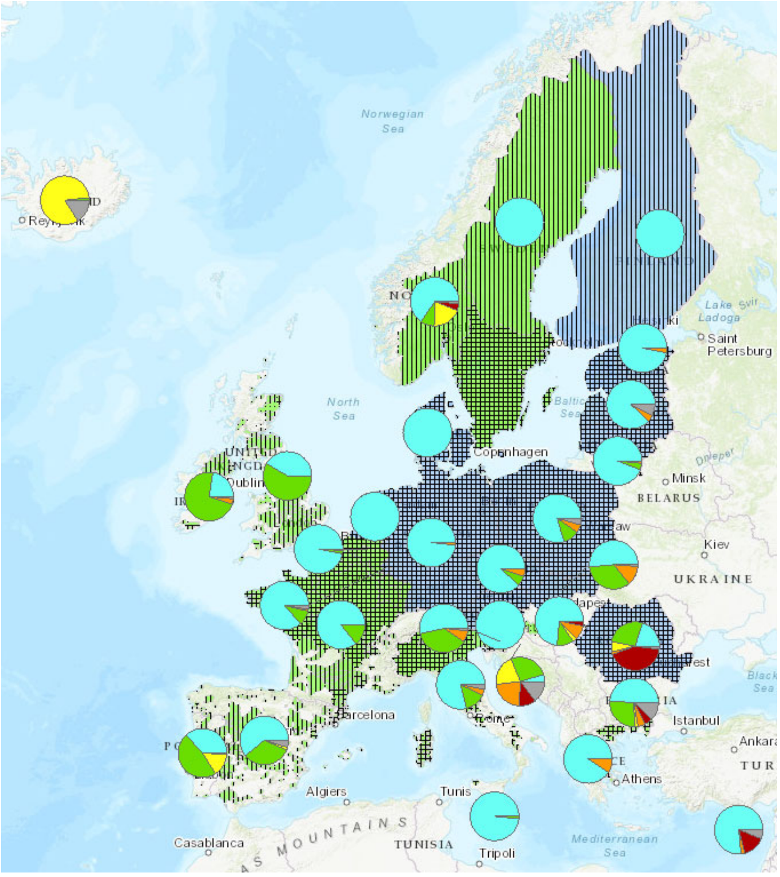
- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

Urban sanitation and ww challenge



Urban wastewater collected and treated-Europe





WWT in Europe

UWWT agglomerations treatment pathways

UWWTD agglomerations treatment pathways

Waste water treatment pathways by member state

- More stringent treatment
- Secondary treatment
- Primary treatment
- Addressed through individual and appropriate systems (IAS)
- Not collected in collecting systems and not addressed through IAS
- No treatment / no information

UWWTD receiving areas, catchments

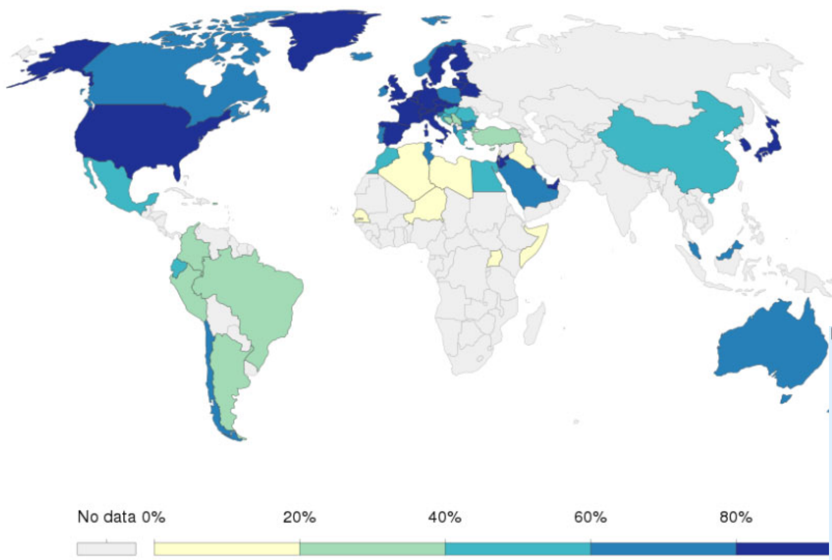
Catchments - sensitivity type

- Nitrogen
- Phosphorus
- N and P
- Other

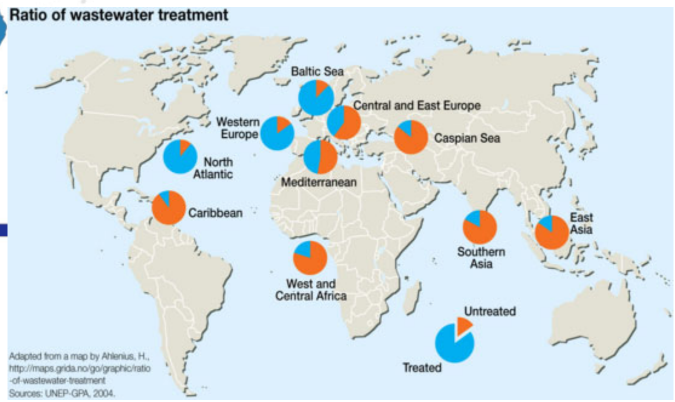
Catchments

- Application of Art. 5(8)
- Sensitive area

Share of domestic wastewater that is safely treated, 2018



Source: UN Statistics Division (2019)



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Wastewater management

Needs, challenges and legislation: EU and WHO

Harsha Ratnaweera

THT311-2021

Outline

- Sources of wastewater and need for treatment
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What is wastewater?

Wastewater is...

Combination of the liquid or water-carried wastes

Wastewater types...

Household and municipal wastewater

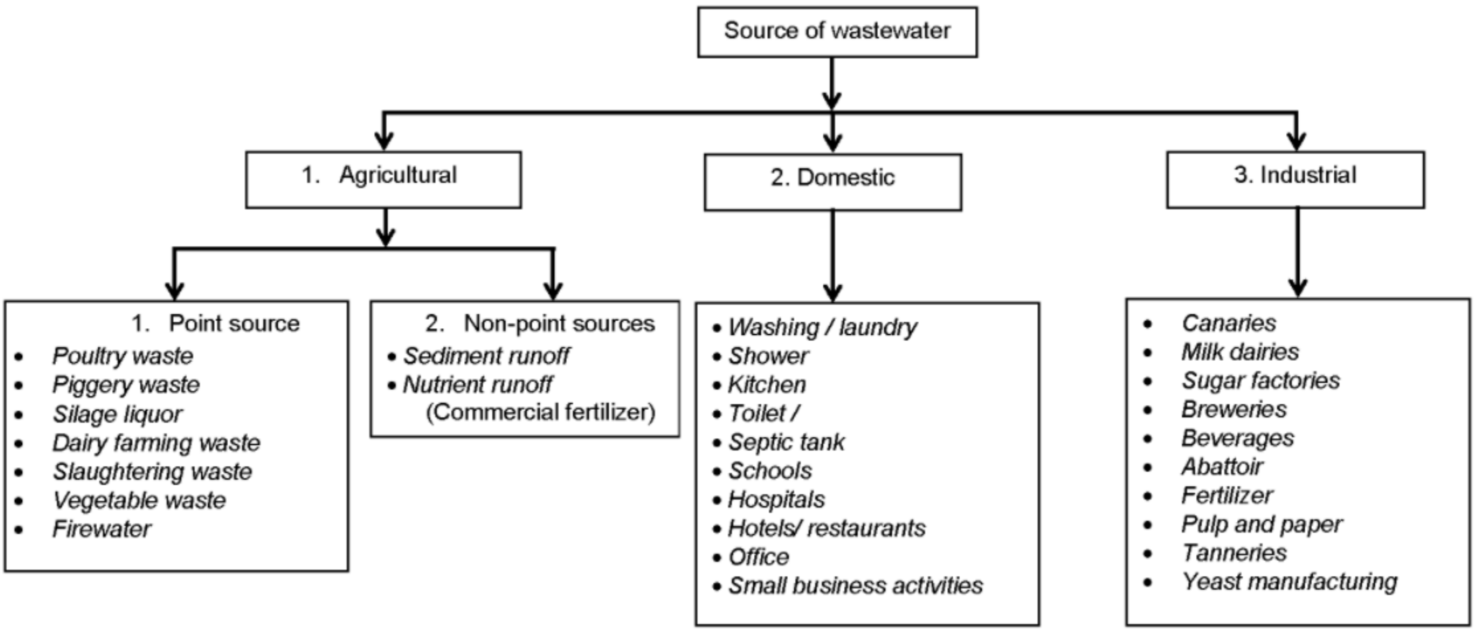
Industrial wastewater (cooling and process water)

Agricultural wastewater

Rainwater overflows

Infiltrated water

Sources of wastewater



Wastewater constituents

Nutrients

Nitrogen N, phosphorus P and carbon C

Heavy metals

Industrial/commercial wastewater (Zn, Cu, Cr etc.)

Suspended solids

Solid particles in suspension

Biodegradable organics

Mostly carbohydrates, fats and proteins

Wastewater constituents

Pathogens

Viruses, bacteria, protozoa

Priority pollutants

Proved or suspected to be carcinogenic, mutagenic, toxic or teratogenicity compounds

Refractory organics

Not easily removed during conventional treatment pollutants (phenols, pesticides, surfactants etc.)

Dissolved inorganics

Pollutants from household activities (Ca, Na, sulphate etc.)

Definitions in UWWTD

One population equivalent 1 p.e.

"The organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day"

Generated load = "size" of agglomeration expressed in p.e.

1 p.e. means pollution load produced by **1 person** within 24 hours and takes into account

- Resident and non-resident population
- Industries covered by Art.11 UWWTD
- Industrial wastewater from small and medium enterprises
- All remaining urban wastewater

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Some wastewater related problems

Human and wildlife acute and chronic health risks

- Brain and nervous system
- Endocrine system disruption
- Toxicity
- Cancer etc.

Drinking water source contamination

- Infiltrated wastewater from sewage leaks into groundwater
- Discharge of untreated wastewater into surface water

Poor ecological and chemical water status

- Eutrophication

Wastewater status in 60's and 70's in Norway

- Almost no WWTPs
- But many sewers with poor quality
- Main purpose was to transport WW from housing areas.

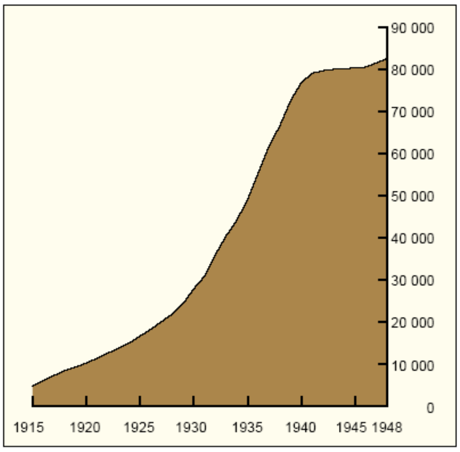
- ”Dillution is solution to pollution”

Massive pollution….

- Increased use of water closets
- Septic tanks as the only treatment
- Serious pollutions in rivers, lakes and fjords.
- High bacteria concentrations
- Low oxygen content in recipients
- Massive algal blooms due to N and P

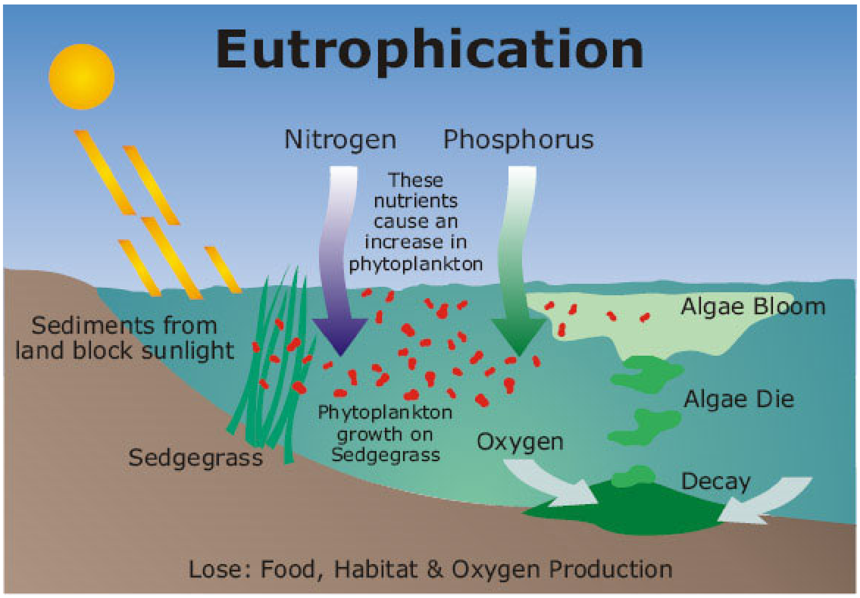
Masseforekomst av planktonalger i Bispevika og Bjørvika på 1970-tallet. (Foto: Fjellanger Widerøe VisKom).

Number of water closets in Oslo 1915-1948



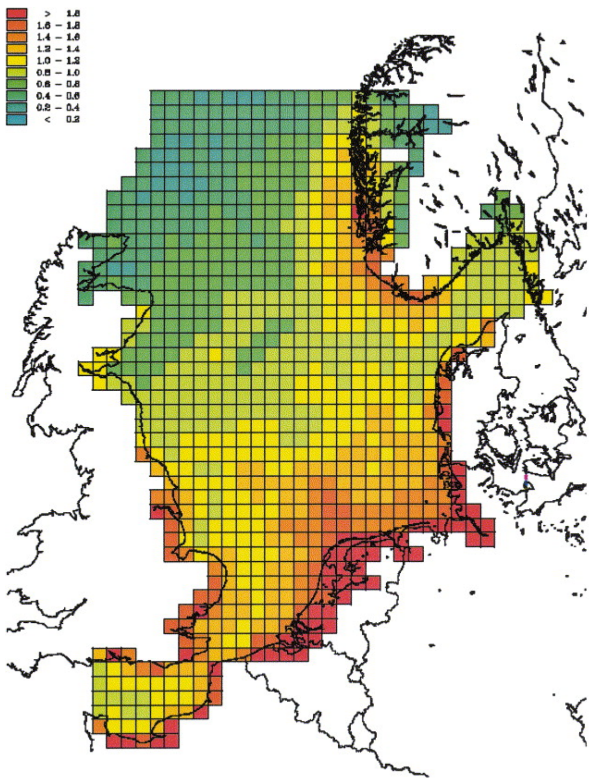
Focus on WW treatment in 1970's

- Pretreatment
- Mechanical treatment
- Biological treatment
- Chemical treatment- Mostly primary and secondary treatment without biological stage

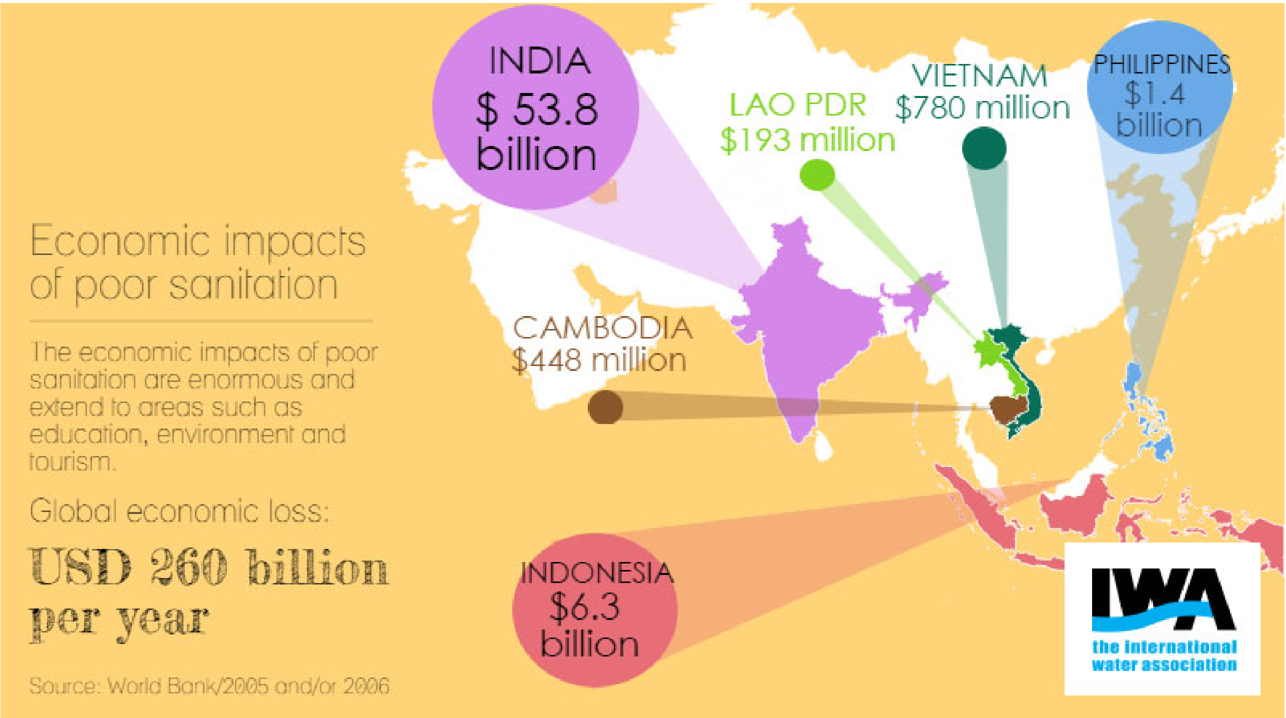


- Org-C + O_2 ➔ CO_2
- NH_4-N + O_2 ➔ NO_2 + O_2 ➔ NO_3 (➔ N_2)

Nitrogen in North sea 1998



Economic impact on poor sanitation



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Discharge permits in Norway: norskutslipp.no

level.

- Frontpage
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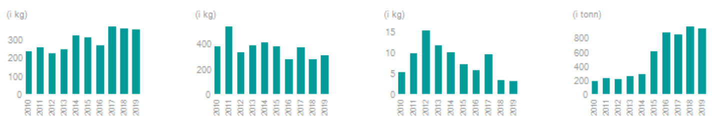

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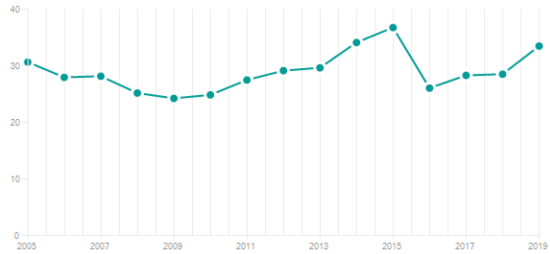

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NH_3-N	15	25	5(8)*	8(15)*	25(30)*	1.5

* Lower than 12 °C in the bracket.

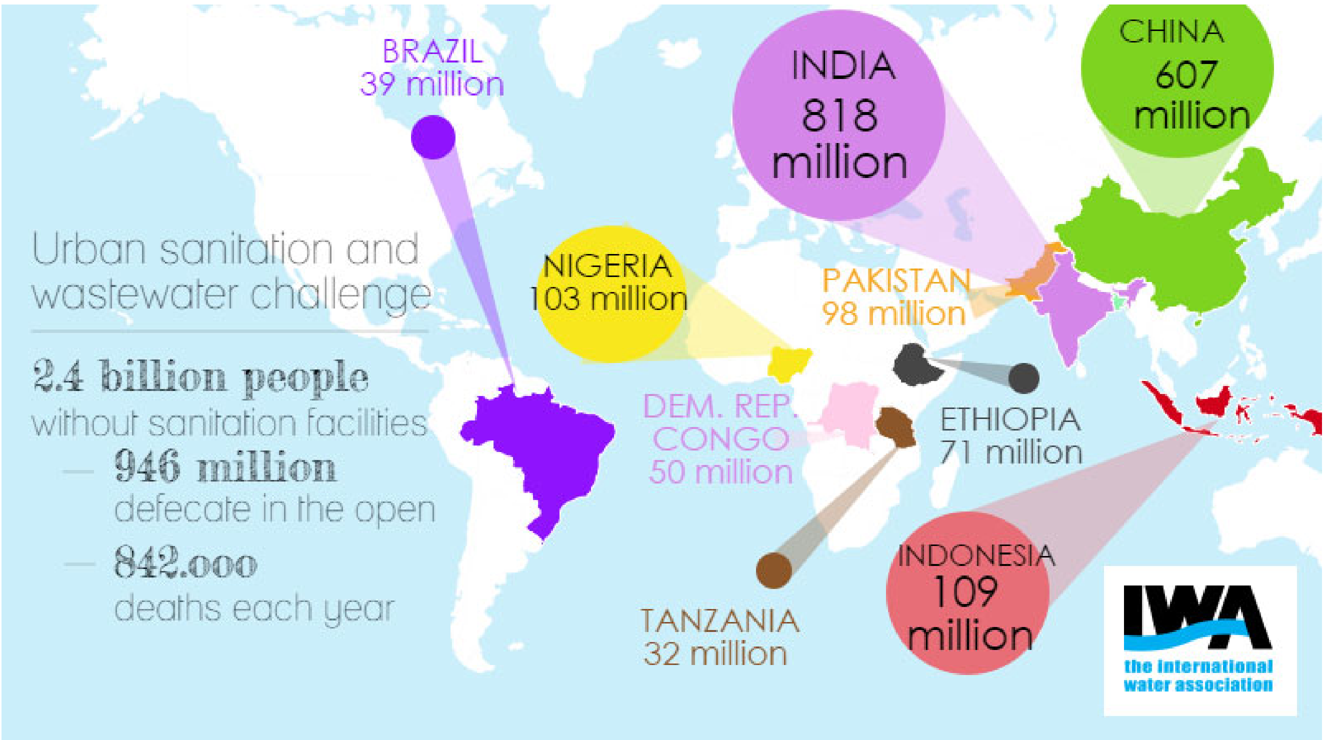
Country	PE treated	pH	t (°C)	SS (mg SS/l)	DO (mg O_2/l)	COD (mg COD/l)	BOD_5 (mg BOD_5/l)	TN (mg N/L)	Total ammonium (mg NH_4-N/l)	Total ammonia (mg NH_3-N/l)	TP (mg P/l)	Microbial indicators
EU Urban Wastewater Treatment Directive (UWWTD)[p]	>2,000			35/90% reduction		125/75% reduction	25/70-90% reduction	–			–	
	10,000 – 100,000							15			2	
	>100,000							10			1	
Ireland	≤10			30			20	5	20		2	
	>2,000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
France	<20			30			35					
	20 - 2000	6–8.5	<25	50% reduction		60% reduction	35, 60% reduction					
	>2000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
Romania	>2,000	UWWTD apply as a minimum, but may be more stringent to comply with Water Framework Directive (WFD)										
Ecuador		6 - 9	±3[q]	130		200	100	50 TKN	30		10	<2000 FC MPN/100 ml
Tanzania		6.5–8.5	20–35	100 TSS		60	30	15 TKN			6	<10,000 TC counts/ 100 ml
Jordan				60 TSS	>1	150	60	70			15 as T-PO_4	<1,000 *E. coli* MPN/100 ml Nematodes < 1
India 2015		6.5–9		20 TSS		50	10	10	<5			<100 FC MPN/100 ml
India 2017/18	Metro	6.5–9		50 TSS			20					<1,000 FC MPN/100 ml
	Non-metro			100 TSS			30					
India NGT 2019		5.5–9		20 TSS		50	10	10			1	<230 FC MPN/100 ml
India 1986[r] Inland water		5.5–9	<5	100		250	30	100 TKN		5 as free NH_3	5 diss. PO_4 as P	
Land irrigation				200			100					

Note to the table: Coliforms represented include E. coli, Fecal Coliforms (FC) and Total Coliforms (TC).
[o]Detail for ranges of permitted consents omitted from this version for clarity.
[p]TP and TN only considered in designated "sensitive" areas.
[q]Of the receiving water body.
[r]Total set covers a range of 40 parameters and three further application areas for discharge into public sewer, marine coastal areas.

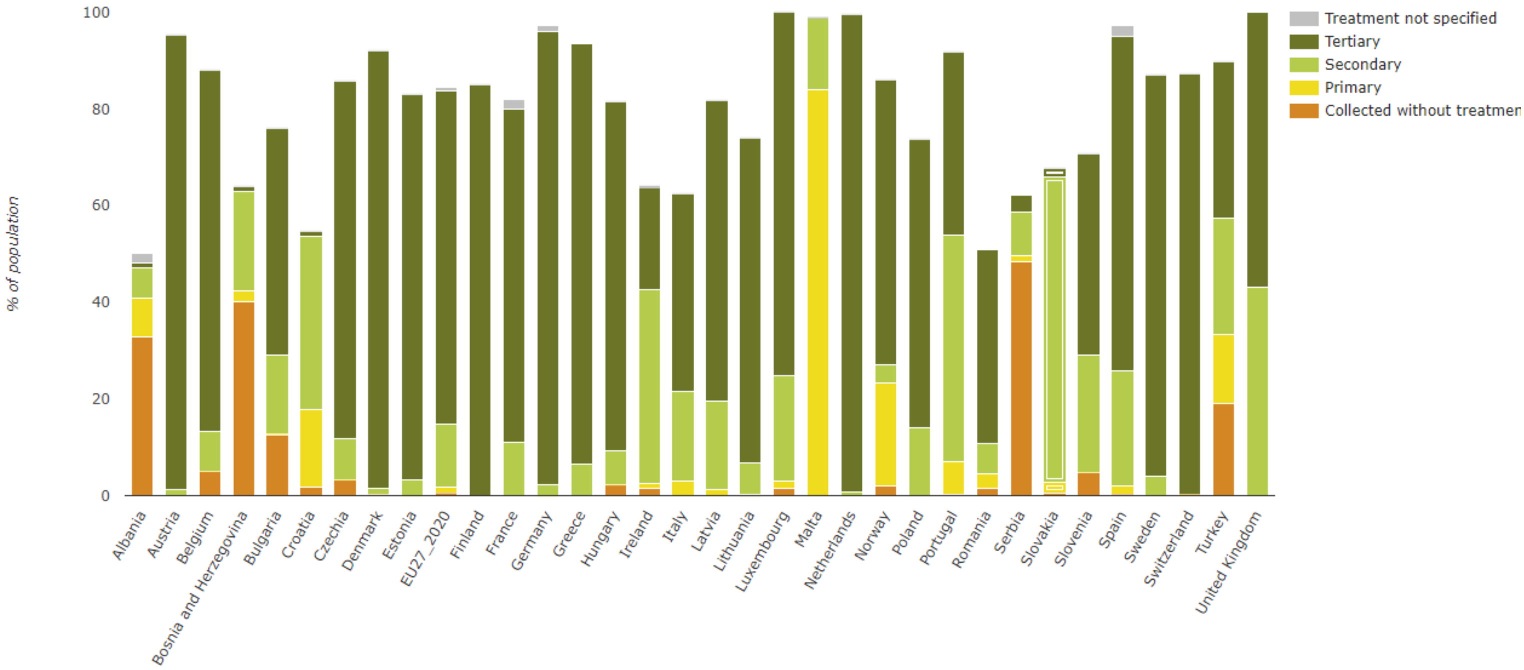
Outline

- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

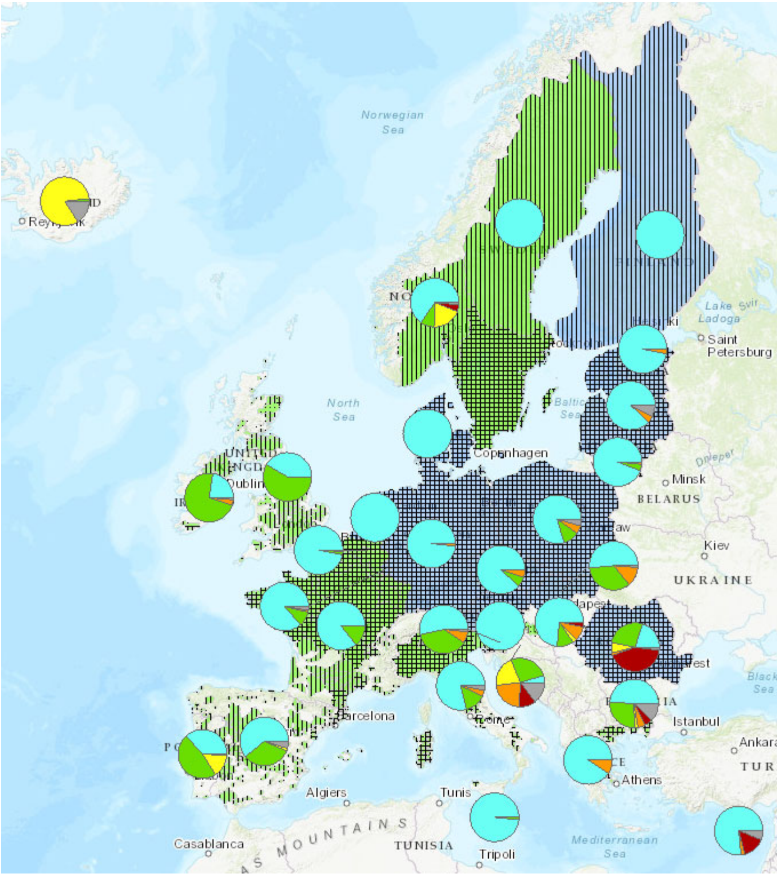
Urban sanitation and ww challenge



Urban wastewater collected and treated-Europe



WWT in Europe



UWWT agglomerations treatment pathways

UWWTD agglomerations treatment pathways

Waste water treatment pathways by member state

- More stringent treatment
- Secondary treatment
- Primary treatment
- Addressed through individual and appropriate systems (IAS)
- Not collected in collecting systems and not addressed through IAS
- No treatment / no information

UWWTD receiving areas, catchments

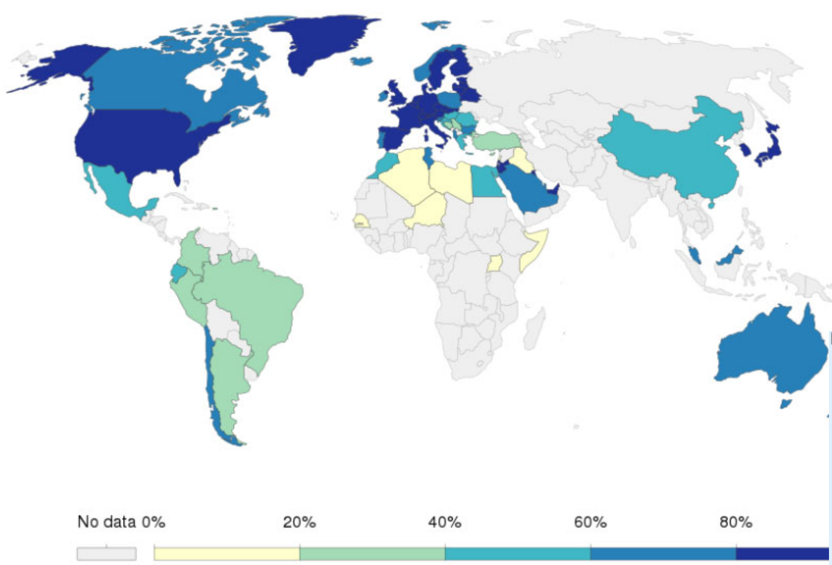
Catchments - sensitivity type

- Nitrogen
- Phosphorus
- N and P
- Other

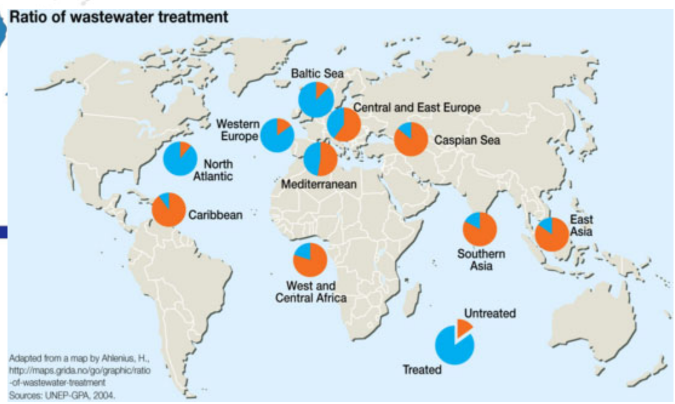
Catchments

- Application of Art. 5(8)
- Sensitive area

Share of domestic wastewater that is safely treated, 2018



Source: UN Statistics Division (2019)



Open www.menti.com code 1120 3592

Wastewater management
Needs, challenges and legislation:
EU and WHO

Harsha Ratnaweera
THT311-2021

Outline

- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

What is wastewater?

Wastewater is...

Combination of the liquid or water-carried wastes

Wastewater types...

Household and municipal wastewater

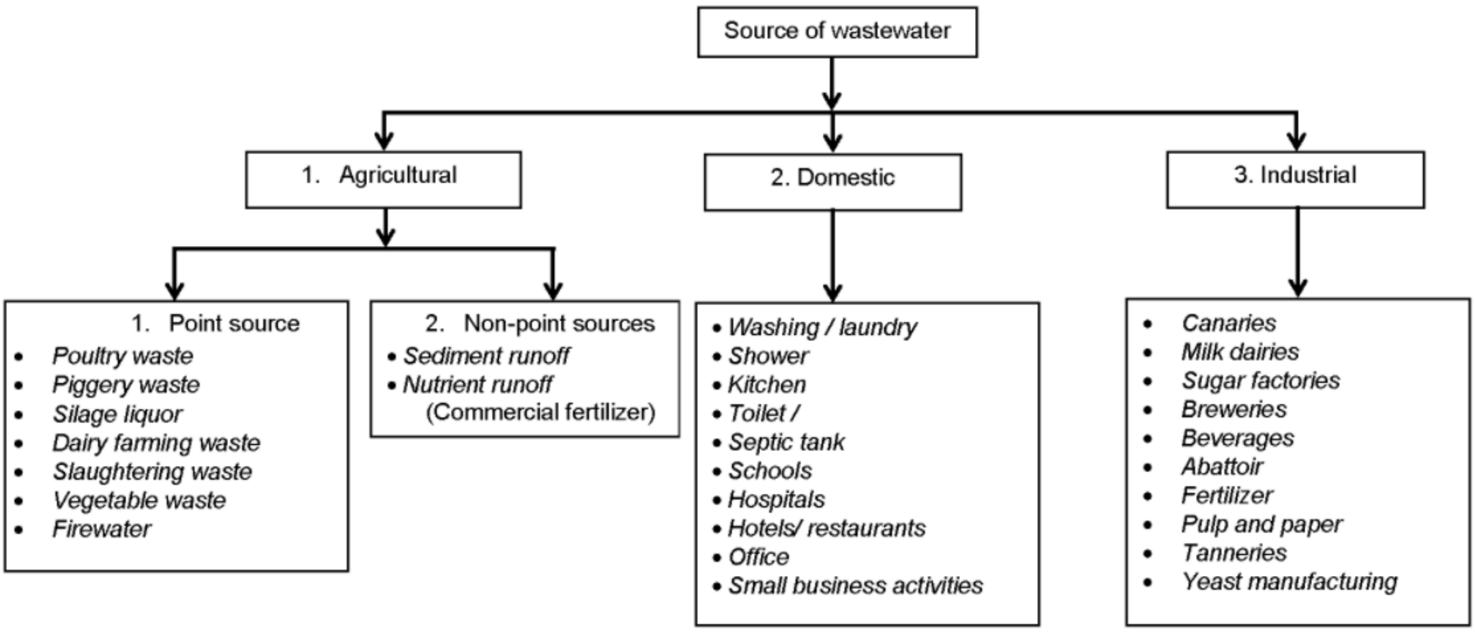
Industrial wastewater (cooling and process water)

Agricultural wastewater

Rainwater overflows

Infiltrated water

Sources of wastewater



Wastewater constituents

Nutrients

Nitrogen N, phosphorus P and carbon C

Heavy metals

Industrial/commercial wastewater (Zn, Cu, Cr etc.)

Suspended solids

Solid particles in suspension

Biodegradable organics

Mostly carbohydrates, fats and proteins

Wastewater constituents

Pathogens

Viruses, bacteria, protozoa

Priority pollutants

Proved or suspected to be carcinogenic, mutagenic, toxic or teratogenicity compounds

Refractory organics

Not easily removed during conventional treatment pollutants (phenols, pesticides, surfactants etc.)

Dissolved inorganics

Pollutants from household activities (Ca, Na, sulphate etc.)

Definitions in UWWTD

One population equivalent 1 p.e.

"The organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day"

Generated load = "size" of agglomeration expressed in p.e.

1 p.e. means pollution load produced by **1 person** within 24 hours and takes into account

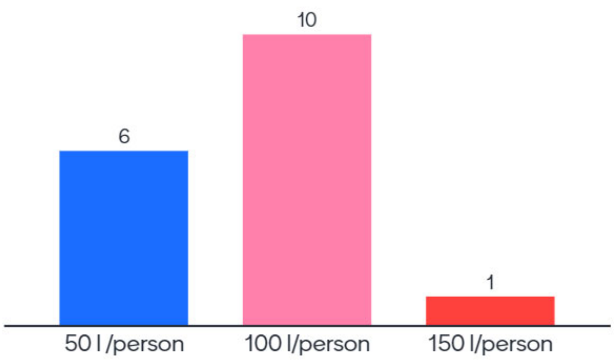
- Resident and non-resident population
- Industries covered by Art.11 UWWTD
- Industrial wastewater from small and medium enterprises
- All remaining urban wastewater

Your answers

Go to www.menti.com and use the code 1120 3592

How much water do we (in an urban area/city) use per day for domestic purposes?

Mentimeter



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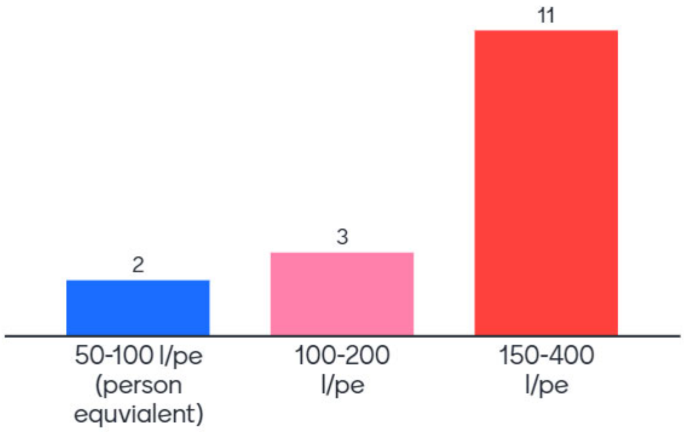
Your answers

How much wastewater should we expect to treat per day (at treatment plants)?

Mentimeter



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Some wastewater related problems

- Human and wildlife acute and chronic health risks
  - Brain and nervous system
  - Endocrine system disruption
  - Toxicity
  - Cancer etc.
- Drinking water source contamination
  - Infiltrated wastewater from sewage leaks into groundwater
  - Discharge of untreated wastewater into surface water
- Poor ecological and chemical water status
  - Eutrophication

Wastewater status in 60's and 70's in Norway

- Almost no WWTPs
- But many sewers with poor quality
- Main purpose was to transport WW from housing areas.

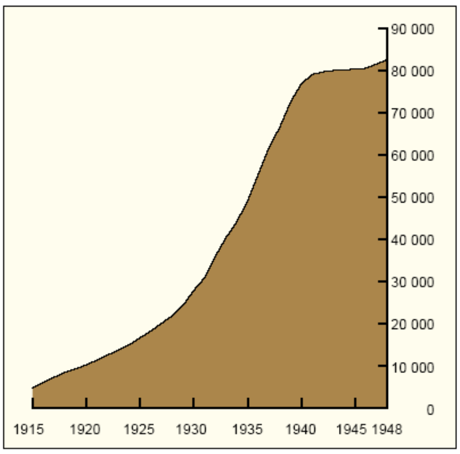
- "Dillution is solution to pollution"

Massive pollution….

- Increased use of water closets
- Septic tanks as the only treatment
- Serious pollutions in rivers, lakes and fjords.
- High bacteria concentrations
- Low oxygen content in recipients
- Massive algal blooms due to N and P

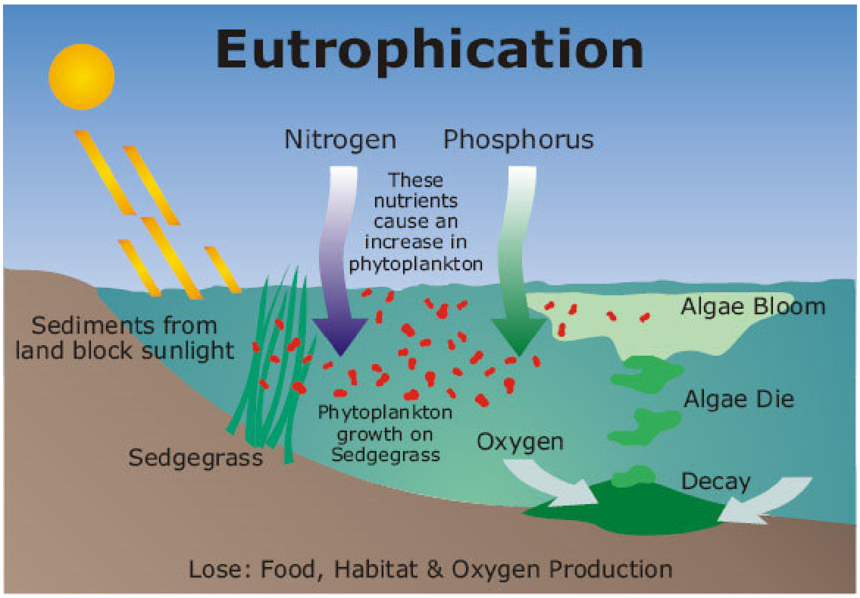
Masseforekomst av plank-tonalger i Bispevika og Bjørvika på 1970-tallet. (Foto: Fjellanger Widerøe VisKom).

Number of water closets in Oslo 1915-1948



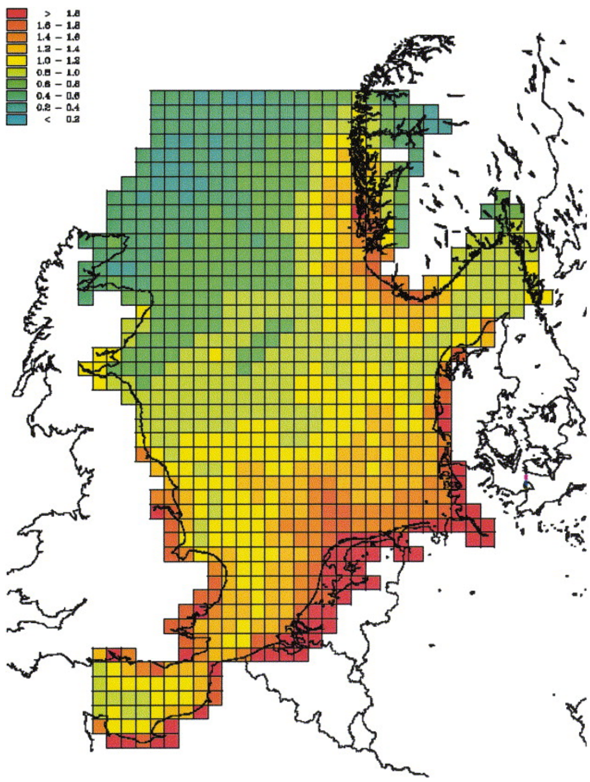
Focus on WW treatment in 1970's

- Pretreatment
- Mechanical treatment
- Biological treatment
- Chemical treatment- Mostly primary and secondary treatment without biological stage

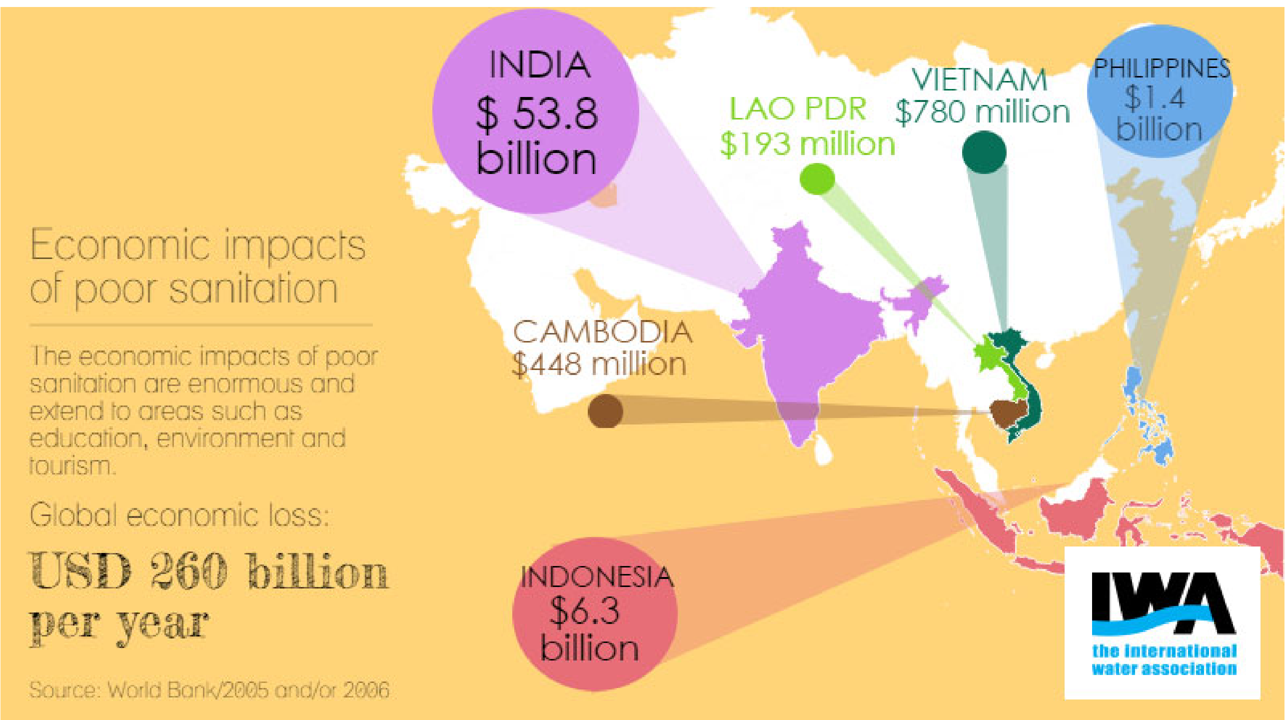


- Org-C + O_2 ➔ CO_2
- NH_4-N + O_2 ➔ NO_2 + O_2 ➔ NO_3 (➔ N_2)

Nitrogen in North sea 1998



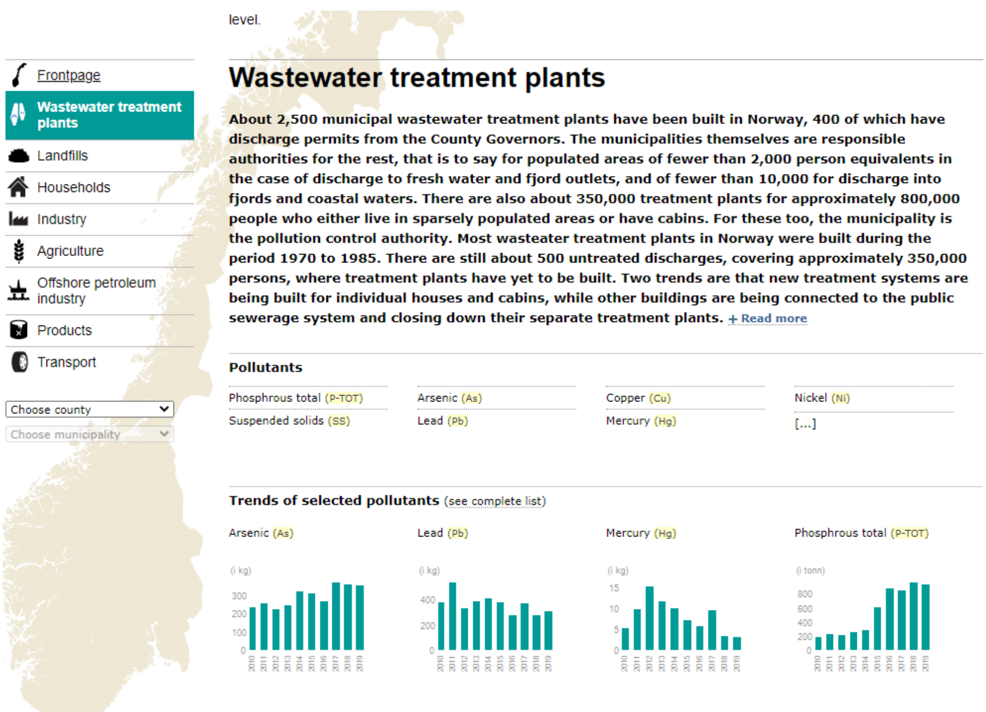
Economic impact on poor sanitation

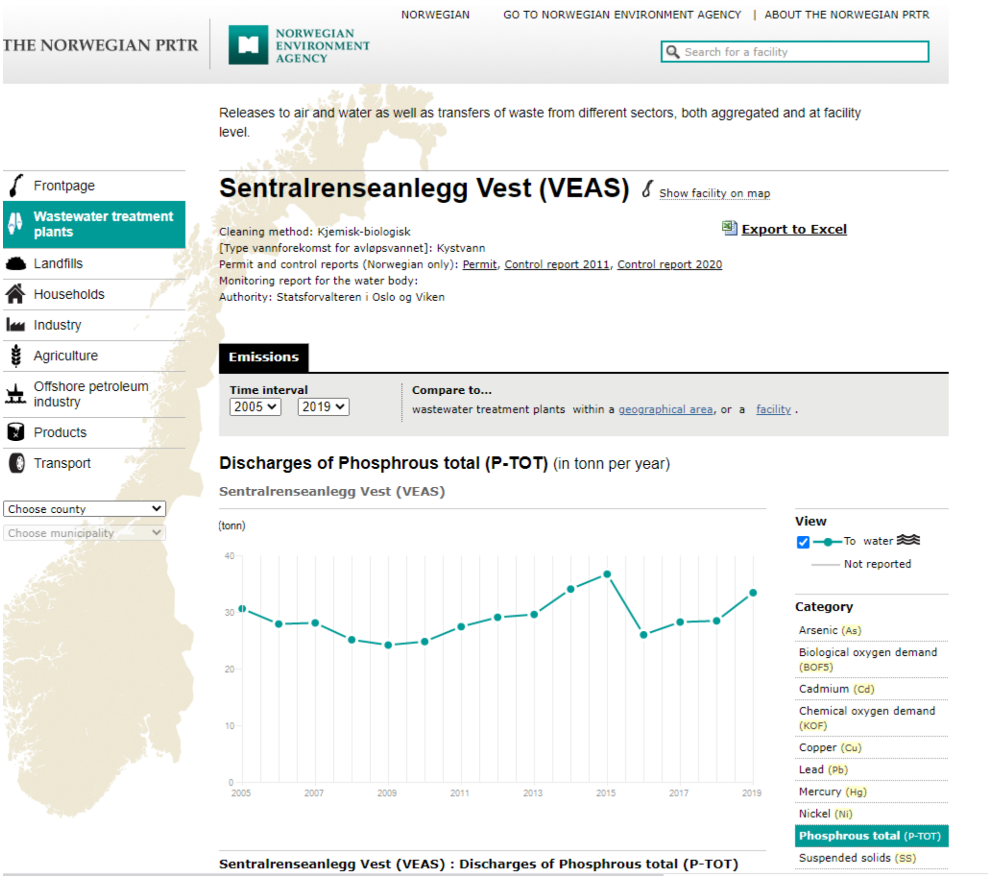


Outline

- Sources of wastewater and need for treatment
- WW discharge legislations
- Status of WW treatment

Discharge permits in Norway: norskutslipp.no





EU Directives

- Bathing Water Directive 1976
- Sewage Sludge Directive 1986
- Drinking Water Directive 1998/2021
- Nitrates Directive 1991
- Urban Waste Water Treatment Directive 1991
- Water Framework Directive 2000
- Floods Directive 2007
- Groundwater Directive 2009

Water pollution – EU rules on urban wastewater treatment (update)

In preparation

Roadmap

Feedback period

21 July 2020 - 08 September 2020

FEEDBACK: CLOSED

UPCOMING

Public consultation

Consultation period

First quarter 2021

FEEDBACK: UPCOMING

Commission adoption

Planned for

First quarter 2022

FEEDBACK: UPCOMING

About this initiative

Summary	Making sure that urban wastewater is clean and safe is vital for protecting public health and the environment. This key part of EU water policy is covered by the Urban Wastewater Treatment Directive. This initiative will revise the Directive after a recent evaluation of it identified certain shortcomings and new societal needs that must be addressed.
Topic	Environment
Type of act	Proposal for a directive

Roadmap

FEEDBACK: CLOSED

Type

Inception impact assessment

More about roadmaps

Feedback period

21 July 2020 - 08 September 2020 (midnight Brussels time)

View feedback received >

European Commission

Urban Wastewater Treatment Directive (91/271/EEC)

Aims to...

Protect the environment from the adverse effects of wastewater discharges

Concerns...

Collection, treatment and discharge of **urban wastewater**

Treatment and discharge of certain **industrial wastewaters**

Requires...

Certain level of **treatment** (primary, secondary or tertiary) depending on the **sensitivity** of receiving area

Definitions in UWWTD

Sensitive areas

Freshwater bodies, estuaries and coastal waters which are **eutrophic or may become** in the near future if protection measures are not taken

Surface freshwater used for abstraction of drinking water which **could contain 50 mg/L of nitrate** (Directive 75/440/EEC)

Areas where further treatment is necessary to **satisfy other Directives**

Sensitive areas in Nordic countries

Receiving water – agglomerations > 2000 pe Number (in red: % of total pe)

Country	Coastal waters			Fresh water and estuaries		
	Less sensitive	Normal	Sensitive	Less sensitive	Normal	Sensitive (incl. soil)
Denmark	Only sensitve areas		70 %	Only sensitve areas		30 %
Sweden	Only sensitve areas		39 58 %	Only sensitve areas		328 48%
Finland	0 %	0 %	26 43 %	0 %	0 %	164 57 %
Norway	37 23 %	0 0 %	23 42 %	0 0 %	7 7 %	92 26 %
Iceland	Only less sensitve areas					

Ødegaard, 2017

Wastewater limit values in UWWTD

Parameter	Type of waters	
	Normal waters	Sensitive Waters
BOD5	25 mgO2/L	25 mgO2/L
Minimum % of reduction	70 - 90%	70 - 90%
COD	125 mgO2/L	125 mgO2/L
Minimum % of reduction	75%	75%
TSS	35 mg/L	35 mg/L
Minimum % of reduction	90%	90%
Total Nitrogen		
10 000 - 100 000 p.e.	-	15 mg/L (70 - 80%)
>100 000 p.e.	-	10 mg/L (70 - 80%)
Total Phosphorus		
10 000 - 100 000 p.e.	-	2 mg/L (80%)
>100 000 p.e.	-	1 mg/L (80%)

WW discharge limits in Africa and Asia

.4 Parameter	.4 Unit	Effluent Discharge Standards						
		Africa				Asia		
		Nigeria	Tanzania	Ghana	Uganda	Thailand	Malaysia	India
Temperature	°C	40	-na-	-na-	35	40	40	-na-
pH	-	6–9	6.5–8.5	6–9	6–8	5.5–9	5.5–9.0	6.5–8.5
BOD	mg O_2/L	30–50	30	50	50	20–60	50	30
COD	mg O_2/L	60–90	60	250	100	120–400	100	250
Oil and grease	mg/L	10	5	5	10	5–15	10	10
DS	mg/L	200	3000	1000	1200	3000	-na-	-na-
SS	mg/L	25	100	50	100	50	100	50–100
Total N	mg/L	10	10	-na-	10	-na-	-na-	10

WW discharge limits in China

Indicator	Integrated Wastewater Discharge Standard (GB8978–1996)		Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB 18918–2002)			Environmental Quality Standards for Surface Water (GB-3838-2002)
	Grade I	Grade II	Grade I-A	Grade I-B	Grade II	Grade IV
SS	20	30	10	20	30	–
COD	60	120	50	60	100	30
BOD_5	20	30	10	20	30	6
TN	–	–	15	20	–	1.5
TP	–	–	0.5	1	3	0.3(0.1 lake)
NH_3-N	15	25	5(8)*	8(15)*	25(30)*	1.5

* Lower than 12 °C in the bracket.

Country	PE treated	pH	t (°C)	SS (mg SS/l)	DO (mg O_2/l)	COD (mg COD/l)	BOD_5 (mg BOD_5/l)	TN (mg N/L)	Total ammonium (mg NH_4-N/l)	Total ammonia (mg NH_3-N/l)	TP (mg P/l)	Microbial indicators
EU Urban Wastewater Treatment Directive (UWWTD)[p]	>2,000			35/90% reduction		125/75% reduction	25/70-90% reduction	–			–	
	10,000 – 100,000							15			2	
	>100,000							10			1	
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India 2015		6.5–9		20 TSS		50	10	10	<5			<100 FC MPN/100 ml
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	Non-metro			100 TSS			30					
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Note to the table: Coliforms represented include E. coli, Fecal Coliforms (FC) and Total Coliforms (TC).
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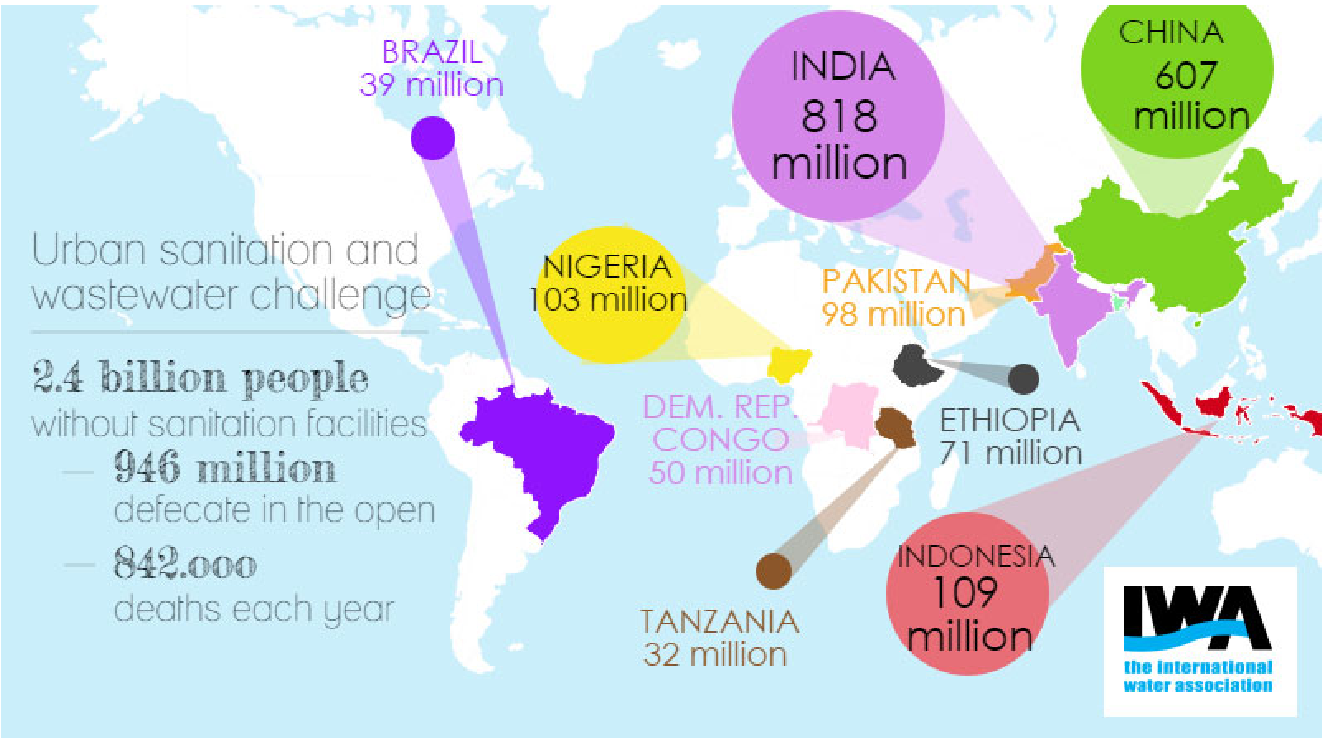
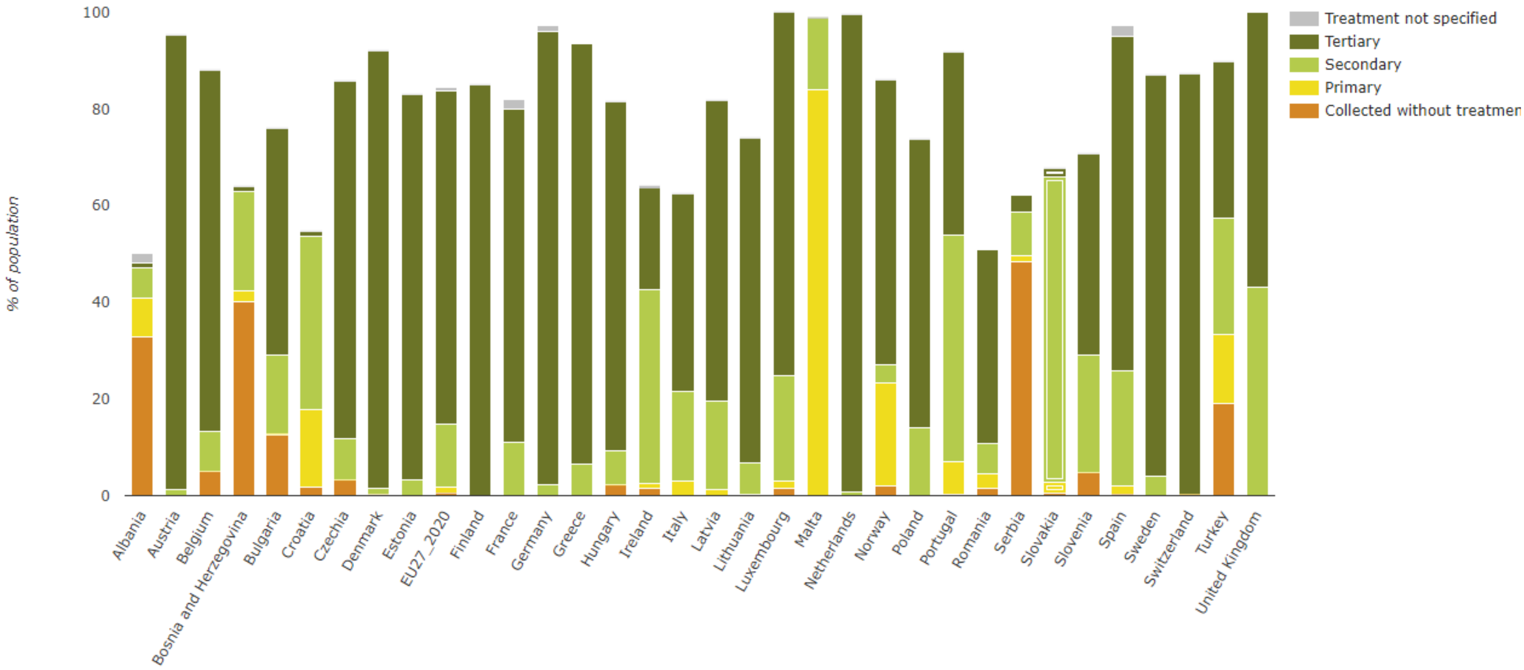


Urban wastewater collected and treated-Europe



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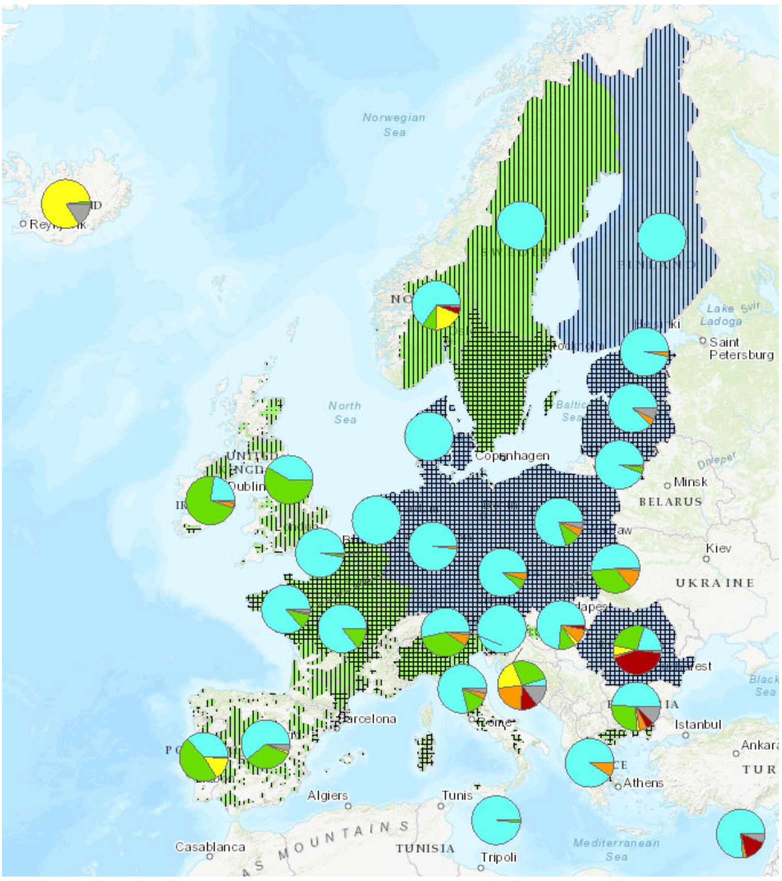

UWWT agglomerations treatment pathways

UWWTD agglomerations treatment pathways

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UWWTD receiving areas, catchments

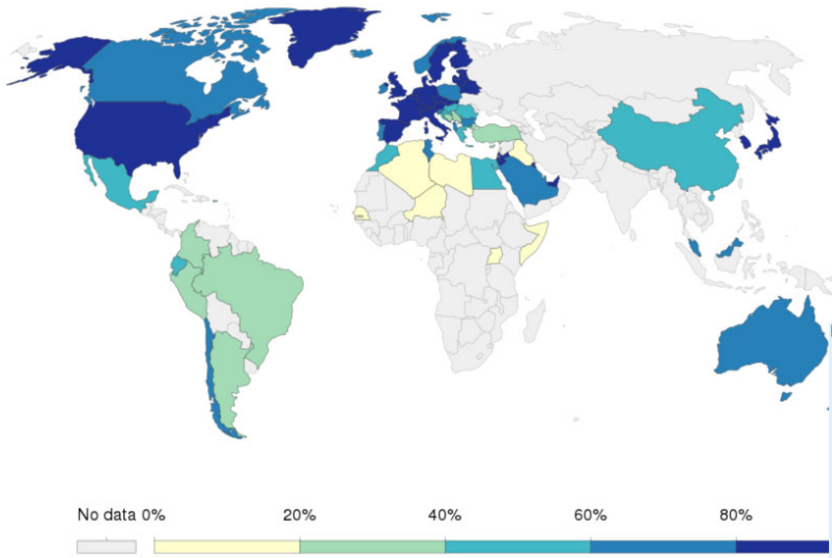
Catchments - sensitivity type

- Nitrogen
- Phosphorus
- N and P
- Other

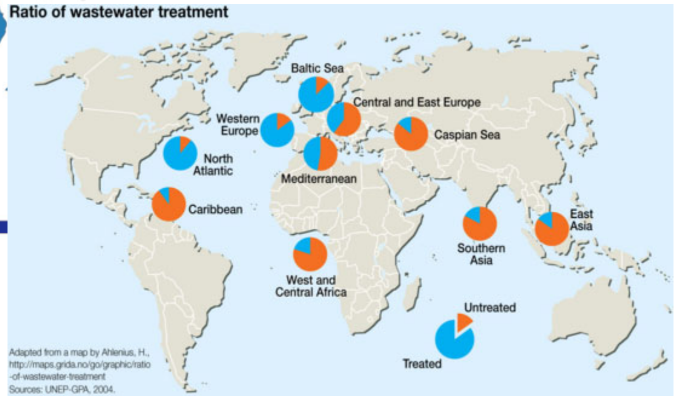
Catchments

- Application of Art. 5(8)
- Sensitive area

Share of domestic wastewater that is safely treated, 2018



Source: UN Statistics Division (2019)



Your answers

Mentimeter

Why do we need to treat wastewater?

ecological state of natur
for future
polluting substunces
safety
planet health
in order to improve the
enviroment
ecological state
health
environment protection
to avoid illness
people's health
reuse
extinction of species
microrganisms
planet
ecology
healthy
living
life
nature
boby cant remain alive
it is important for a per
prices
recycling
heath

23

Your answers

Water, a scarce resource – need for sound management

THT 311-2021

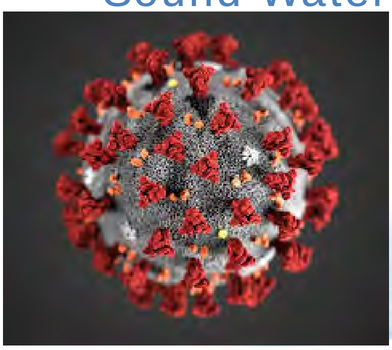
Water Resources Management & and Water and Wastewater Treatment

Haakon Thaulow

Ex: Norwegian Water Research Institute - NIVA

Covid - 19 - Water

- Handwash: Key protection measure!
- Not detected in water supply systems (EPA)
  (but some researchers - - -)
- Covid 19: Water supply – wastewater
  No more risk than other virus
- UN: More financing for water protection needed
- Water crucial to combat Covid 19!
- Sound Water Management !



World Food Programme

Nobels fredspris 2020

OPPSUMMERT

Nobels fredspris for 2020 tildeles Verdens matvareprogram (WFP). WFP får prisen for innsatsen i kampen mot sult, for bidrag til å skape forutsetninger for fred i konfliktutsatte områder, og for å være pådriver i arbeidet mot bruken av sult som våpen

DET KONGELEGE
KLIMA- OG MILJØDEPARTEMENT

Meld. St. 13

(2020–2021)

Melding til Stortinget

Klimaplan for 2021–2030

Parliamentary report to the Storting- «White Paper»

NIVA

UN: Two major challenges:

Biodiversity

Climate Change

-Water Stories I

- UNs Sustainable goals – Waters key role
- UN -World Water Day - Water and Climate
- Water Crises - World Economic Forum
- Freshwater as a resource
  «Water Crises Drivers »
- The «Water–Energy-Food» nexus
- Water Crises – Water Wars? - where and why?

Water Stories II -

- Strategies for actions and solutions - IWRM Integrated Water Resources Management
- The European approach- the EU Water Framework Directive
- Water Resources in Norway – our situation in brief

SUSTAINABLE DEVELOPMENT GOALS

FN s bærekraftsmål- 2030

NIVA

SUSTAINABLE DEVELOPMENT GOALS

17 GOALS TO TRANSFORM OUR WORLD

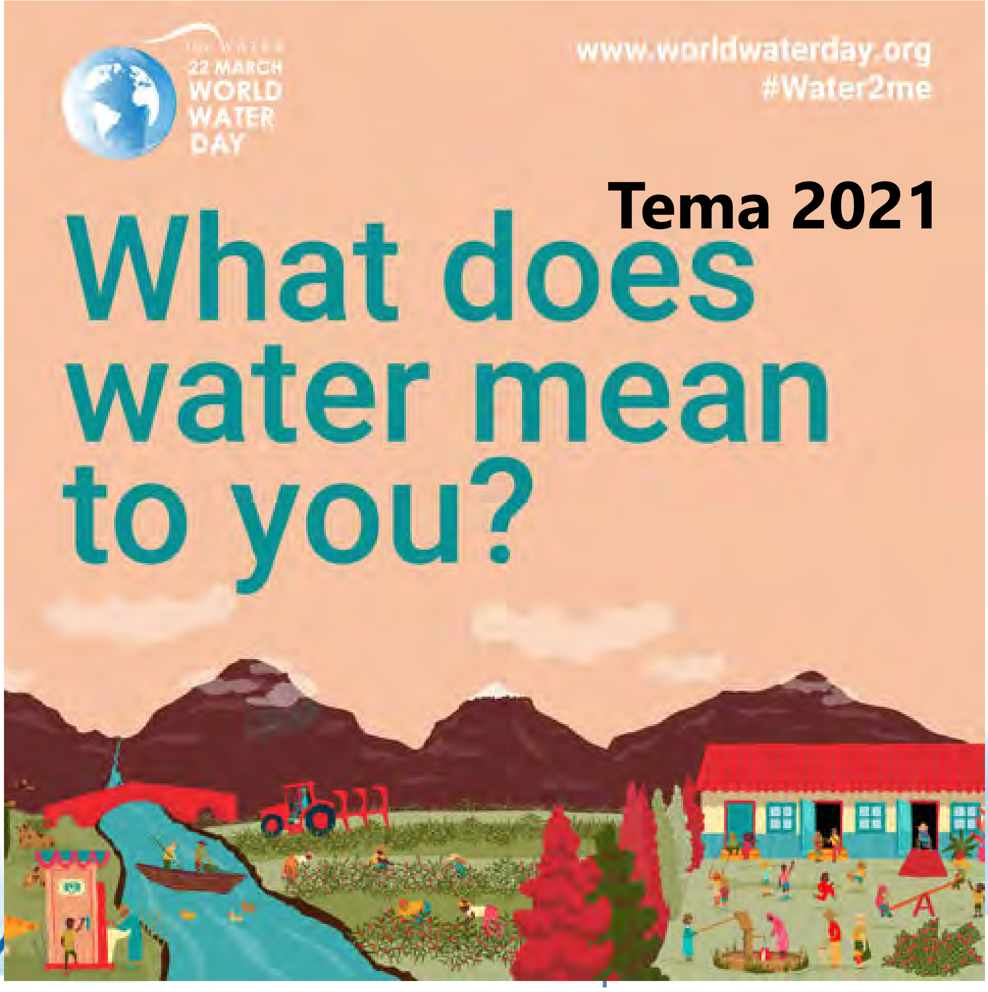
- By **2030**, achieve **universal and equitable access to safe and affordable drinking water** for all
- By **2030**, achieve **access to adequate and equitable sanitation and hygiene** for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- By **2030**, **improve water quality by reducing pollution**, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- By **2030,** substantially **increase water-use efficiency** across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- By **2030**, implement **integrated water resources management** at all levels, including through transboundary cooperation as appropriate
- By **2020**, **protect and restore water-related ecosystems**, including mountains, forests, wetlands, rivers, aquifers and lakes
- By **2030**, **expand international cooperation and capacity-building support** to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
- Support and strengthen the **participation of local communities** in improving water and sanitation management

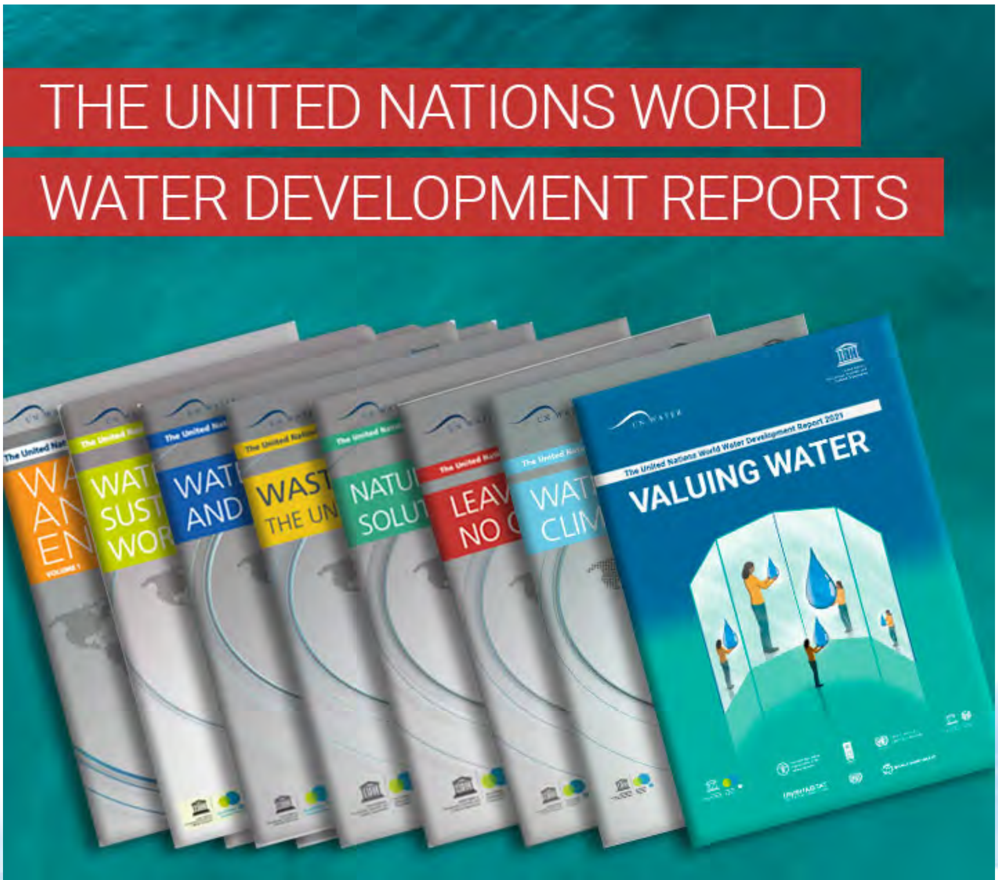
6 CLEAN WATER AND SANITATION

UN Water

World Water Development Report – 2021

March 22nd: «World Water Day»


22 MARCH
WORLD
WATER
DAY
www.worldwaterday.org
#Water2me
Tema 2021
What does
water mean
to you?


THE UNITED NATIONS WORLD
WATER DEVELOPMENT REPORTS
VALUING WATER

WATER AND CLIMATE CHANGE

World Water Day 2020, on 22 March, is about water and climate change – and how the two are inextricably linked.

Adapting to the water effects of climate change will protect health and save lives.

Using water more efficiently will reduce greenhouse gases.

We cannot afford to wait. **Everyone has a role to play.**

2020

Water and Climate Change

Wilder, warmer, wetter: larger and more frequent droughts, ocean level rise - -

Water and Climate Change

– **Causes and mitigation measures to reduce emissions of climate gases: water <u>not important</u>**

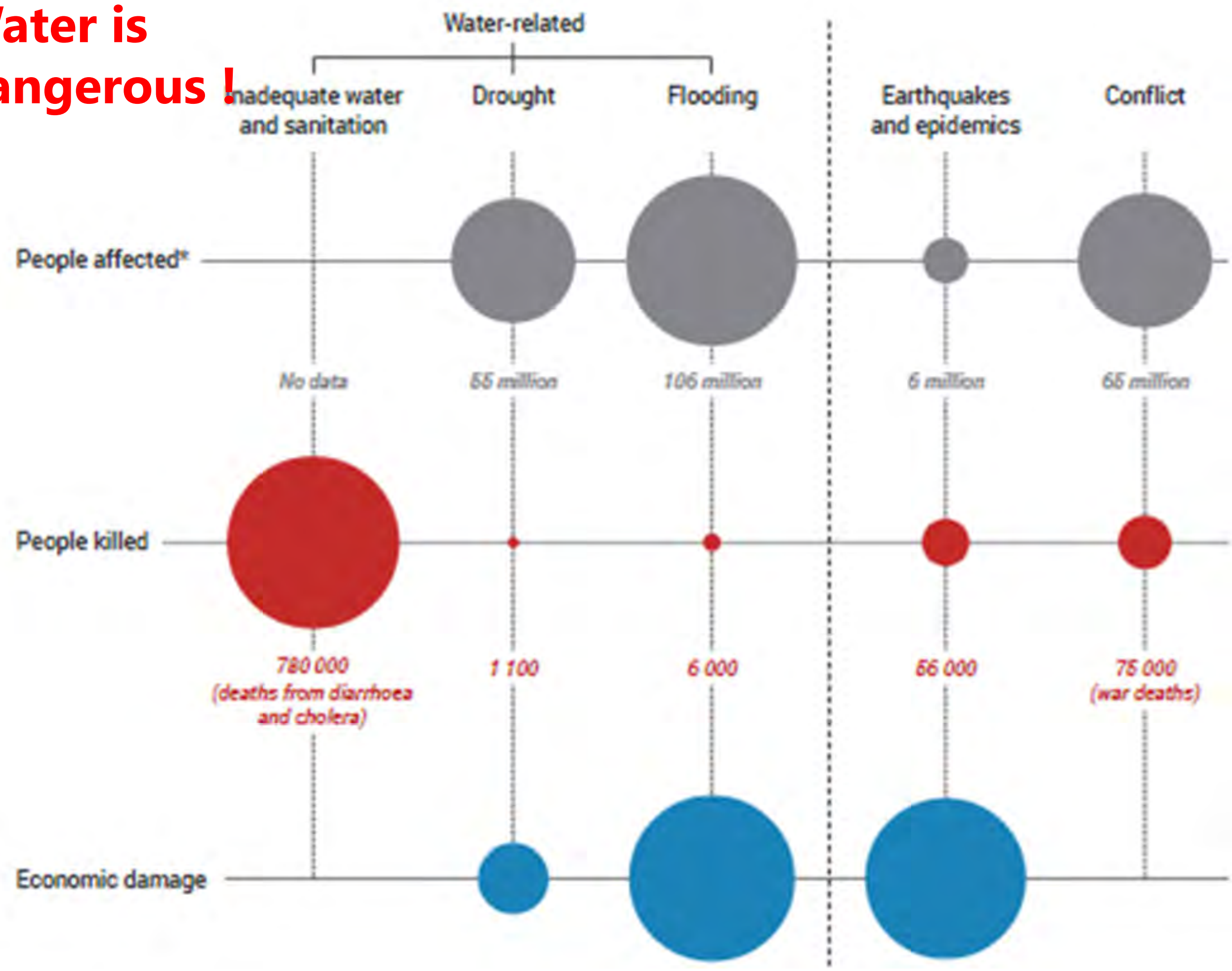
– **Impacts and adaptation measures: <u>Water in focus</u>**

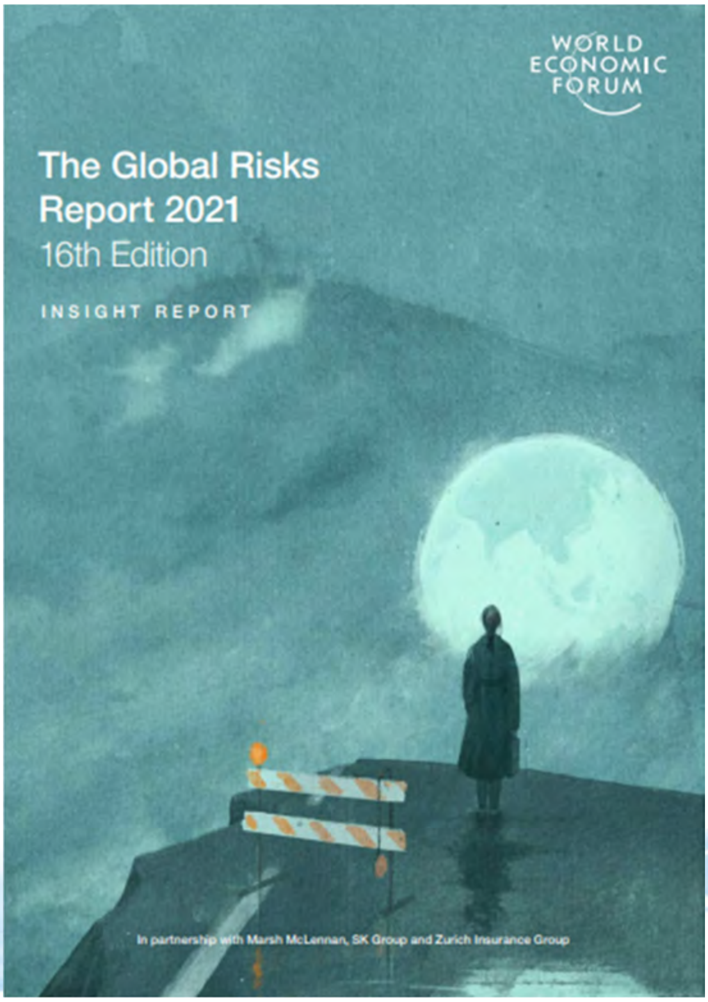
David Attenborough;
«The Garden of Eden is no more»

«Global Risk Report» 2021

World Economic Forum Annual Meeting -Davos

Water is dangerous !





NIVA

How do respondents perceive the impact ↑ and likelihood → of global risks?

2021

Top Risks
by likelihood

1. Extreme weather
2. Climate action failure
3. Human environmental damage
4. Infectious diseases
5. Biodiversity loss
6. Digital power concentration
7. Digital inequality
8. Interstate relations fracture
9. Cybersecurity failure
10. Livelihood crises

Top Risks
by impact

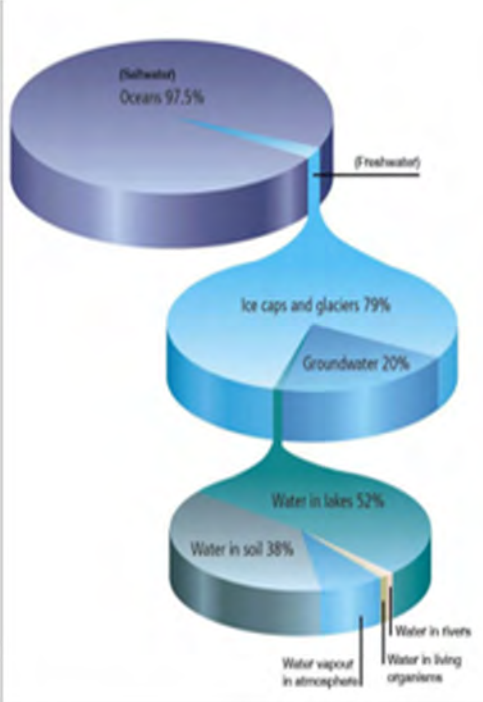
1. Infectious diseases
2. Climate action failure
3. Weapons of mass destruction
4. Biodiversity loss
5. Natural resource crises
6. Human environmental damage
7. Livelihood crises
8. Extreme weather
9. Debt crises
10. IT infrastructure breakdown

2020

Freshwater as a resource

Enough ,– but scarce - - -

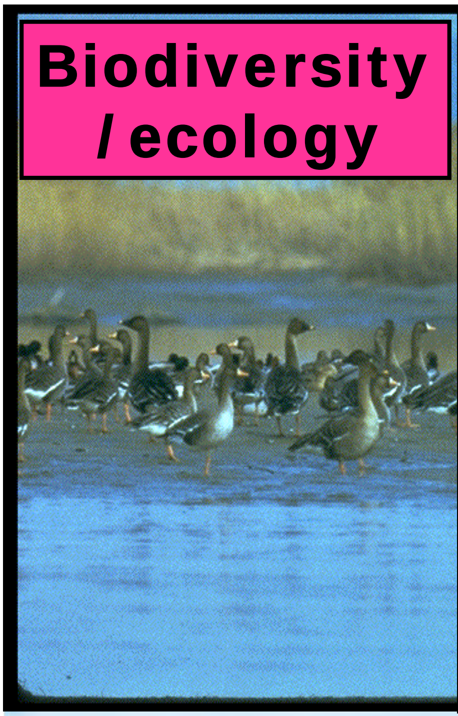
- 2,5% av all water of earths water is freshwater
- 2/3 of freshwater locked in glaciers/ice
- 20 % of the rest is inacessable
  er utilgjengelig
- 75 % of the rest- wrong place
  - at the wrong time
- For practical use; 0,08-0,1 % of total amount of water on earth -.

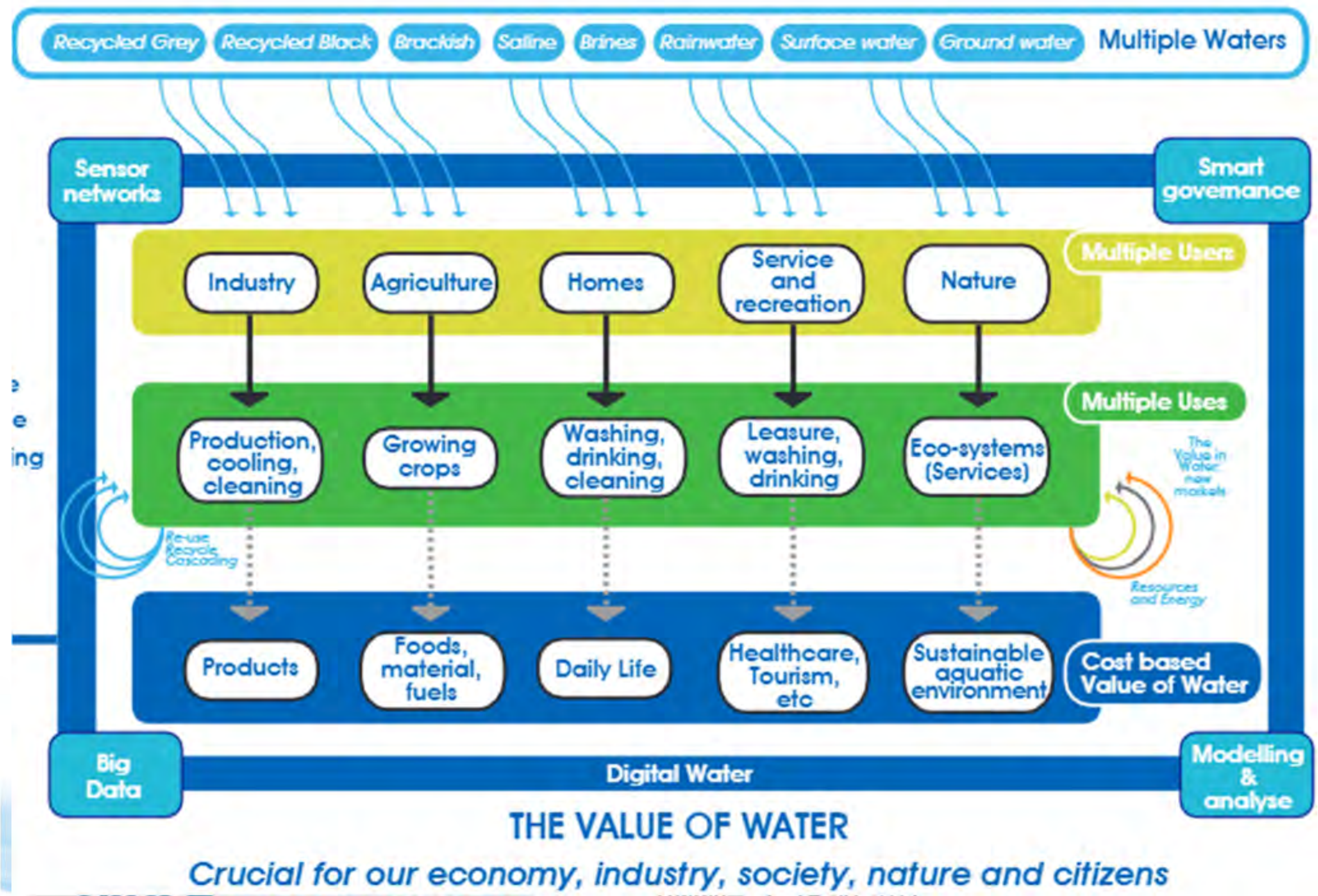


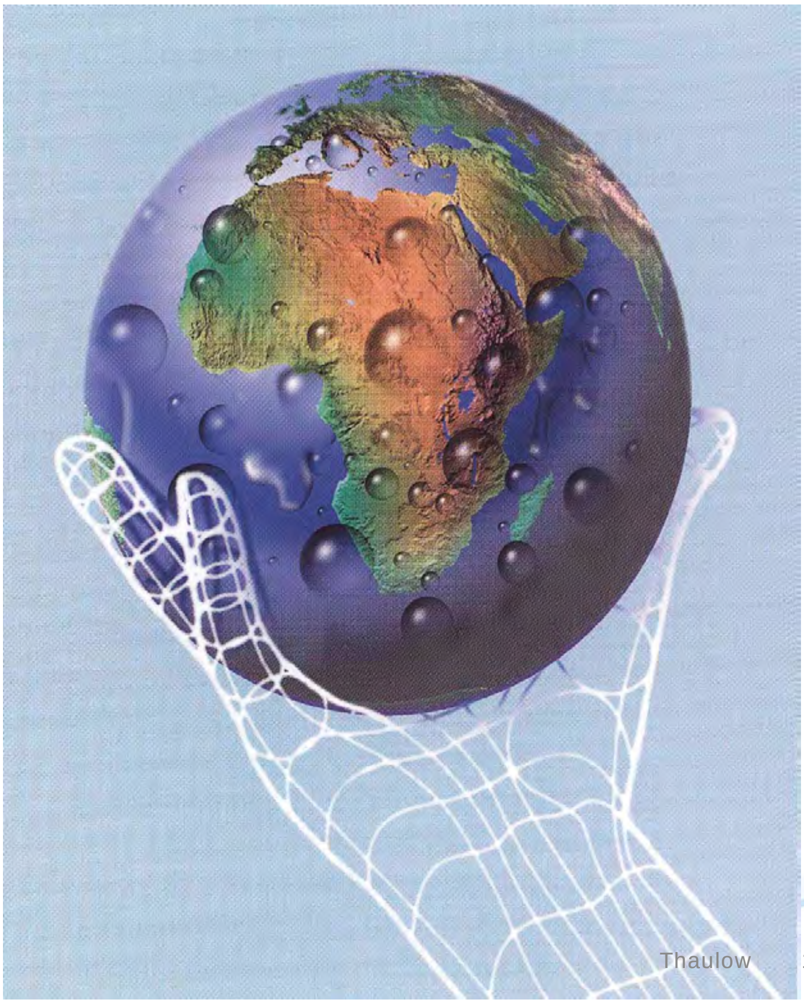
Water supply

Water for

Water Resources important for :







What is the problem?

Too little!

Too much!

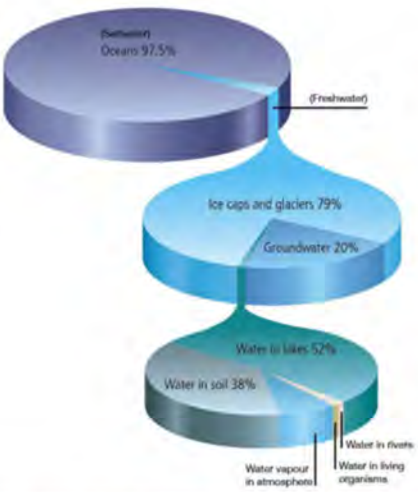
Poor quality!

Wrong place at wrong time!

Characteristica

- Universal, globally sufficient and renewable
- Irreplacable
- Problem areas: regional/local – not global (climate, ozon)
- Crossing national borders – international river basins dominate
- Water Management-complex issues – interdisciplinarily and crossectorial approaches –cooperation!

WATER RESOURCES FACTS



https://thiswoo.files.wordpress.com/2008/10/water-stats-pie21.jpg

Vannfakta (Kilde: Verdensbanken og The United Nations World Water Development Report 2018)

- 40% of the world population live in water scarce areas, and approximately 25% of world's GDP is exposed to this challenge.
- The roughly 1 billion people living in monsoonal basins and the 500 million people living in deltas are especially vulnerable.
- There are 276 transboundary basins, shared by 148 countries, which account for 60% of the global freshwater flow. Similarly, 300 aquifers systems are transboundary in nature.
- 2 billion people are dependent on groundwater.
- 40% shortfall (demand-supply) of water by 2030.

- Glimpses of water problems I

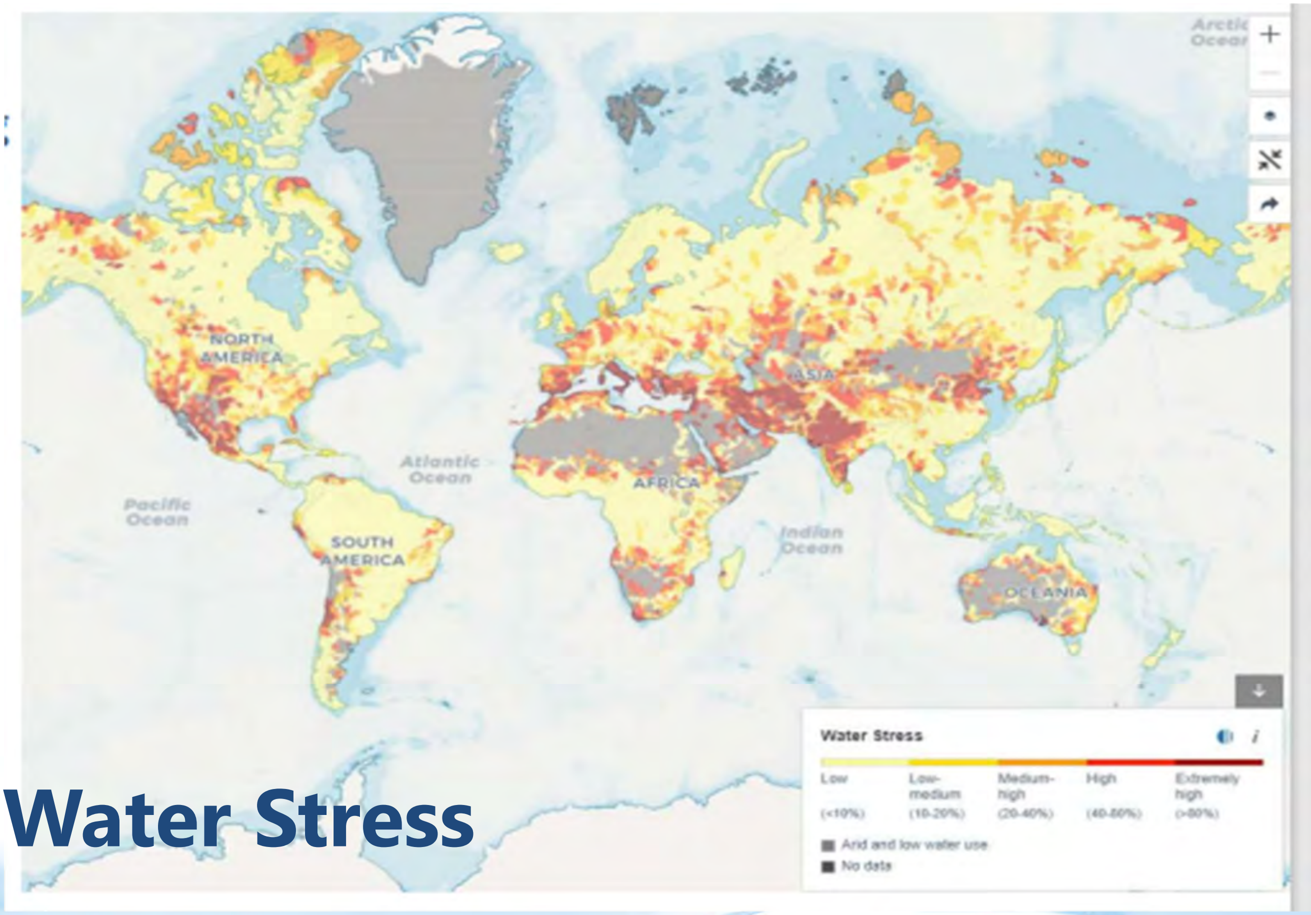
- 54 % of available water »used» , water availability per capita will decrease
- 800 millions lack safe water supply, more than 2 billions satisfactoriy sanitary solutions
- 2 billions in more than 40 countries affected by water shortage
- Freshwater ecosystems most threatned, 1/5 number of species strongly decreasing

- Glimpses of Water Problems II

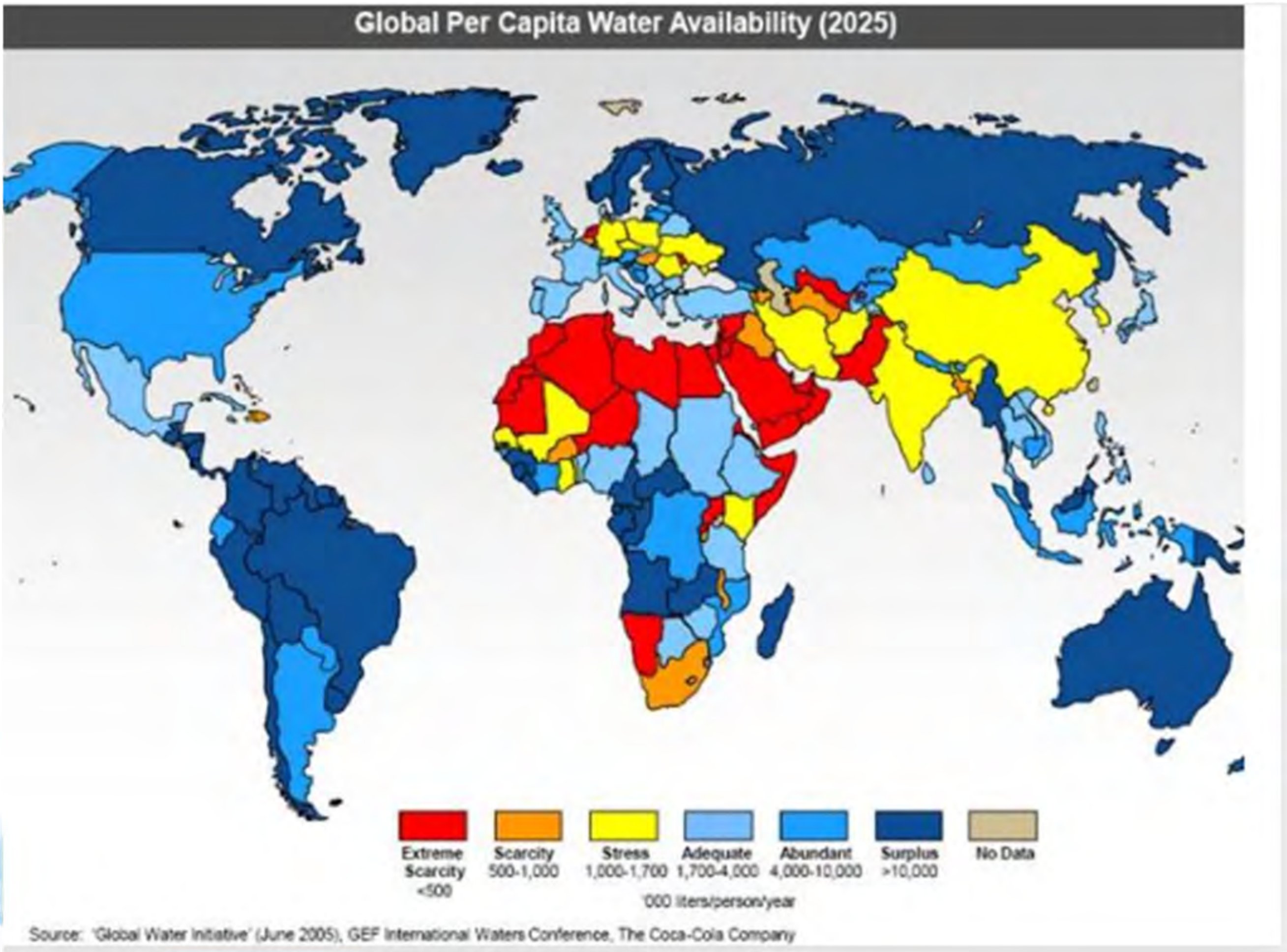
- 50% experience lack of water one month a year

- 40 % of acriculture production depend on irrigation

- Last 20 years – 166 000 deaths due to floods and droughts



Water Stress



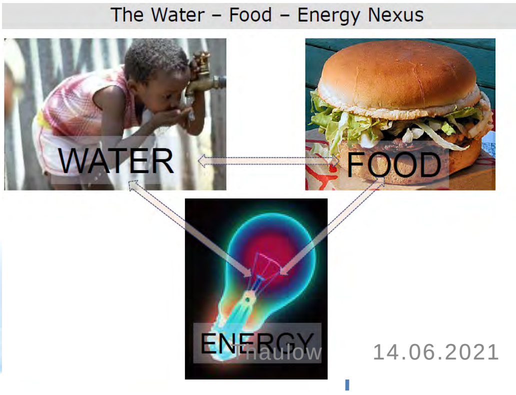
Glimpses of future water problems

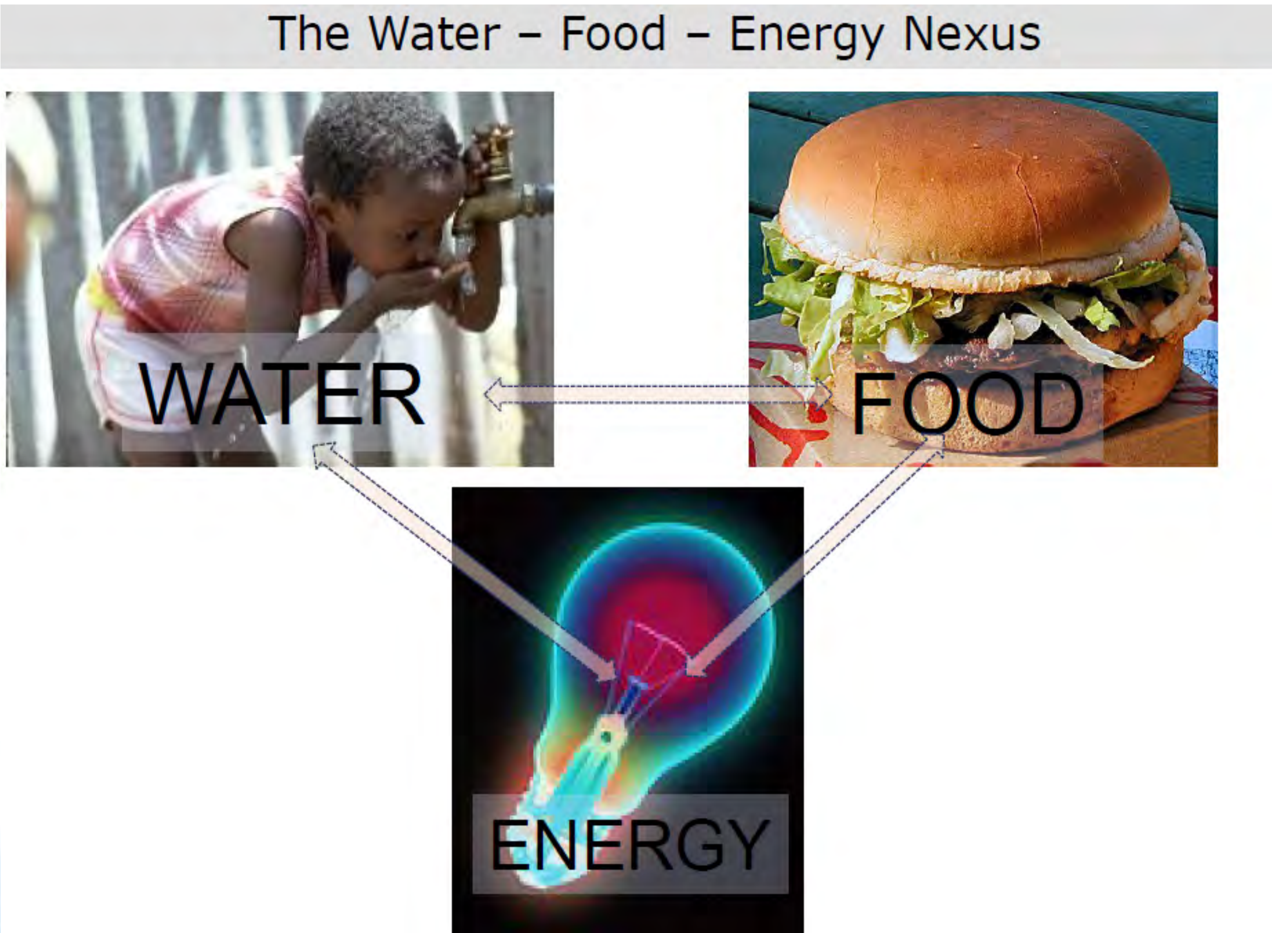
- 2/3 in water-scarce regions by 2025
- 700 millions expected to have to migrate
- 95 % increased probability for water conflicts next century

Glimpses of **future** water problems

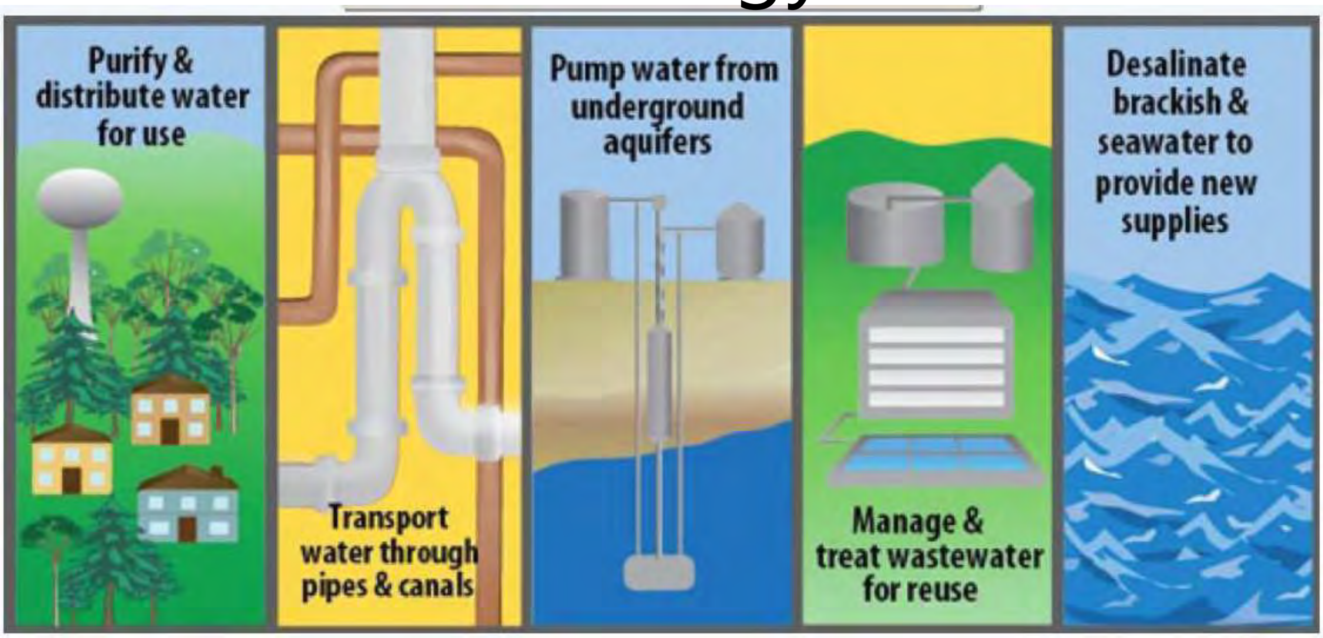
- UN: By 2050 without changing course: 50% av worlds population shortage of clean water

- Water security: Water-Food-Energy Nexus



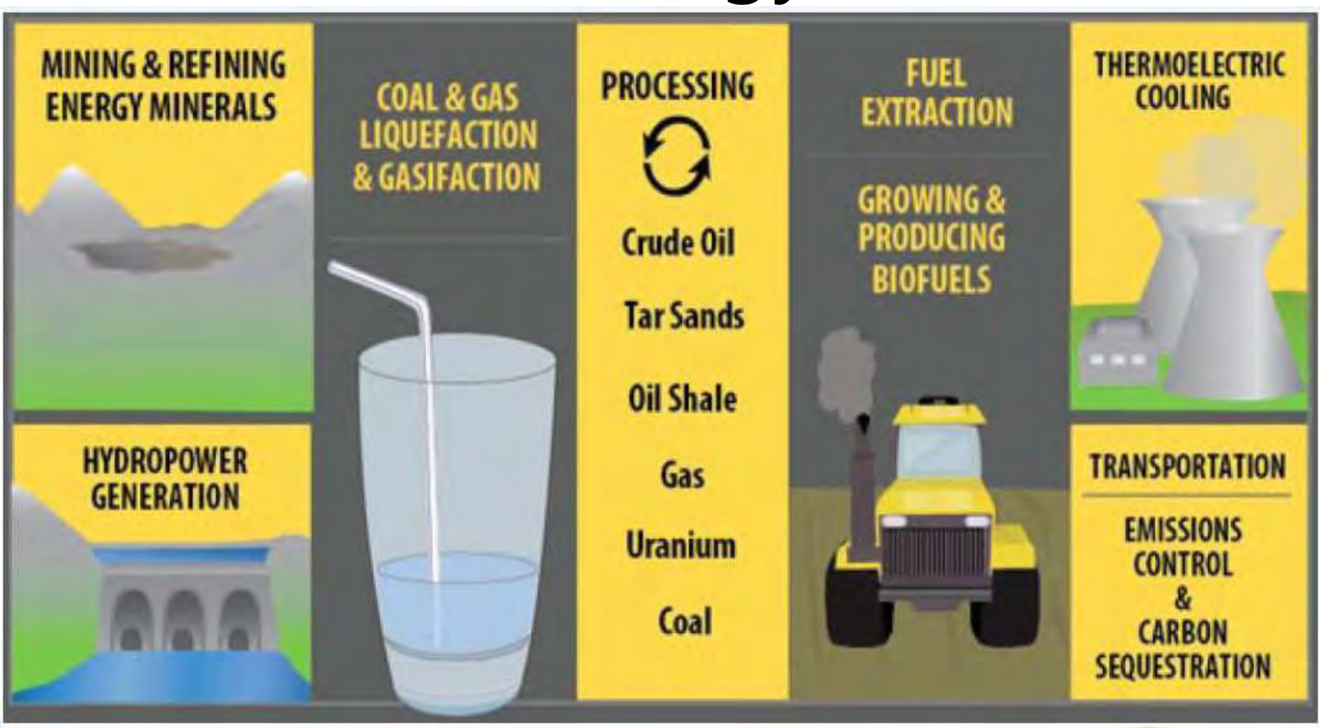


«Water and Energy Nexus»

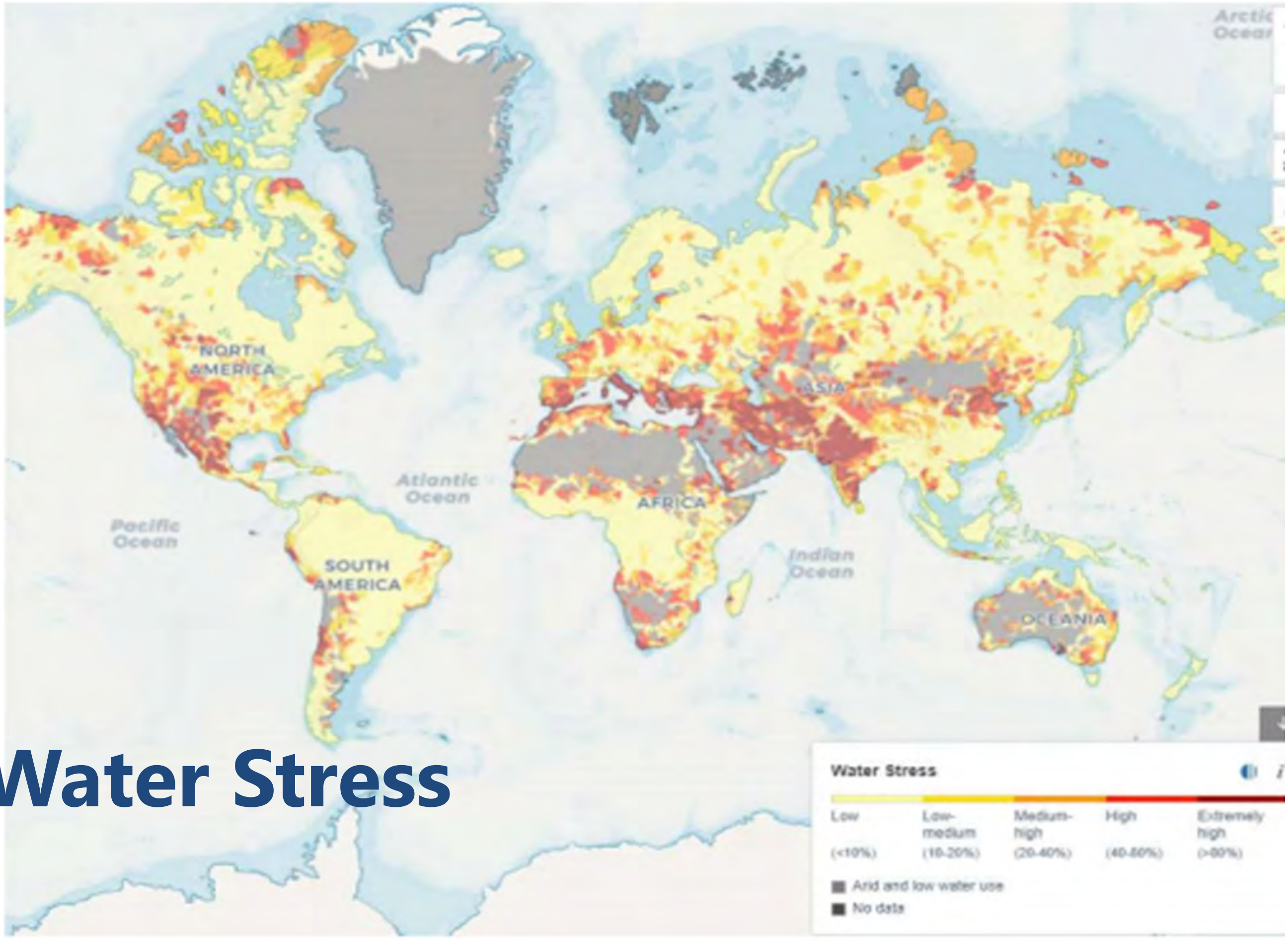


Water needs energy !!

«Water and Energy Nexus»

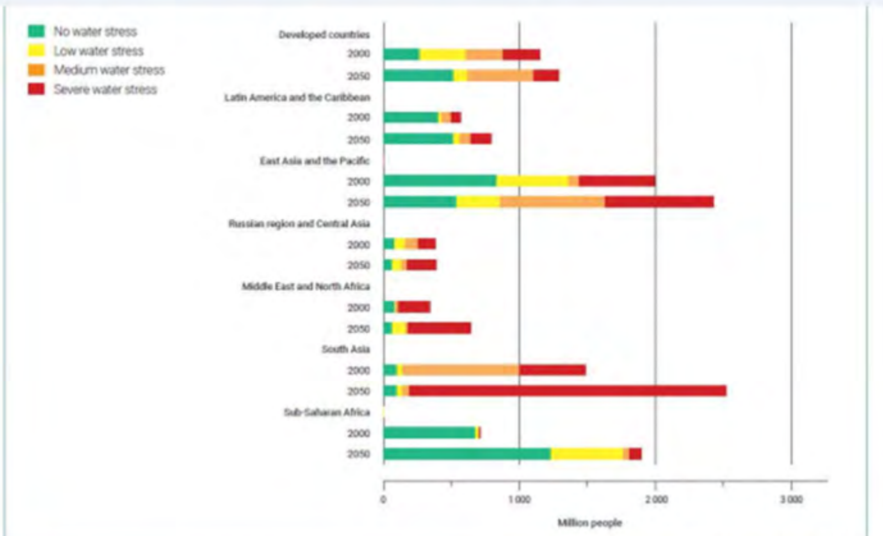


Energy needs water !



Water Stress

Personer og vanntilgang: 2000 og 2050



Figur 10 i WWDR, 2020

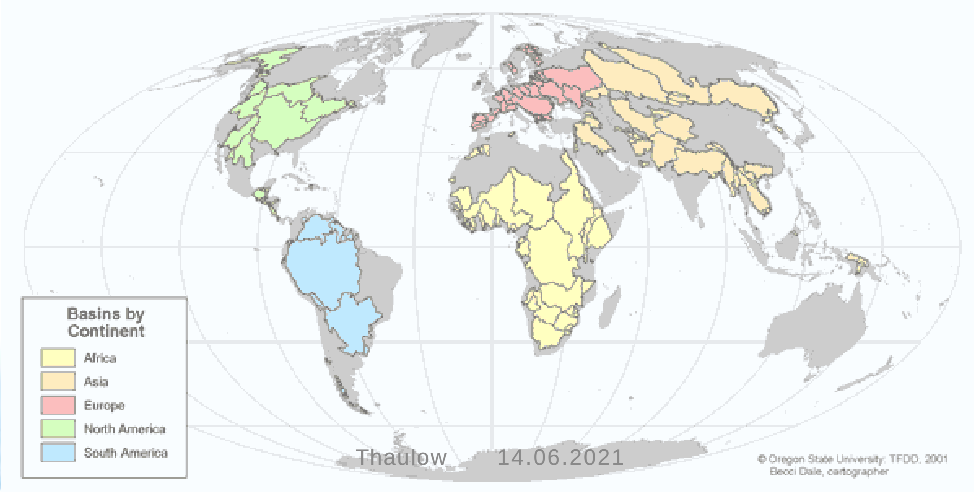
Name, Surname
ORGANIZATION
date

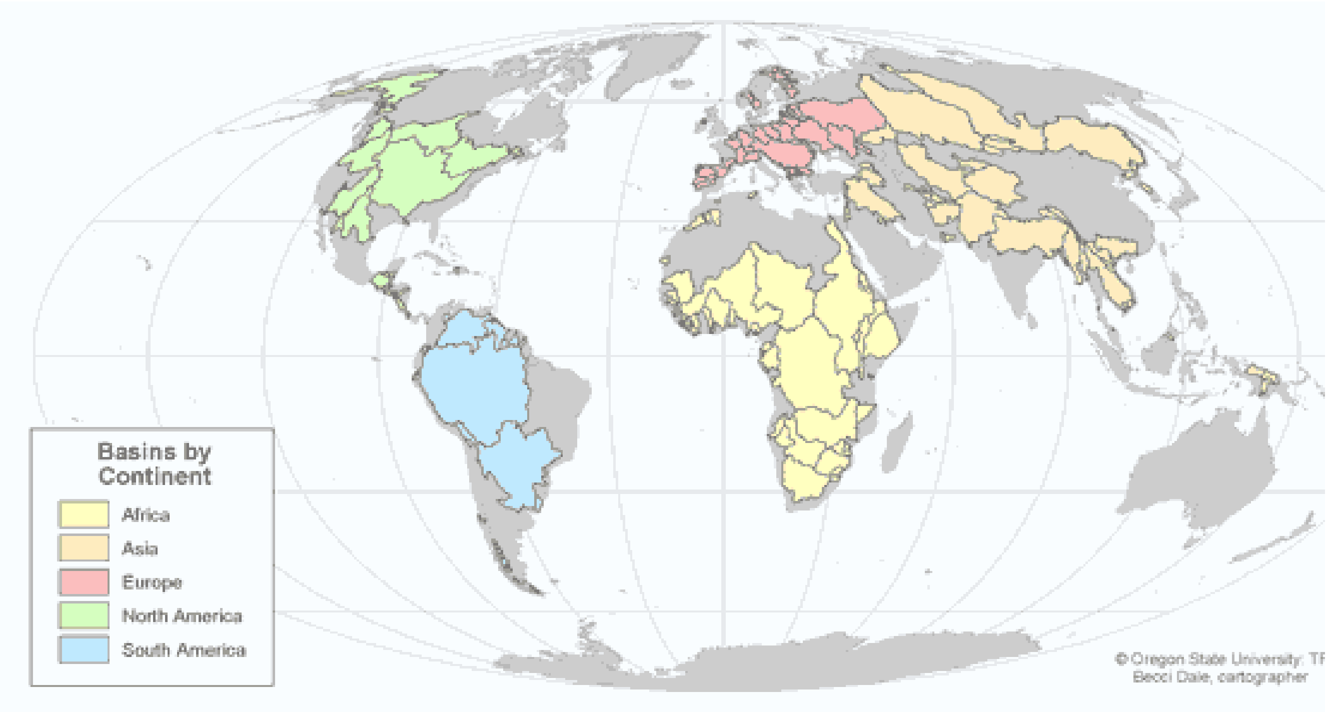
Water Stress - Persons and Water Availability 2000 and 2050

276 international river basins

Key resource for water supply and ecosystem services in 145 countries – cover more than 50% of worlds surface, 40 % of worlds population and 60 % of freshwater resources

Formalised cooperation only for 40% of international water resources





Danube – through 19 countries !!

Water Problem «drivers»

Water problem drivers

- **Climate Changes**
- **Population increase – urbanisation**
  - Yearly 80 mill new world citizens
  - More than 2 billions more by 2050
- **Food production - irrigation**
  - 10 % reduced crop pr degree increased temperature
- **Energy – renewable – hydropower**
  - Away from fossilbased energy

Water problem drivers

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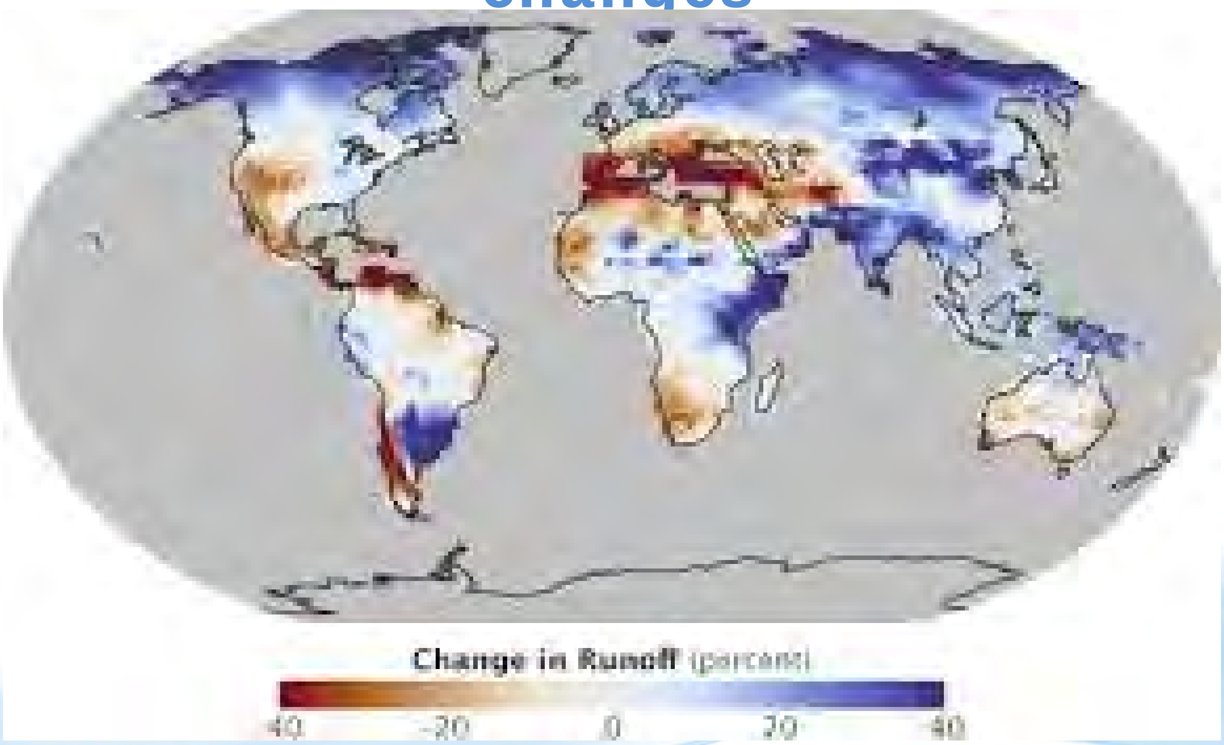
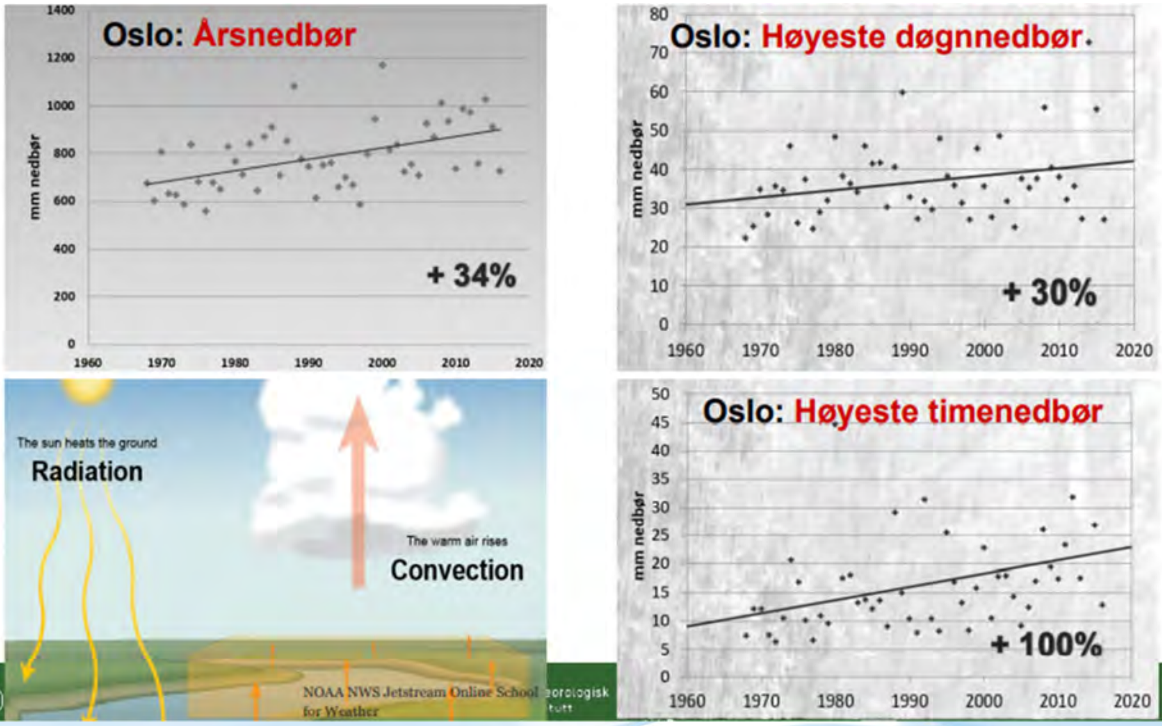
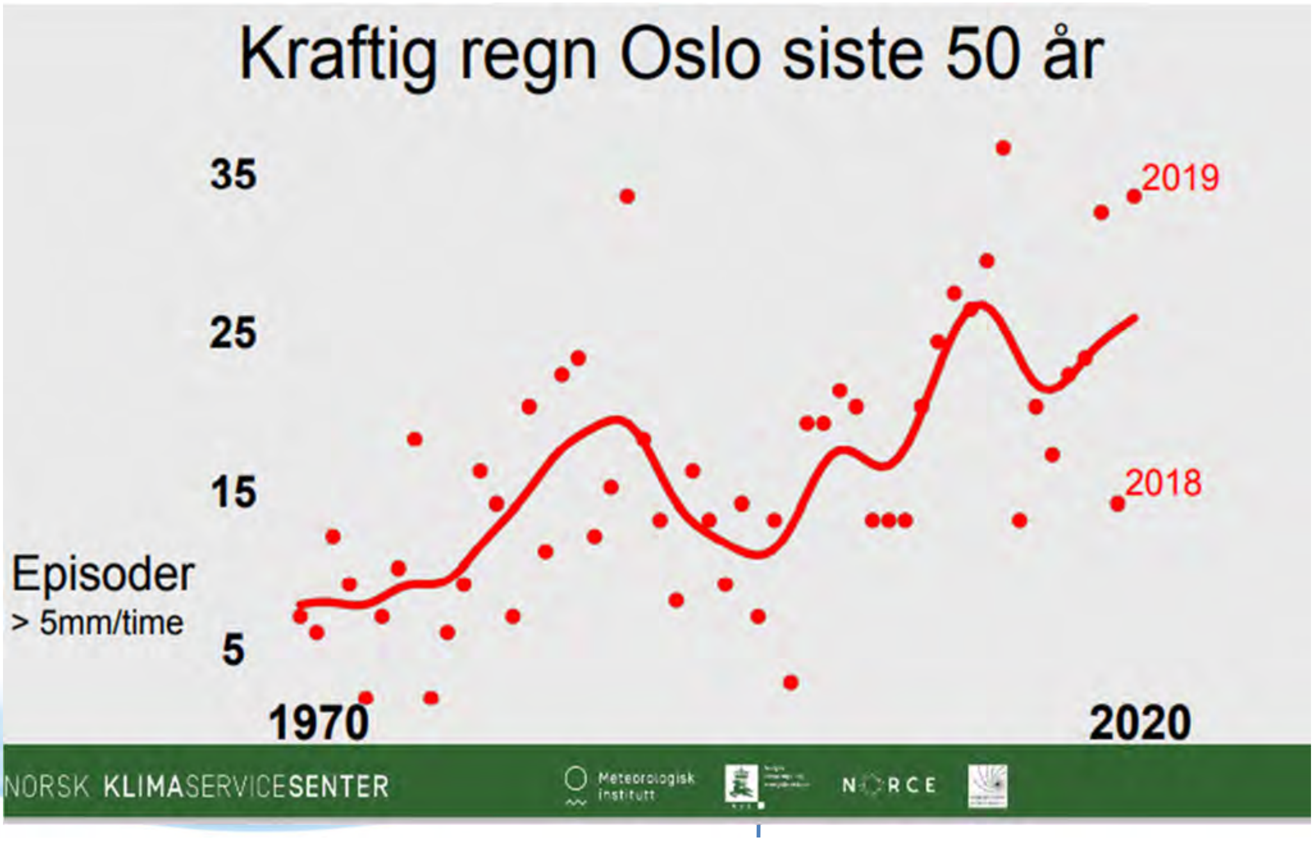
Climate Change and River runoff changes



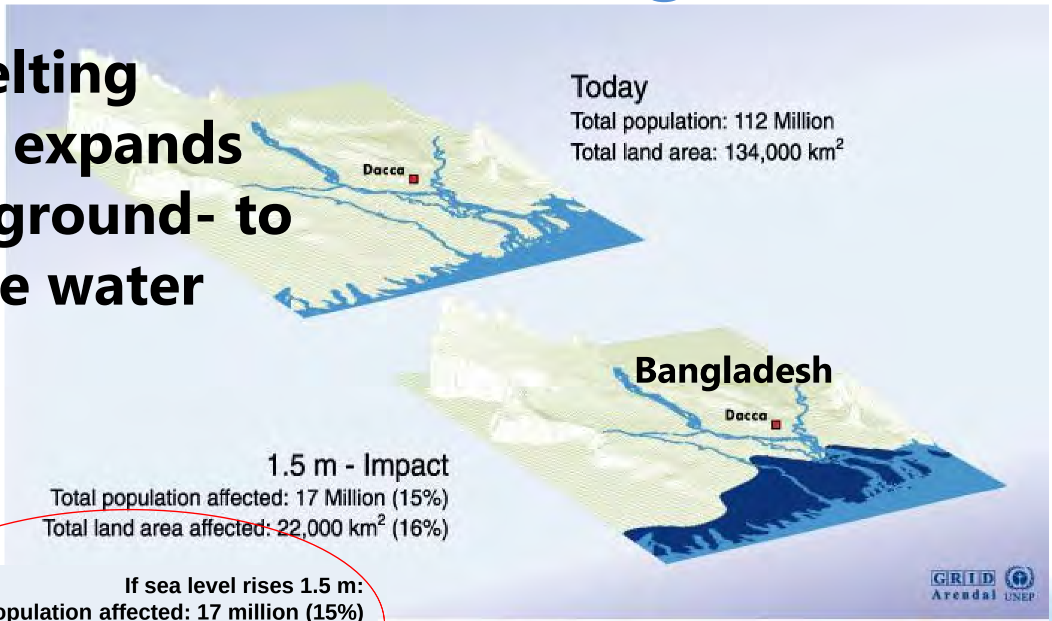
More yearly, more intense and more often rains in Oslo since 1965





Ocean level rising - - -

- Ice melting
- Water expands
- From ground- to surface water



If sea level rises 1.5 m:
Total population affected: 17 million (15%)
Total land area affected: 22,000 km^2 (16%)

IPPC 2019: 49-84 cm < L/H Scenario 2100

Source: UNEP/GRID Geneva; University of Decca; JRO Munich; The World Bank; World Resources Institute, Washington, D.C.

Ocean level

- – **Increase due to water expands with higher temperature**
- – **More melting of glaciers/icecaps (Greenland, Antarctica).**

- **IPCC (2019): Probable level increase this century : 43 cm (low discharge scenario), 84 cm (high discharge scenario). Continue to increase after 2100.**

- **Many scientists believe the level will rise considerably faster - - .**

Water problem drivers

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- over 2 billions more by 2050 - -

Urban areas sprawl –
Tokyo >20 mill!

20-30 % increased consumption towards 2050

Infrastructure for water supply and sewerage insufficient / overloaded. Sinking groudwater level - overpumping - -

Water problem drivers

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Food for 2 billions more by 2050 - - -

Water –food supply

- Rainfall pattern changes
- Overpumping of groundwater can have dramatic impacts on food/grain crops
- Towns sprawl over agricultural areas

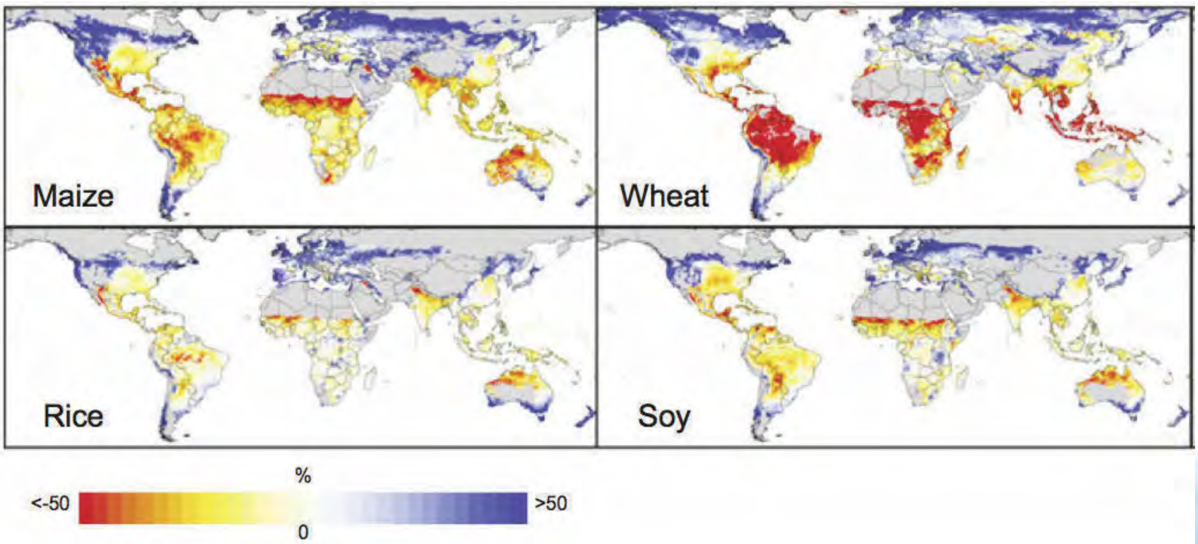
IPCC beskriver det globale bildet:

- **Vekst i befolkning og kjøpekraft** ventes å øke verdens matvarebehov med 50-60 prosent innen 2050.
- Kaloriene (95 prosent) produseres på **landarealene**
- 17% av proteinet kommer fra **blå sektor**
- **Produktive landarealer** reduseres og **forringes**
- Vannressursene blir knappere og **overutnyttes**
- **IPCC Havrapporten** advarer om **redusert produktivitet i havøkosystemene** (-25% i 2100 ved RCP 8.5 utlippsbane)
- **Klimaendringer virker negativt på produksjon både i hav og på land – økende trusler mot matsystemene og matsikkerheten**

a Pedersen, NIBIO

NIBIO

Mean crop changes (%) for important agricultural products - temperature rise of 4° C (ref. 1980–2010)



Verdensbanken, 2014
Omfatter bare modeller som tar med direkte virkninger av CO_2 og nitrogen forbindelser.

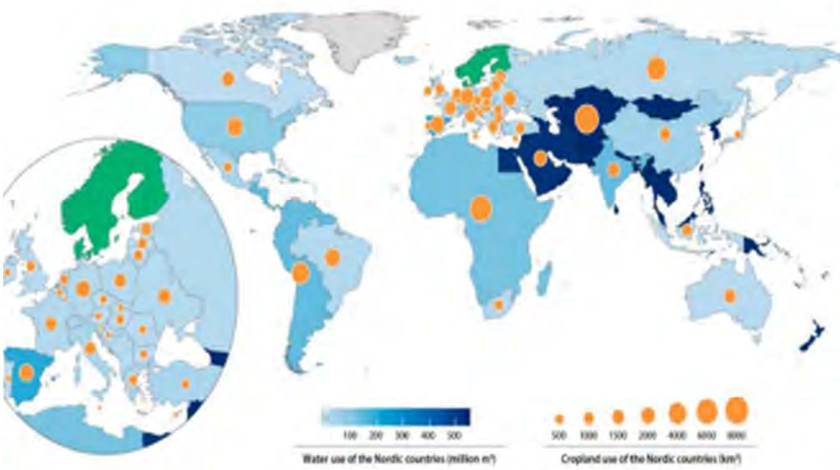
South Norway - dry summer 2018

Tørkesommeren 2018 i Sør-Norge

- 5-6 milliarder i tap for bøndene
- Import av grovfôr and kraftfor

Nordic food security - -

Norges/Nordens matsikkerhetsrisiko (forsyning) øker som følge av klimaendringer i andre land



- Only half of the cropland used for current Nordic food consumption is located within the Nordic countries
- Approximately 90% of blue wate use (related for example to irrigation) takes place outside th Nordic countries
- More than half (around 54%) of the greenhouse gas emissions related to Nordic food consumption are taking place outside the Nordic countries

Kilde: Stockholm Resilience Center Report (2019)

NIBIO

Withdrawal for water supply and irrigation, groundwater level sinking substantially – -

- Middle east; Irak, Jordan, Israel/Palestina, Iran
- China, India
  - Beijing from 100- til 300 meter depth to extract groundwater
  - India – «sinking» large part of energy use related to pumping groundwater – «deeper and deeper»
- USA/Mexico – Texas/California

Water problem drivers

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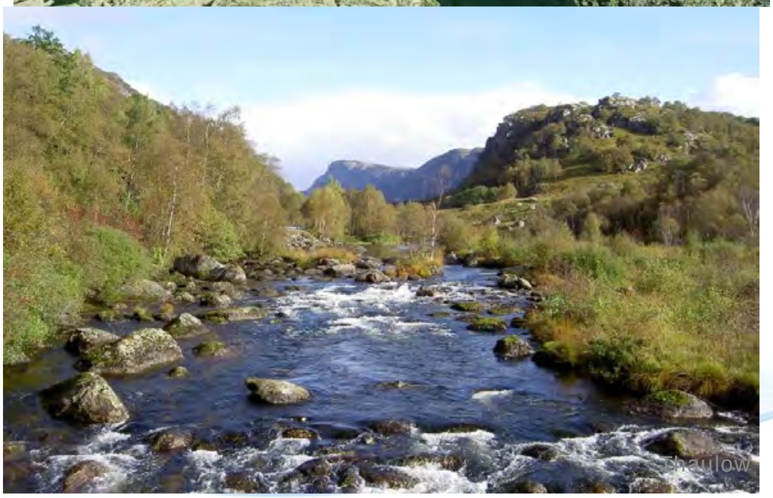
-Renewable energy - hydropower



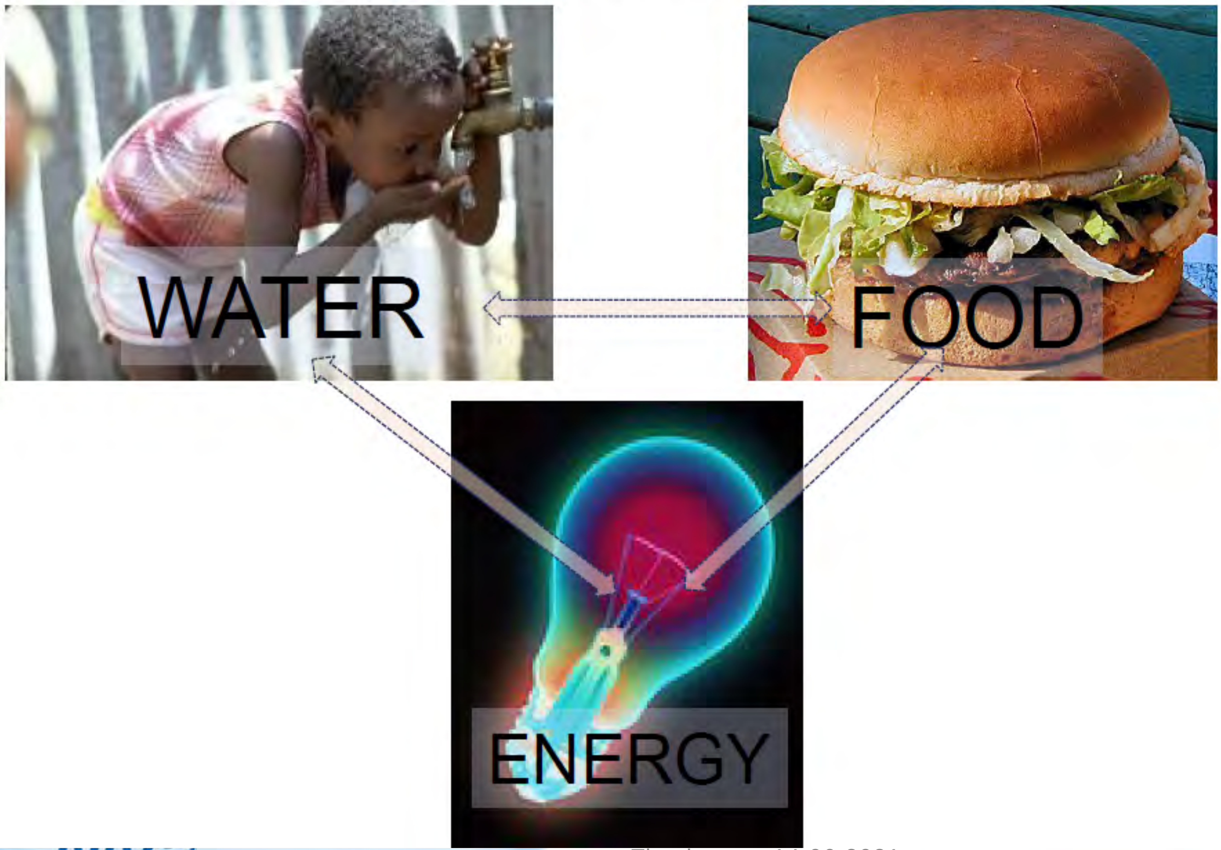
«Environment-environment conflict« the double challenge

UN Climate Panel
UN Biodiversity Panel

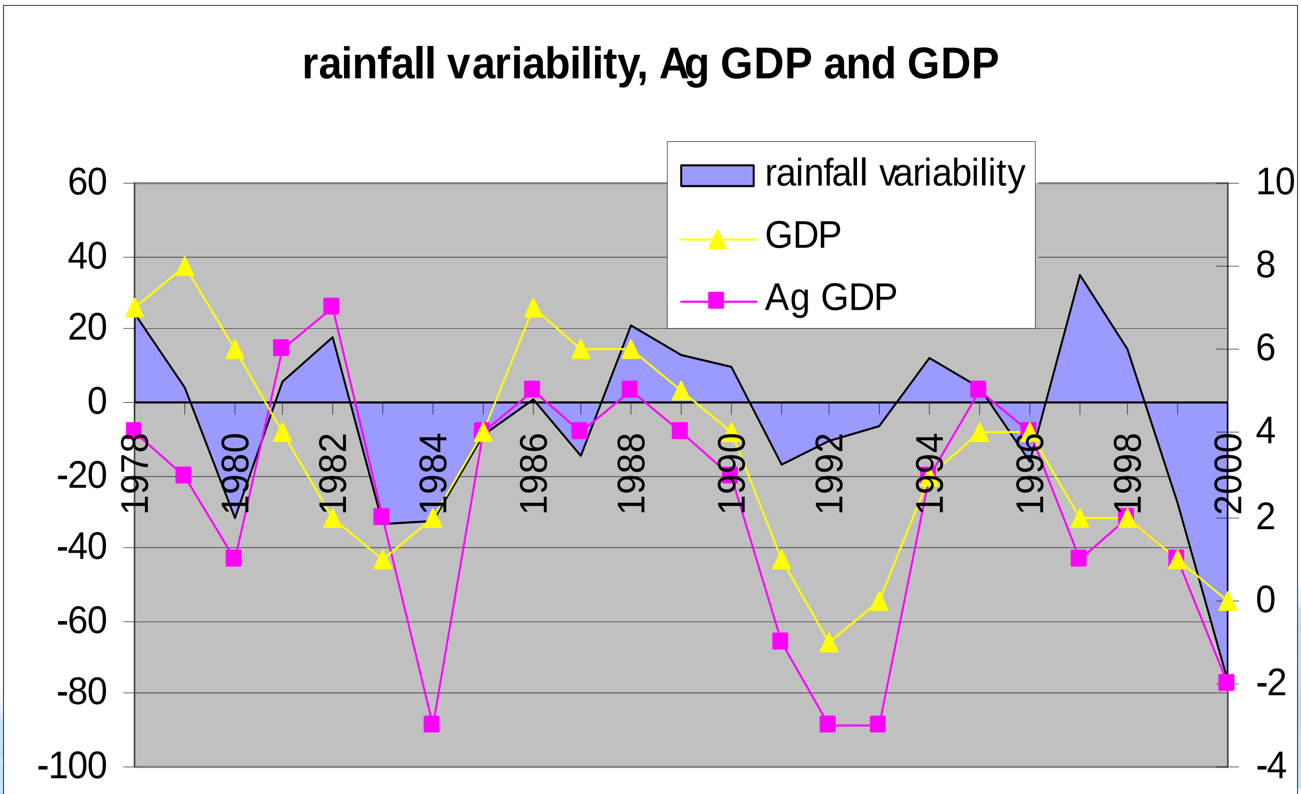
Changes in hydropower production -

New NVE -report: 8 TWh more « climatepower» in Norway

The Water – Food – Energy Nexus

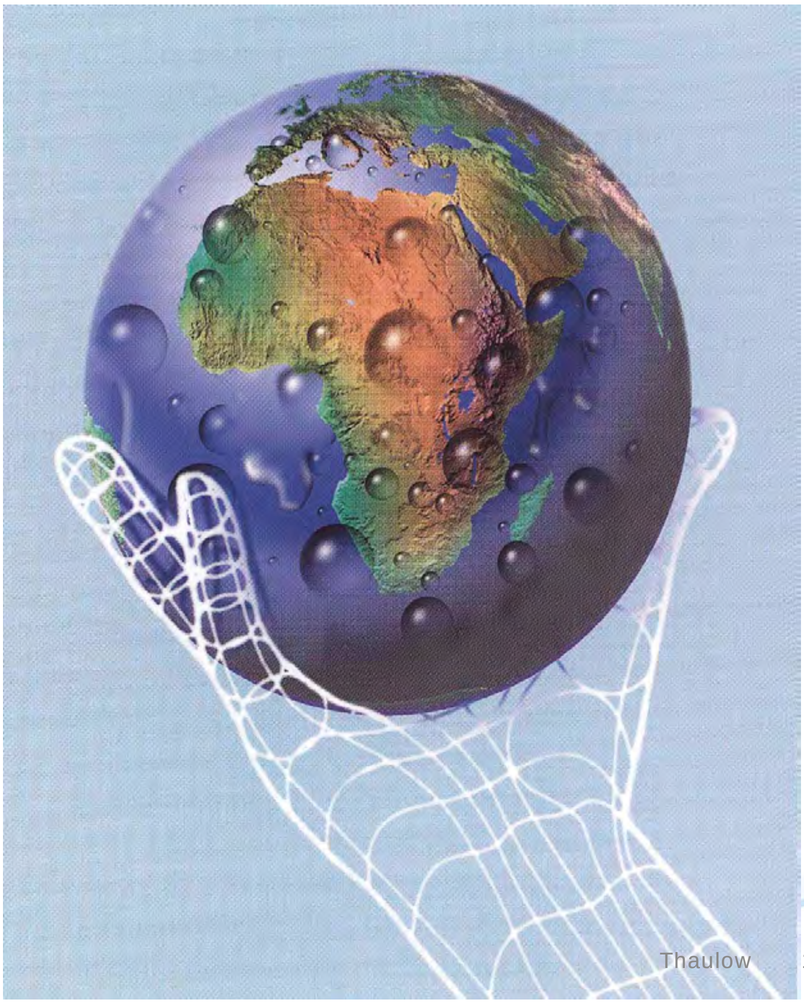


Kenya :extremely vunerable to rainfall variability



Increased water use, more renewable energy , more extreme weather

Water storage !!!



What is the problem?

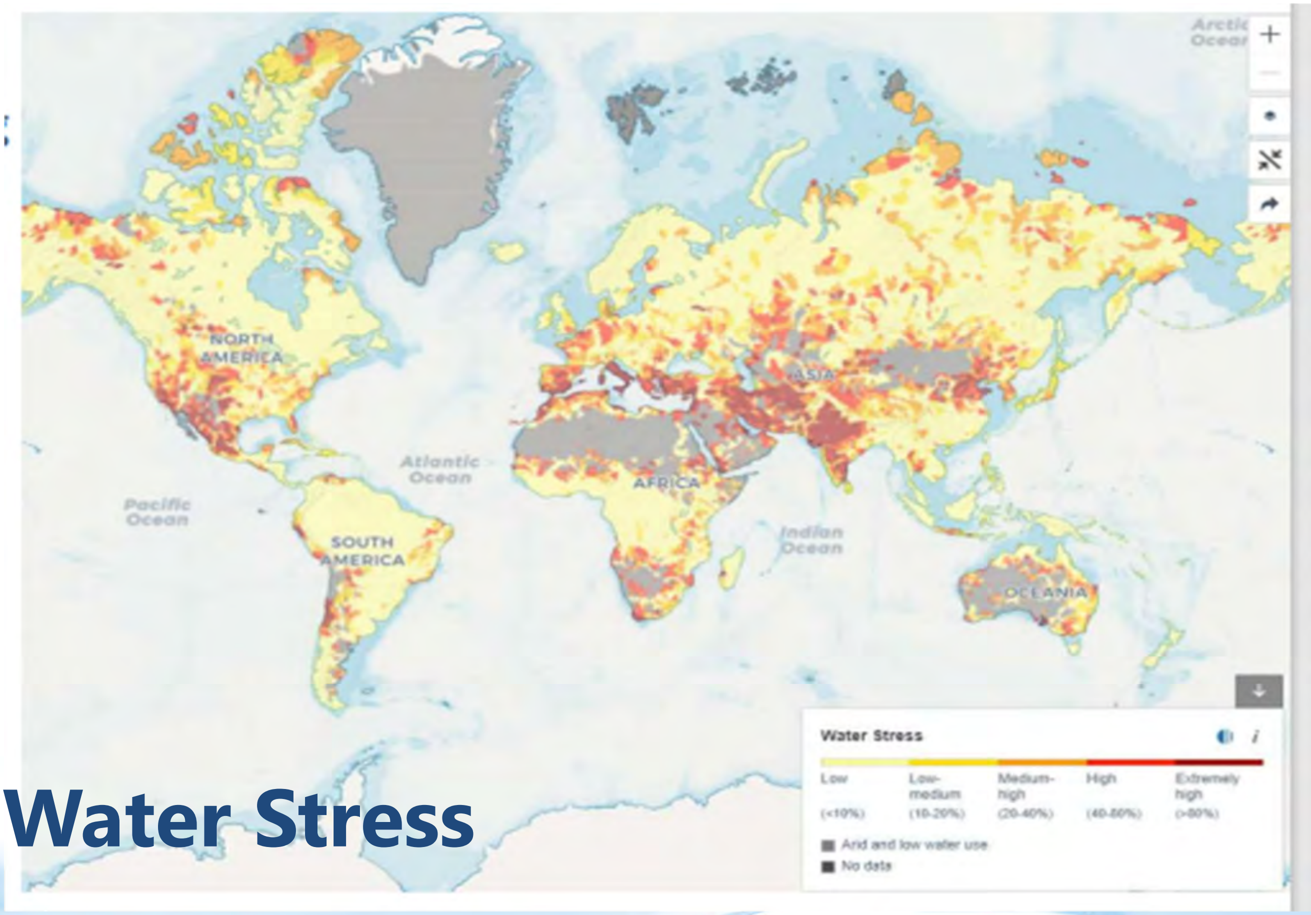
Too little!

Too much!

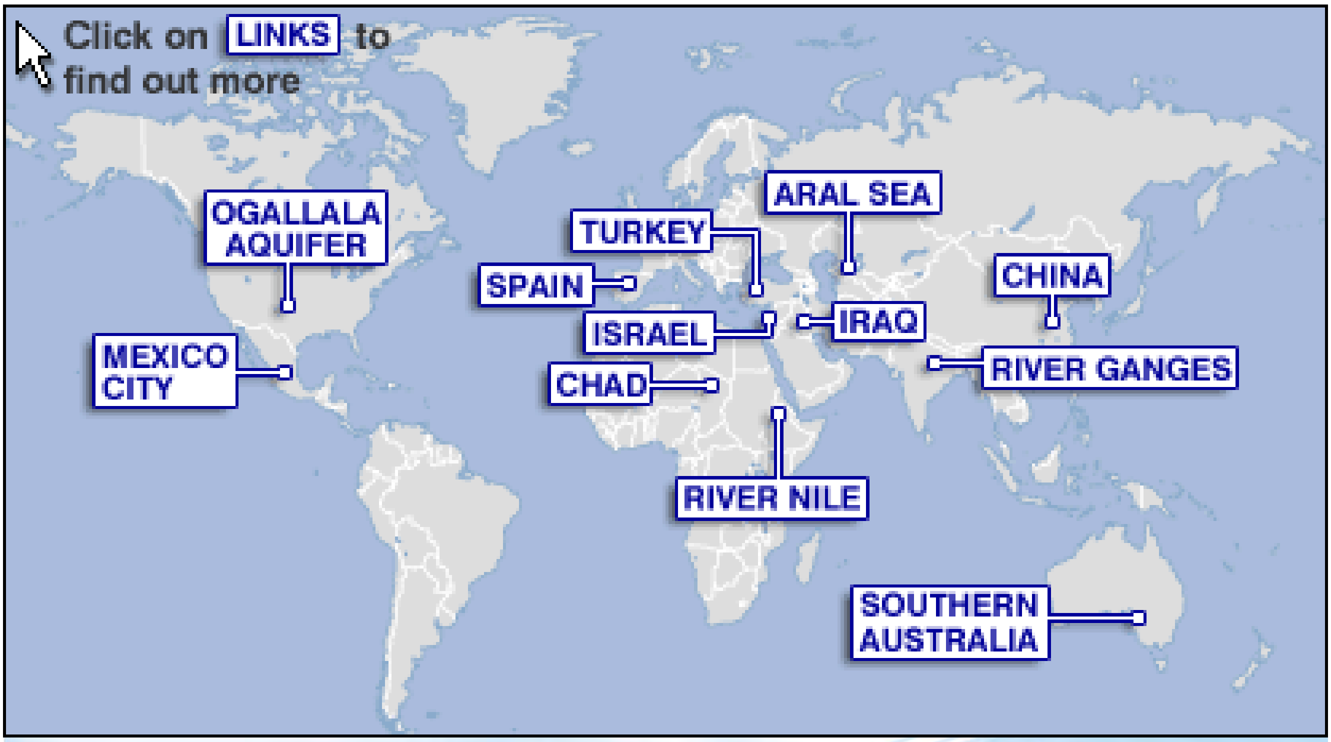
Poor quality!

Wrong place at wrong time!

Water Stress



“Hot Spots” freshwater



Water crises –Water wars ?

- China – water transfer
- Cape Town 2018
- Nile
- Indus
- Ganges –Brahmaputra
- Palestine/Israel
- Colorado River – California
- New Dehli

China

South – North Water Transfer Project

62 milliarder USD

Cape Town –water crises 2018

Cape Town water crises first half of 2018

- Climate/drought- water infrastructure, population growth. politics
- «Day Zero» several times postponed til july
- Rainfall and actions:
- 50 l/p.d, 2 min shower, no garden watering
- Loyal following of rules,-lists of water criminals!
- Waterprice increase 30% - changing priorities of water rights- from agriculture to domestic/industrial supply

Australia's water crisis is a harbinger of things to come around the world

2019

Following forest firers - -

- pouring rain and floods - -

Key drivers behind water conflicts and possible water wars:

- **Limited water resources too little water**
- **International river basins**
- **Withdrawal of water and upstream storage – reservoirs/dams**

-Increased water demand, population growth, agriculture/irrigation

17 countries - -

UN: Areas-rivers for possible Water Wars:

"It is still possible to shift course if we an cope with climate change problems" - - - - .

Egypt in conflict with all upstream countries - - -

«The blue Nile - -»

Grand Ethiopian Renaissance Dam

Almost finished

Egypt-Etiophia

INDUS
India - Pakistan

21

Ganges – Brahmaputra
400 millions depending

Colorado River – Water supply to Los Angeles area.
Argriculture/irrigation.
Often dry befor entering Mexico –Bay of California

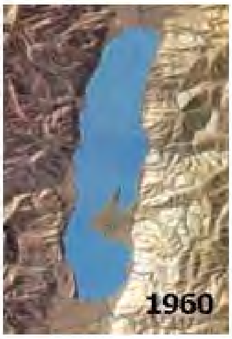
Water shortage California 2014-2016

California fires in 2017, 2018 and 2019 –

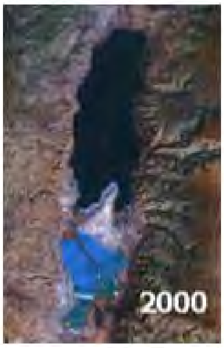
Drought and wind !

Palestina – Israel

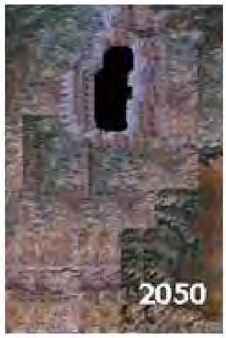
The Dead sea dies -



The Dead Sea in 1960



The Dead Sea in 2000

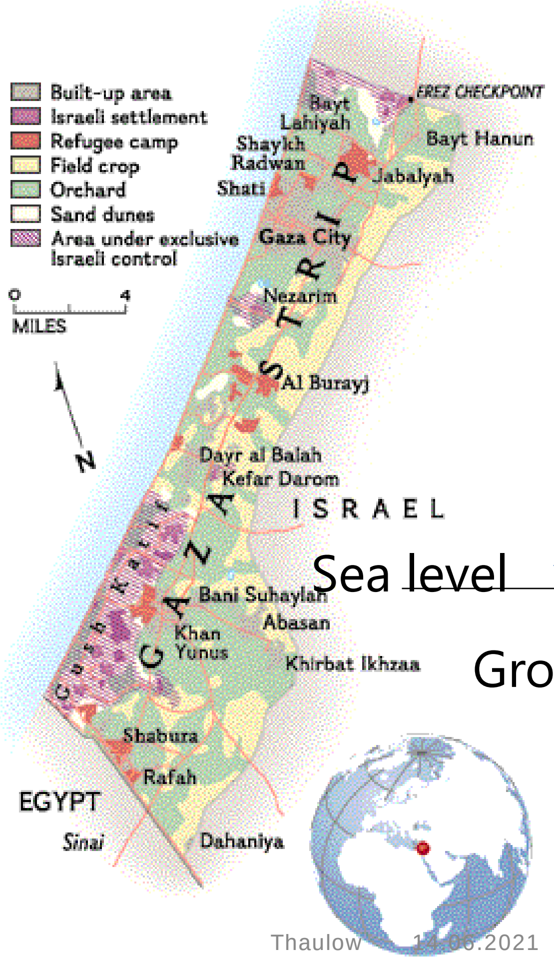


Expected plan in 2050

Read Sea- Dead Sea Canal

Water supply – Desalination- Hydropower

Stabilize Dead Sea surface level

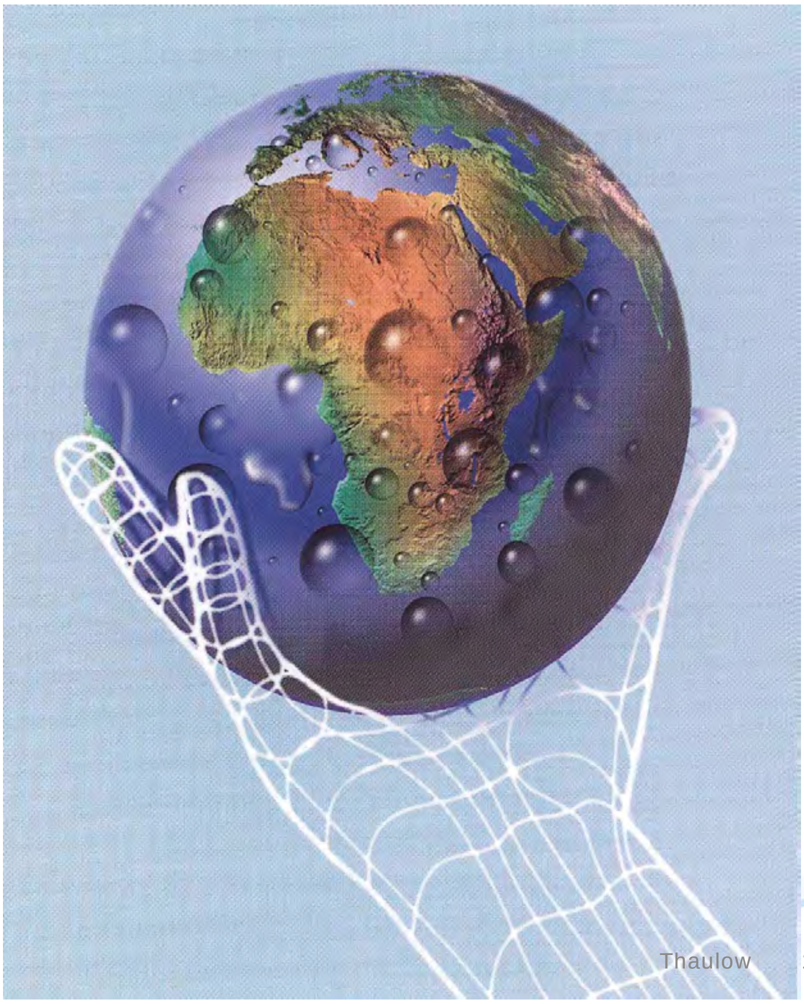


Sea level

Groundwater level

Israel /Palestina :
Water cooperation following the Oslo II agreement

سلطة المياه الفلسطينية
PALESTINIAN WATER AUTHORITY



What is the problem?

Too little!

Too much!

Poor quality!

Wrong place at wrong time!

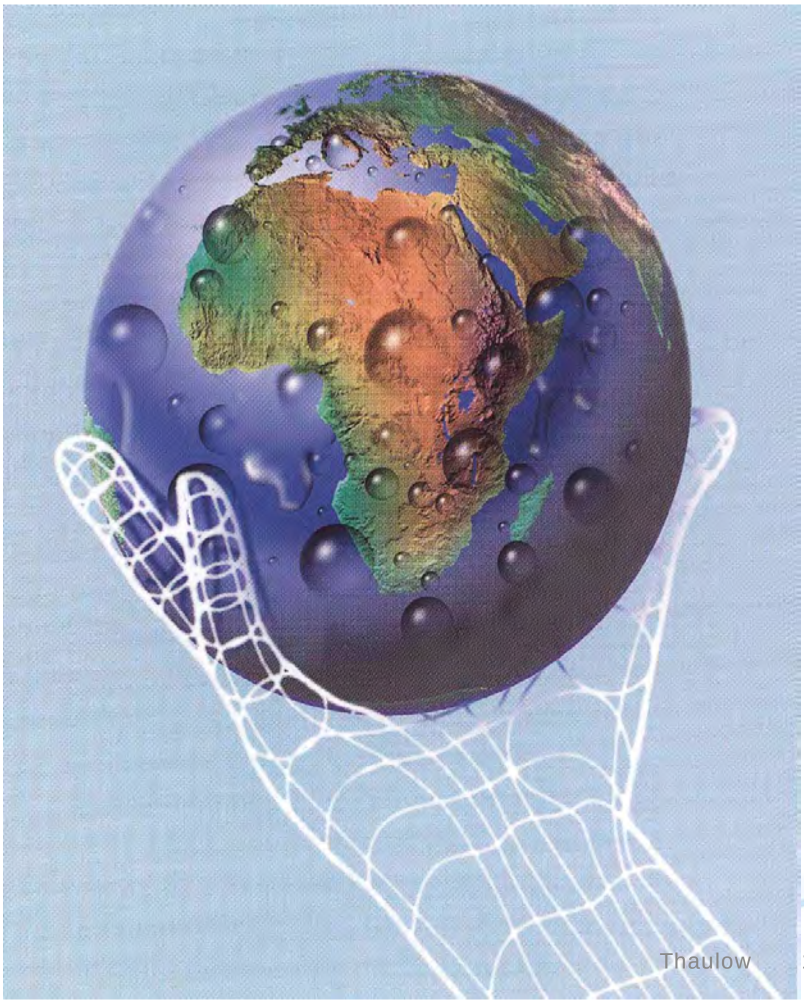
Houston, USA 2017

Flom i Hyderabad (India) 15. oktober 2020

- 100 døde
- Største nedbøren på én dag på 104 år.
- Ødelagte ris- og bomullsavlinger.

Mørkrisdalen, Sogn og Fjordane 2018

Kvam, Gudbrandsdalen 2018



What is the problem?

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Wrong place at wrong time!

- Water Supply for all - -

Safe and clean -

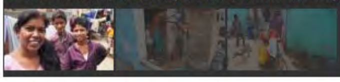
Water infrastructure non existing – groundwater sinking – (Rio favela)

Fakta

Delhi og vannmangel

- Selve hovedstaden New Delhi og de ti øvrige distriktene i National Capital Territory hadde ved folketellingen i 2011 tilsammen over 22 millioner innbyggere.
- Befolkningen øker markant hvert år, og siden vannforsyningskapasiteten er uendret, er vannkrise uunngåelig, særlig i den varmeste årstiden, påpeker den britiske avisen The Daily Mail.
- Myndighetene lover utbygging av ledningsnettet og andre utbedringer.
- Et overvåkingssystem er iverksatt for å avsløre korrupsjon og vannmafia- virksomhet.

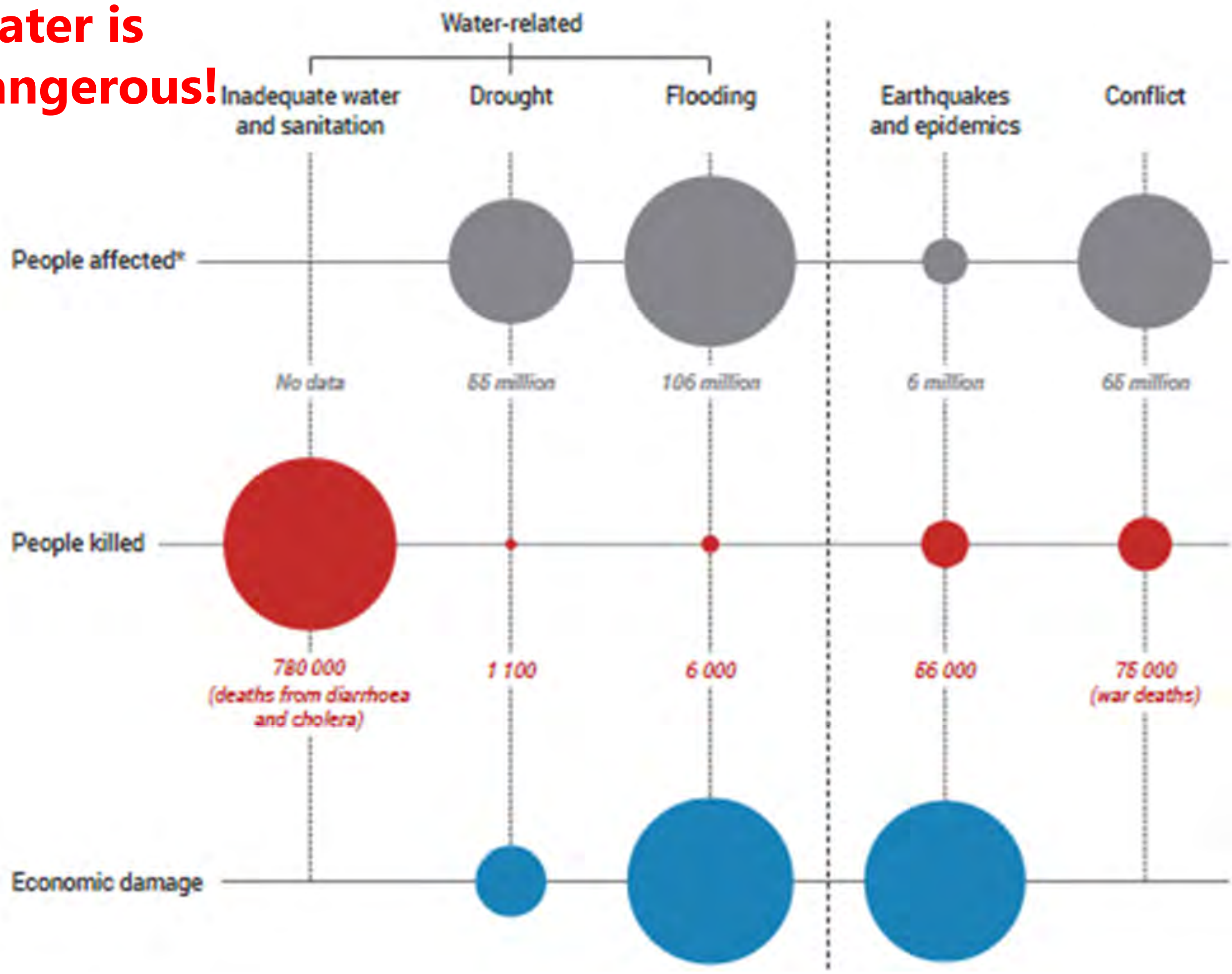
Lærerinnen Urmzila i Kusumpur Pahari-slummen er bekymret over at familiene her må bruke så mye penger for å skaffe seg drikkevann. **FOTO: JØRGEN LOHNE**



Delhis fattige tørster

DELHI (Aftenposten) Familier i Delhis slum betaler så mye for mangelvaren vann at de må kutte ned på matinnkjøp. Korrupsjon og en kynisk mafia får skylden.

Water is dangerous!



Every day approx. 1000 childres die because of contaminated drinking water or unsatisfactorily sanitary conditions.

In some countires every 5 th death among children is caused by diarrhoea due to polluted drinkingwater and lack of good sanitary facilities

Worlds most polluted river Citarum-river -Java

- 28 milloner depending on the river
- Water Supply to Jakarta (80%), irrigation, receiving water, hydropower
- 20 000 tons waste, 340 000 m3 wastewater from textile factories
- Fishkill, health problems , level of lead 1000 times higher than standard for drinking water

Join a very special River Cruise-!!

Industrial wastewater- --

Industral discharges to polluted river

«Algae soup»

SDG 6 Status UN 2018

“The main challenge across the water sector is to enable and accelerate progress towards achieving SDG 6', based on the findings from assessment of progress on SDG6 targets. The water sector is struggling to improve water resources management and to increase the coverage and quality of water and sanitation services. Some of the many challenges are practical actions that provide the “visible¸ side of water, such as installing taps and toilets, building reservoirs, drilling boreholes, and treating and reusing/recycling wastewater. however, some actions are much less visible”¸

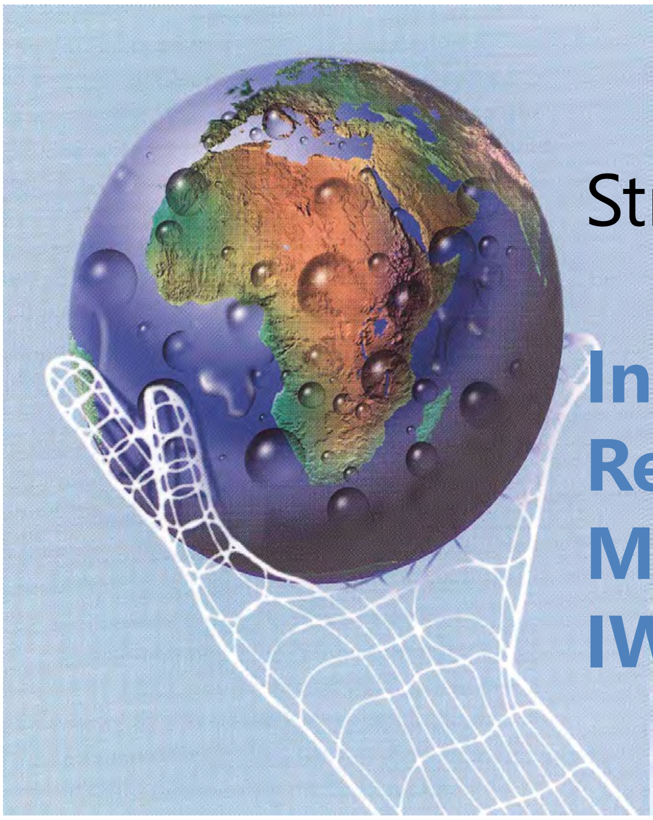
SDG 6-2018 rapport

(ref. 2015)

- 29 % lack safe drinking water supply
- 61 % lack good sanitary solutions
- 892 mill. have toilet in «open areas»
- only 27% i LDC –countries have handwash facililties

- 60% treatment of wastewater in middel/developed countires (major parts of Asia/Africa not included)
- In 22 land (Nord Africa/West/Central/South-Asia) water stress level > 70 % - future water shortages

- 50 % practise Integrated Water Resources management (very uncertain
- 50 % international cooperation/transboundary



Strategy:

Integrated Water Resources Management - IWRM

Integrated Water Resources Management

"IWRM is a process, which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social wel-fare in an equitable manner without compromising the sustainability of vital ecosystems."

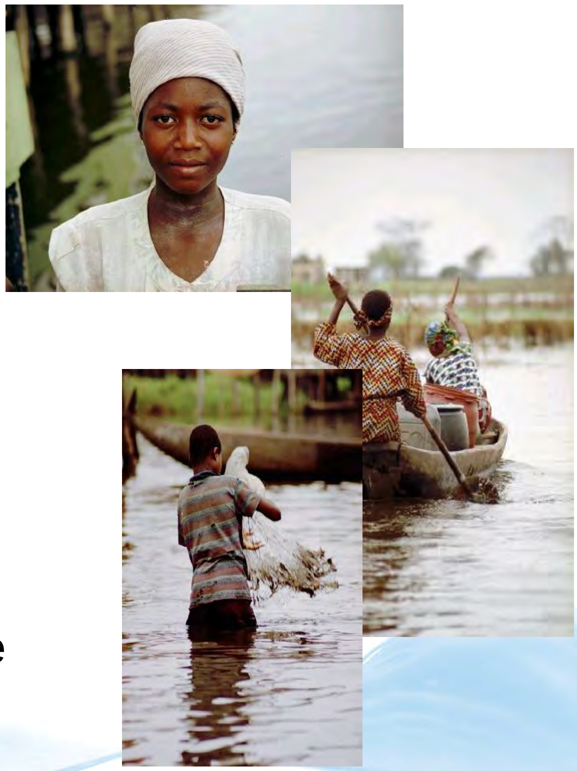
The Technical Advisory Committee of Global Water Partnership

Brukerinteresser og økosystemer tilfredstilles !

Photo: Lake Peipsi (Estonia/Russia): P. Stålnacke

Integrated Water Management – (Dublin principles)

- Water is a limited and valuable resource, essential for life, development and the environment
- Women must be involved
- Participation -principle
- Water has an economic value



Water has a price!

4 IWRM charateristics:

1. **Several users** : (fish, irrigasjon, water supply, energy production)
2. **Several management levels**
3. **Unlike "power situation"** upstream/downstream
4. **Interdisciplinarity; technically complex**

IWRM - EUs Water Framework Directive WFD

- **Protection and sustainable use**
- **Goal: Good ecological status. Ecological and Chemical**
- **Measures; protect, improve, restore**
- **Sectorintegration and broad stakeholder involvement**
- **Regional management plans with environmental goals and abatement plans with proposal for concrete actions**

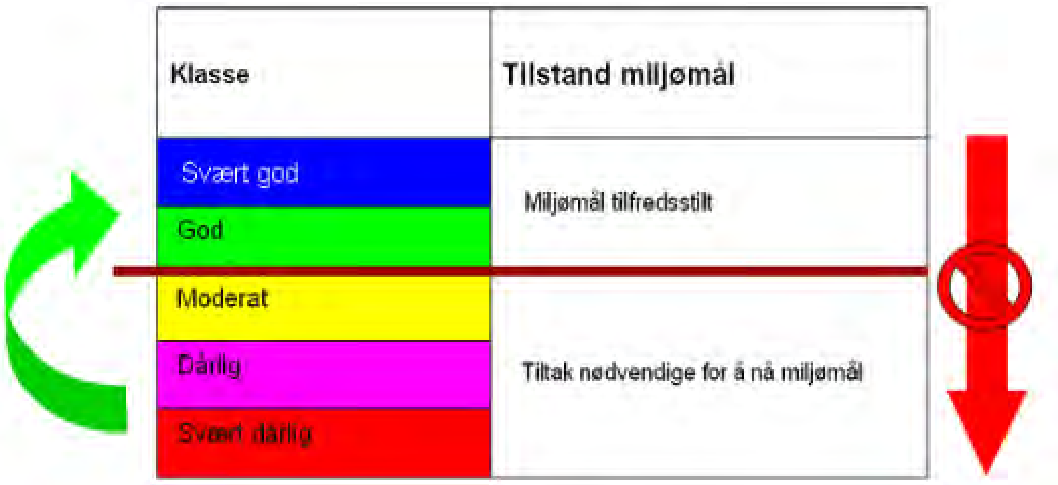
WFD:

1. **Management plans**
Measure programs

2.Water Authorities – River basins

Crossectorial cooperation!

IWRM - EUs Water Framework Directive

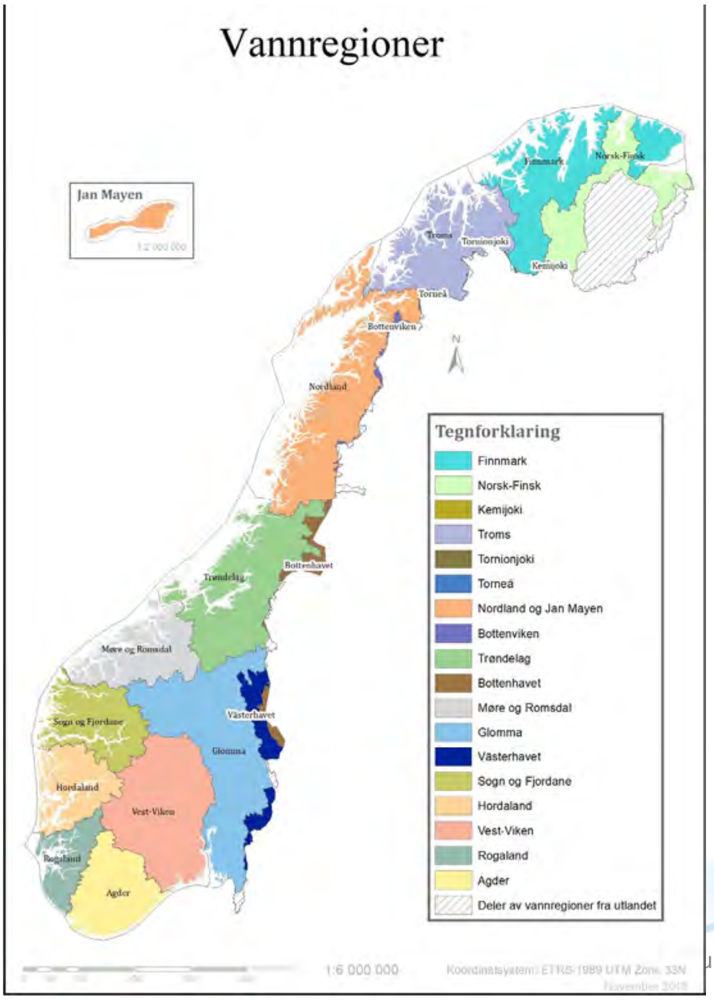


(Håndbok ...)

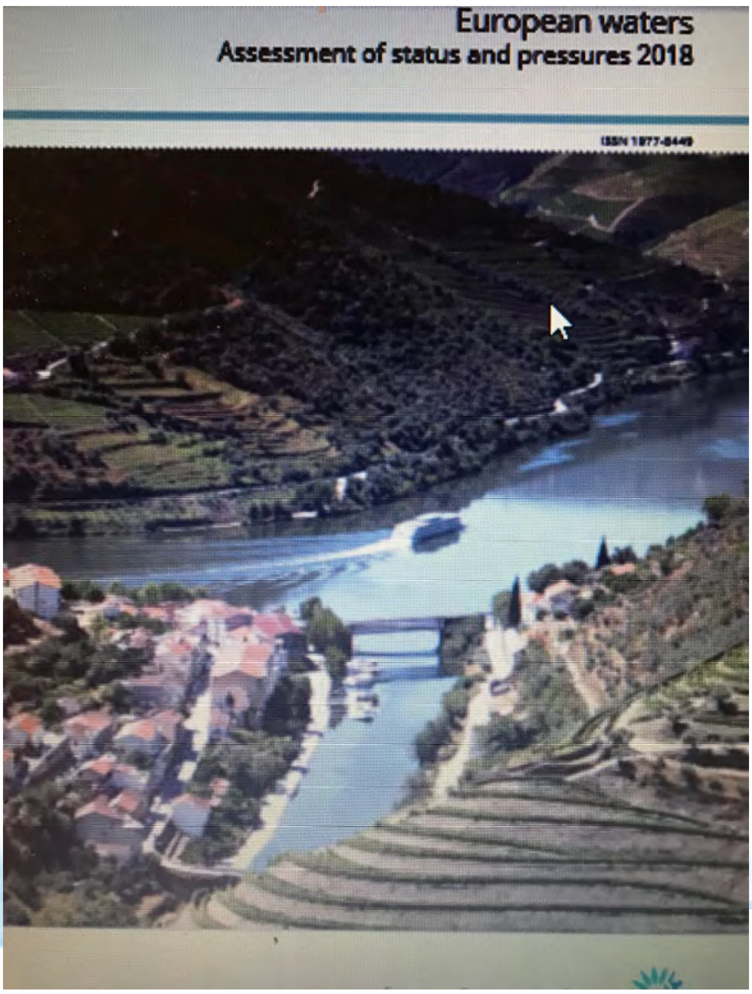
Goals in WDF

- **General for all water bodies:**
- Good ecological status and good chemical status:
  GES: *Defined scientifically*

- **Heavily modified water bodies**
- Good ecological potential: GEP
  «State achieved after reasonable measures implemented»
-



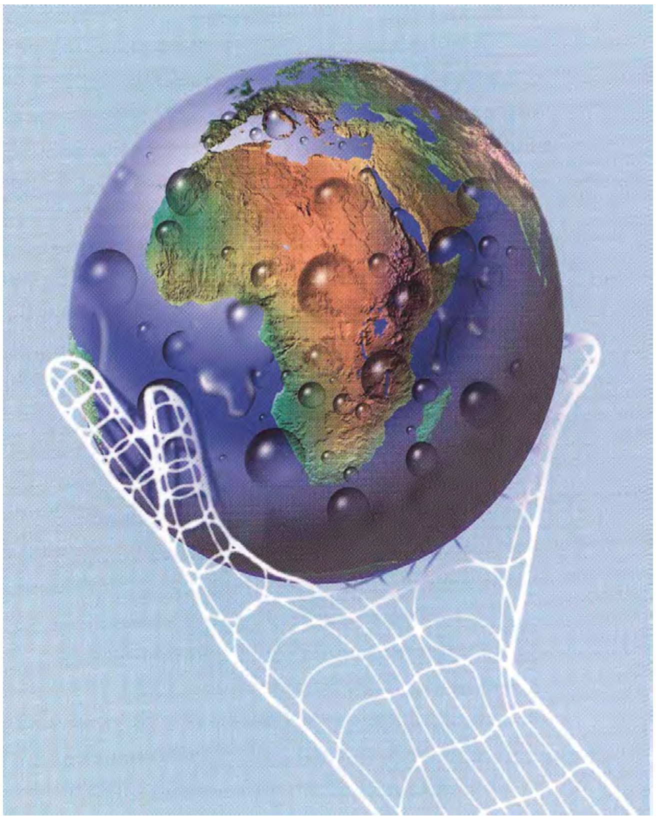
11 Water regions



EU - WFD (2000 - Norway 2006)

2 x 6 years planning cyclus

«Much have been achieved, but much remains to be done»

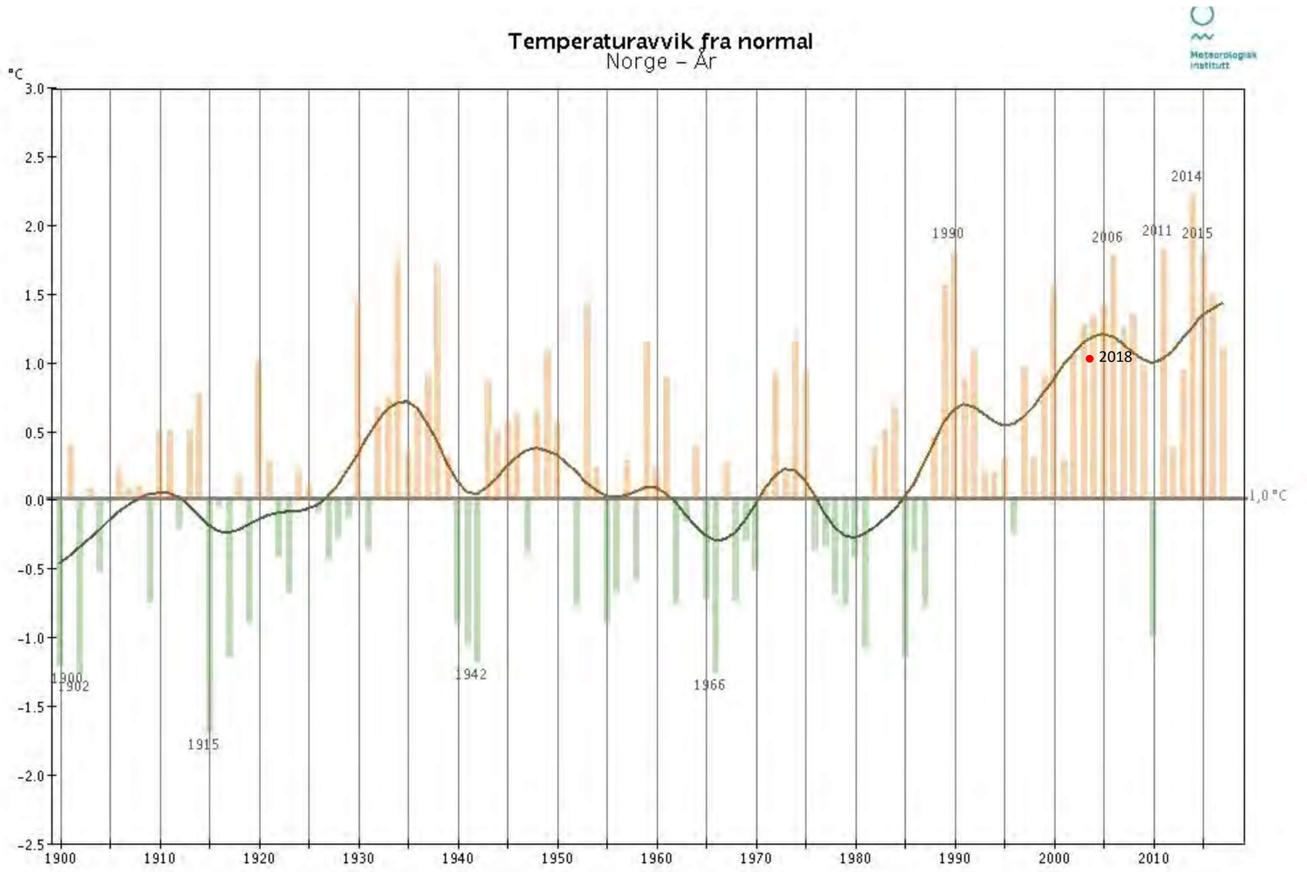


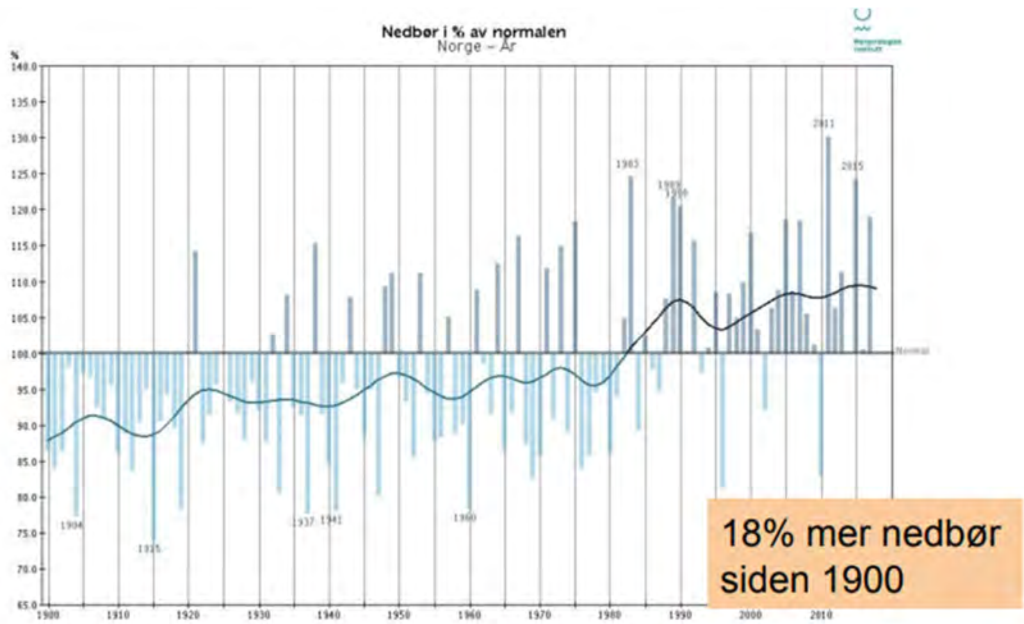
Freshwater in Norway

- Abundant water resources of good quality:
- **Special issues**
  - **Watercourse regulations /Hydropower**
  - **Aquaculture**
  - **Exposed to longtransported airborne pollutants – acid rain (improved)**
  - **Environmental contaminants**
  - **Norway - «downstream country»**

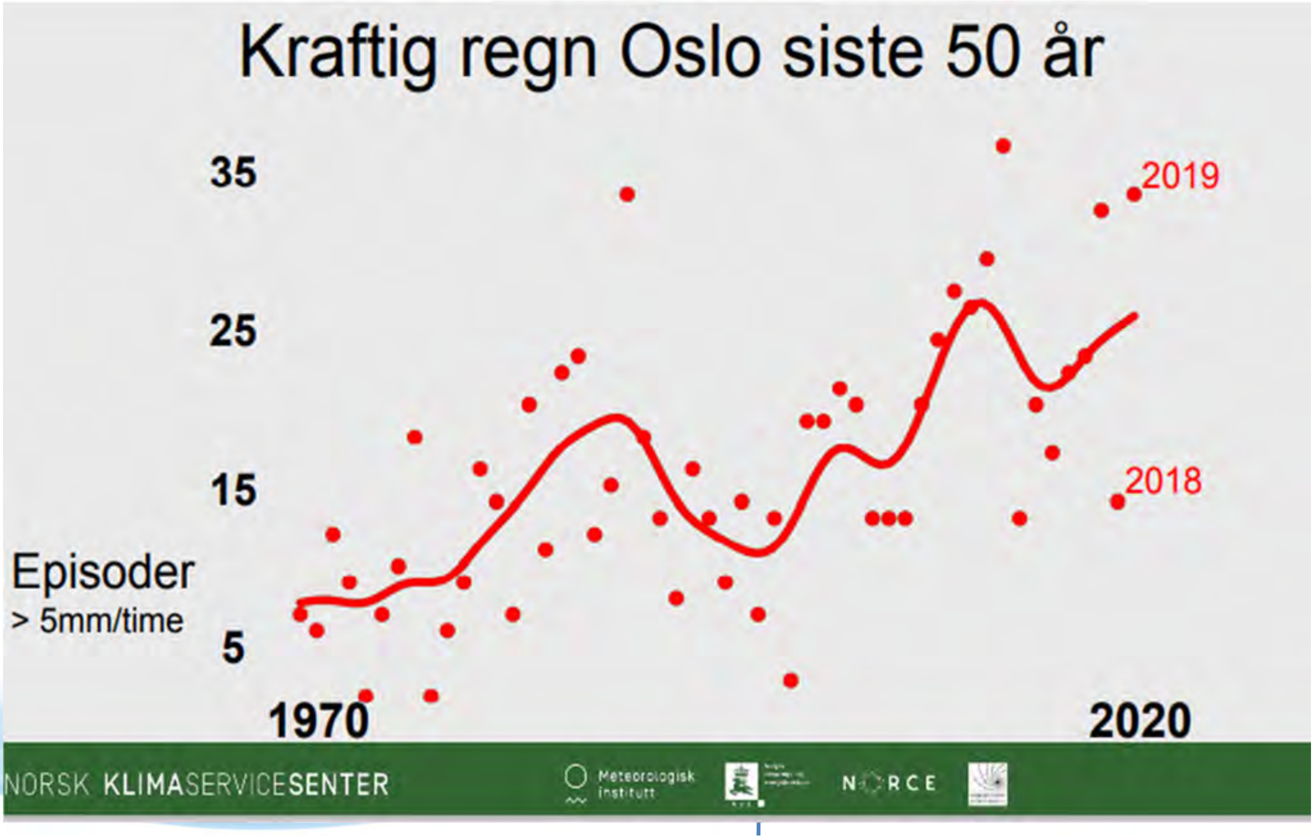
Observed in Norway

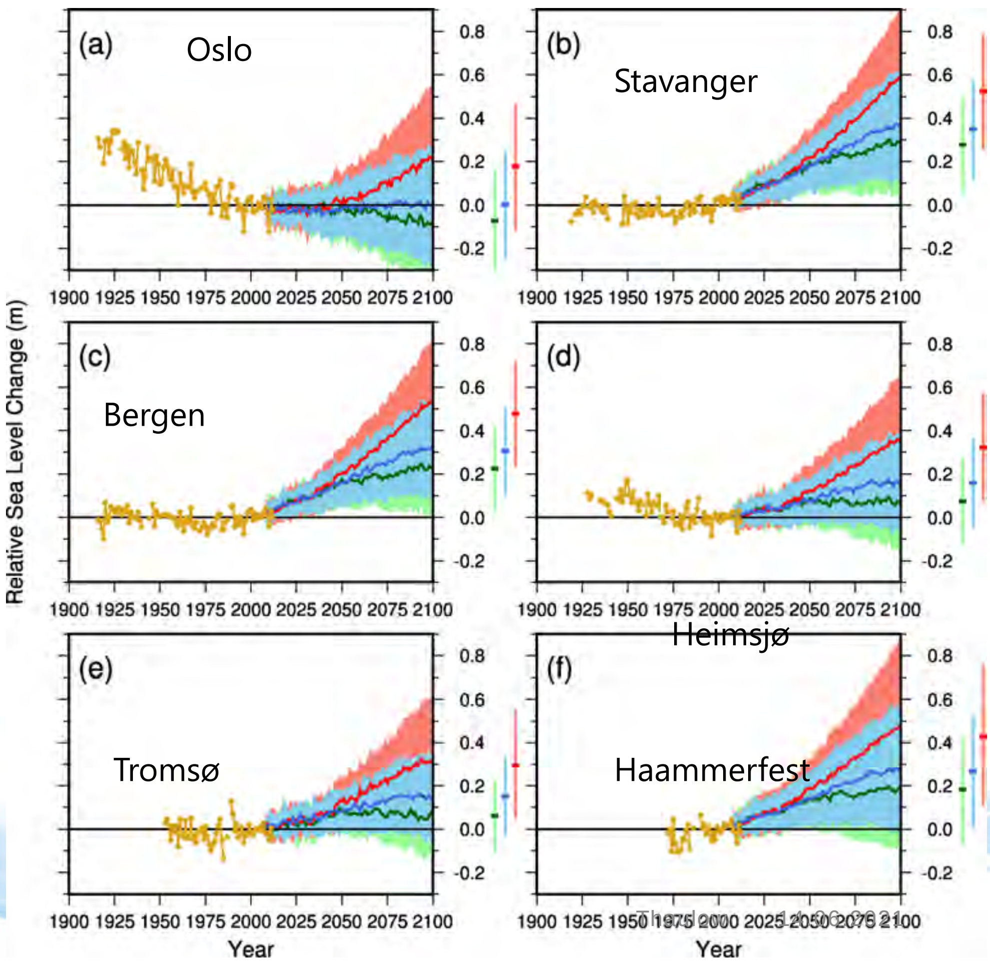
- Warmer
  ca 1 ^{0}C since 1900
- Wetter,- precipitation increased nearly 20 % since 1900
- More «heat records» fewer «cold records»
- More rain floods
- Fewer snowmelting floods
- Springfloods come earlier
- Below 1000 m in southern Norway shorter snow-season
- Glaciers are shrinking





NORSK KLIMASERVICESENTER





Ocean level predictions

Examples of sucessful water quality management in Norway - -

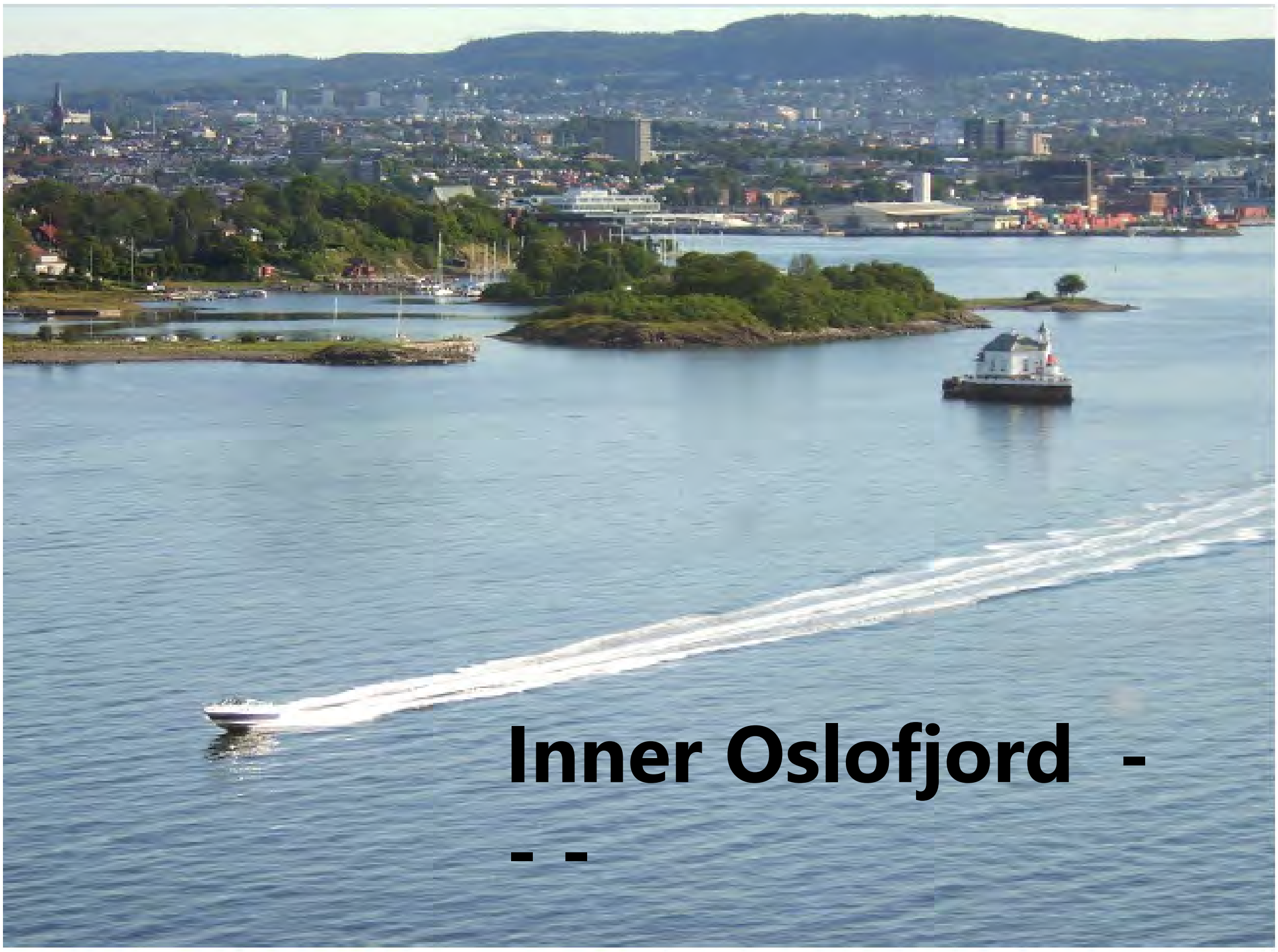
- River Akerselva,

- Inner Oslofjord

Action for a cleaner Akerselv

- Closedown of industries
- Treatment of industrial wastewater
- **Collection sewers along the river on both sides**

Akerselva Environmental Park –



Inner Oslofjord -

- -

Wastewater treatment plants and tunnels

Thank you !

Meeting challenges in the water sector: Climate Change

Harsha Ratnaweera
Professor, Norwegian University of Life Sciences

Europe and urban floods

Making surfaces permeable again

Innovative landscapes: Converting playgrounds to storm water retention tanks

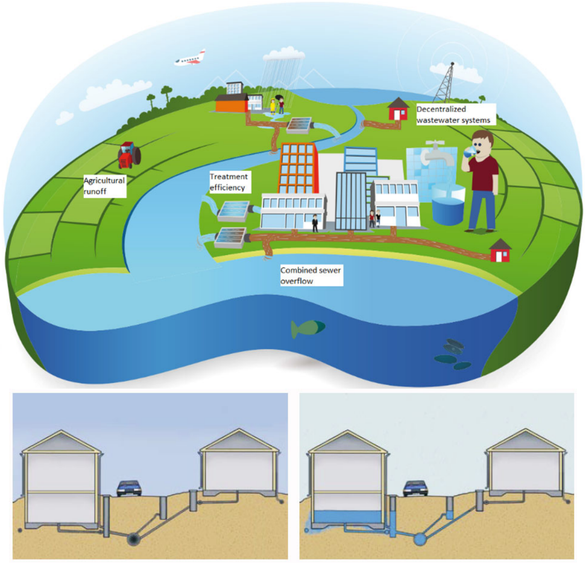
Opening canals

Impact on drinking water supply

- On quantity
- On microbial quality
- On chemical quality

Pollution from sewers

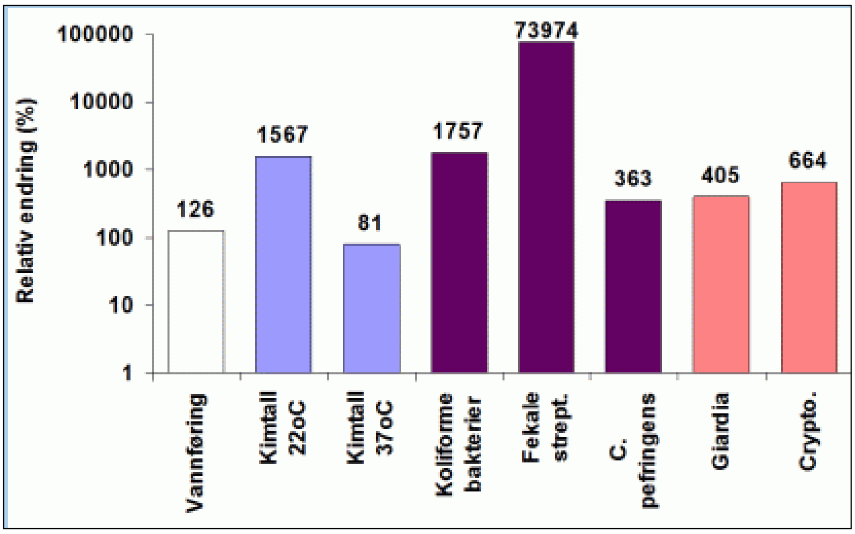
- Combined sewer overflows
  - Pipe overflows
  - Plant overflows
  - Pumping stations
- Flood water will contain waste water



Impacts on water quality

- Rainwater itself is low in (free from?) pathogens!
- But rainfall becomes runoff on the surface or in the ground
  - Mobilization of pathogens in the watershed
  - Discharges from centralized or decentralized wastewater systems
  - Flooding
- Dry periods may be important for pathogen accumulation
- Dilution vs. pathogen mobilization?
- Drought may increase relative pathogen load

Increased runoff ➔ increased bacteria and parasites in raw water



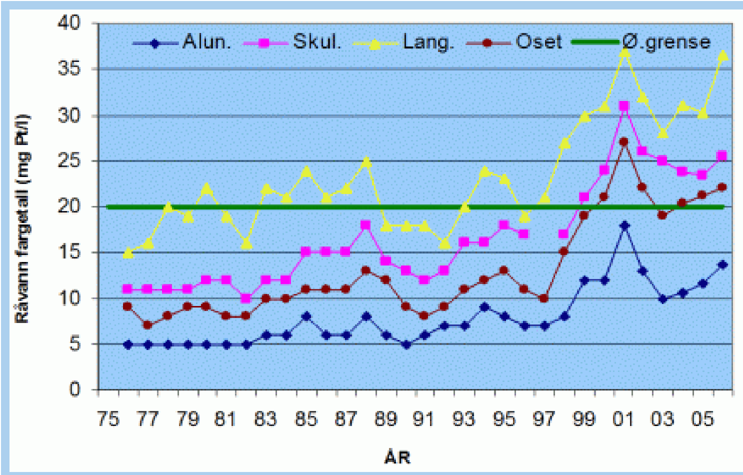
- Results from a German study that shows the relationship between the increase in runoff (water flow) and increase in bacteria and parasites in drinking water

Kistemann et al , 2002

Impact on treatment processes

- Indirect effects on water treatment:
  - Particle load and natural organic matter in DW
  - Disinfection efficiency (chlorine/UV)

NOM / Colour in raw water increase



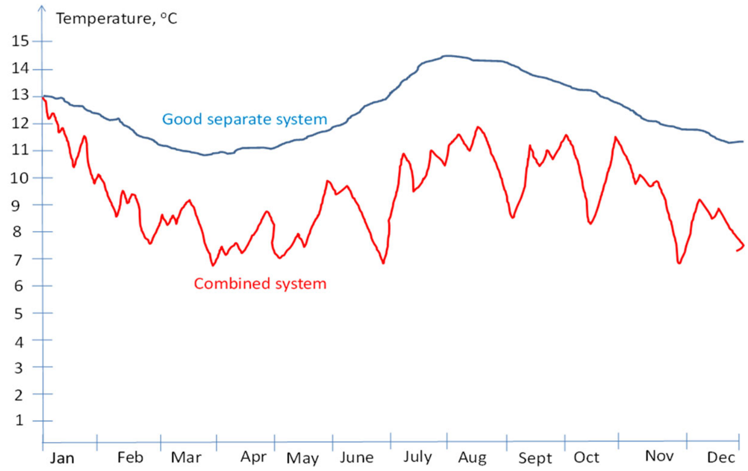
- Various raw water sources in the Oslo/Akershus region

DWTPs which were not built with colour removal (due to low raw water colour) must now add colour removal processes!

How may the challenges of varying temperatures – especially in connection with snow-melt, be solved?

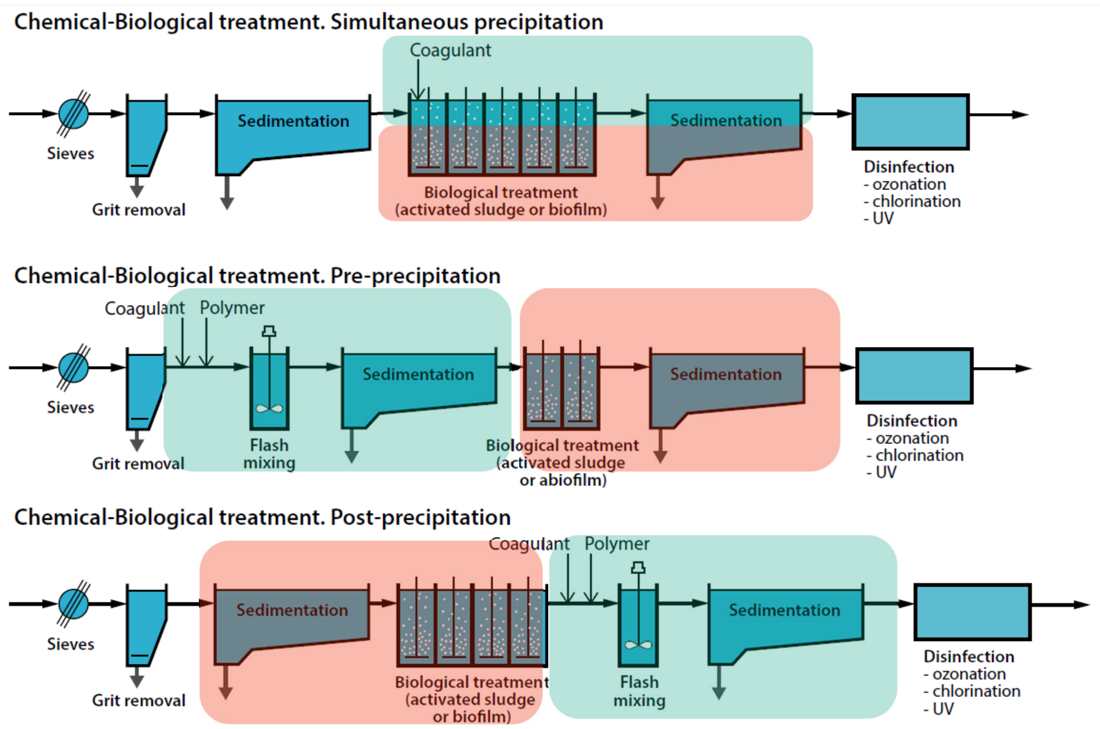
- Use separate systems – do not mix wastewater with rainwater
- Select processes that can stand better variations in temperature

Separate sewers vs combined sewers



Good separate system vs Combined system or system with much external intrusion water

Ødegaard, Rusten, Ratnaweera, EWA-WMCC 2016



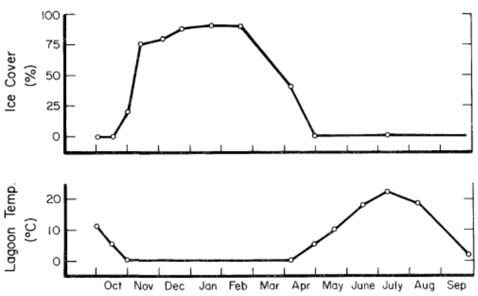
Factors influencing treatment efficiencies and economics

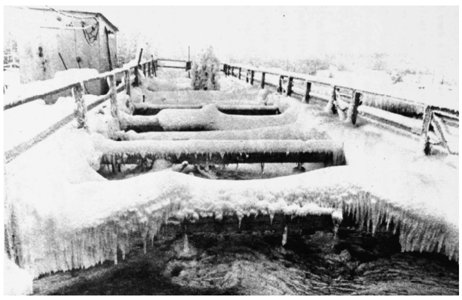
Drier and warmer summers
Wetter and warmer winters

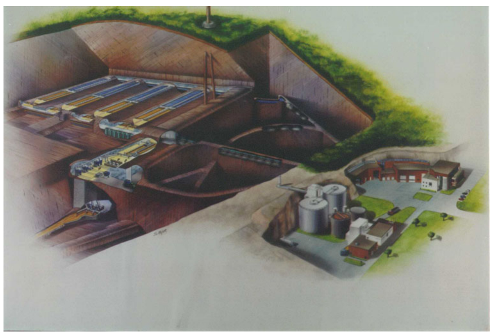
↓ snow accumulation on the surface
↑ amount of sewage transported
↑dilution of influent

↑ Influent volumes
↓ sewage temperatures
↓ Influent concentrations

Why most WWTPs in Norway are covered



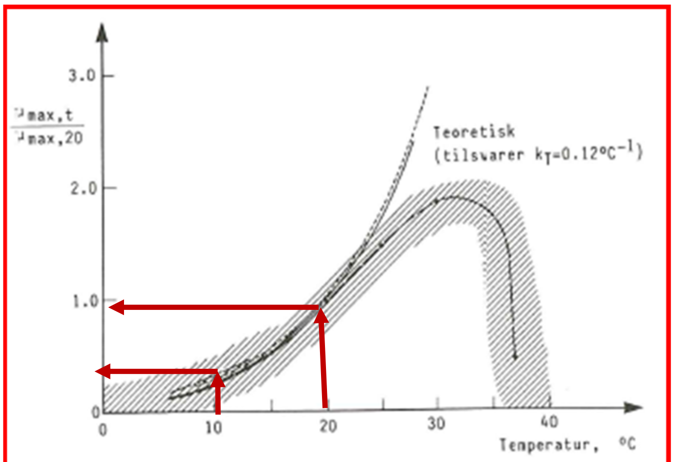




Underground WWTP in Norway

110 000 people
50 000 m^3/day
Removal of COD, N, P

Cold climate: efficiency ⬇ cost ⬆

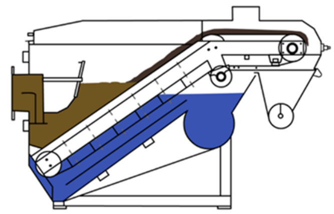


Nitrifikasjonens avhengighet av temperatur (Henze et al, 1990)

Enzyem producing bacteria

🡇 10 degrees = 🡇 of 50% of Nitrification rate
➔ will require bigger reactor volumes to achieve the same treatment efficiencies

More compact processes – primary treatment



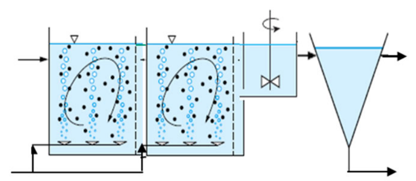
Advantages in cold climates
- Compact technology – in-door
- High DS in sludge (> 25 % if screw press)
- Higher SS-and COD-removals may be achieved with, for e.g. polymers

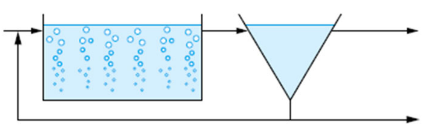
Disadvantages in cold climates
- Mechanical parts to be supervised
- Possible clogging of filter mesh

Common practice: setting tanks.
Needs large space – costly if in-door, Low sludge DS, Unstable sludge

Experience from Tromsø (350km North of Polar circle):
Fine sieves may give about the same treatment results as primary settling

Secondary/tertiary treatment
Suspended vs Attached growth

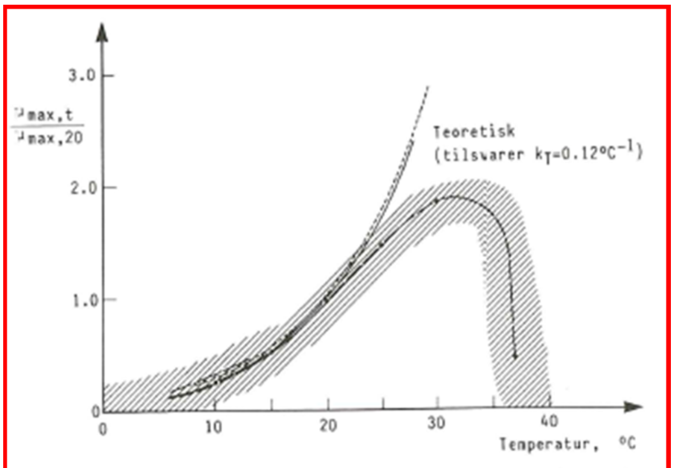




Advantages in cold climates
- Less influenced by fluctuations in Q & load
- Easy to operate (most reactor types)
- Lower foot-print (e.g. MBBR)
- Nitrification easily established at lower volumes
- All separation processes may be used

Disadvantages in cold climates
- Carrier needed – more costly
- Higher DO (energy) needed

Impact on biological treatment



Nitrifikasjonens avhengighet av temperatur (Henze et al, 1990)

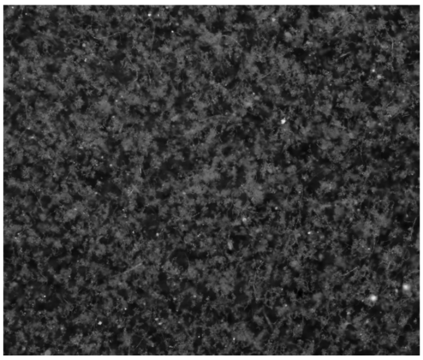
Reduction of 10 degrees = reduction of 50% of Nitrification rate
➔ will require bigger reactor volumes

Impact of temperature on coagulation

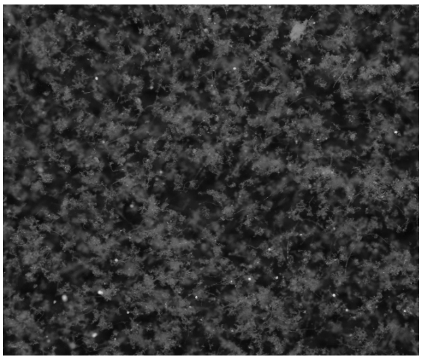
- Floc formation during wastewater coagulation is known to be slower at lower temperatures
- Sedimentation / flotation can therefore be negatively influenced.
  - ↑ sedimentation volumes
  - ↑ coagulant/flocculent demand

Temperature impact on coagulation: floc building

Floc building slows down at lower temperatures



5 ^{o}C - smaller flocs



20 ^{o}C - larger flocs

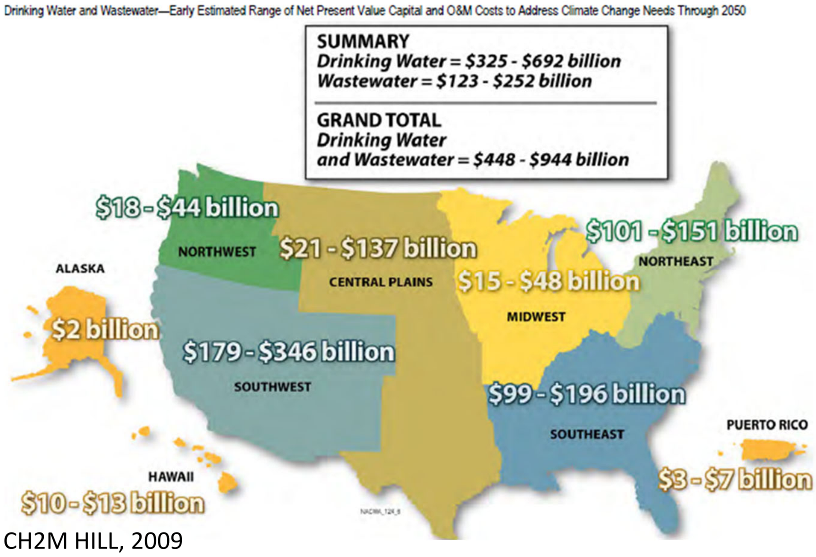
Cost of adaptation

Potential consequences of climate change on the water sector, without adaptation

Activity	Potential economic consequences	Potential non-economic consequences
Water supply		
Domestic/ municipal	Cost of altered health Cost of dealing with droughts	Disruption to established patterns of use
Industrial	Cost of change in industrial productivity	Disruption and uncertainty
Agricultural (including irrigation)	Cost of change in agricultural productivity	Uncertainty
Sanitation and effluent removal	Cost of altered health Cost of impacts on instream ecosystems (e.g. fisheries) Cost of dealing with pollution incidents	
Navigation	Cost of altered navigation opportunities	
Flood management	Change in economic value of flood damages (direct and indirect) Change in economic value of injury and ill health	Disruption and anxiety
Hydropower	Cost of change in generation potential	
Recreation	Cost of changes in recreational opportunities	Change to cultural value of the water environment
Water level and soil water management		Change in habitat characteristics
Ecosystem services		Change in instream and riverine habitats and species

Economical consequences

- Increased costs. Sweden estimates 0.2 billion USD for 2011-2040 improve treatment quality, and 0.6 billion USD for 2011-2100 (only for drinking water).



Confronting CC, CH2M HILL, 2009

10^{th} International Summer School on Water

Norwegian University of Life Sciences

THT 311: Water resources management and water & wastewater treatment

13 June 2021

Faculty of Science and Technology, NMBU

Norwegian University of Life Sciences

Water, Environment, Sanitation & Health – WESH Group

- NMBU
  - RealTek
    - Water & Environment
    - Building technology & Architecture
  - + 6 other faculties

Additionally several other "smaller" groups at other faculties

About the Course Coordinator

Background

- Born in Sri Lanka, lived 18 years
- MSc from NTUU-KPI, Kiev, Ukraine, in 1987, lived 7 years
- PhD from NTNU, Trondheim, Norway, in 1992
- lived 33 years in Norway; worked in several countries for NORAD, SIDA, DANIDA, UN, World Bank.

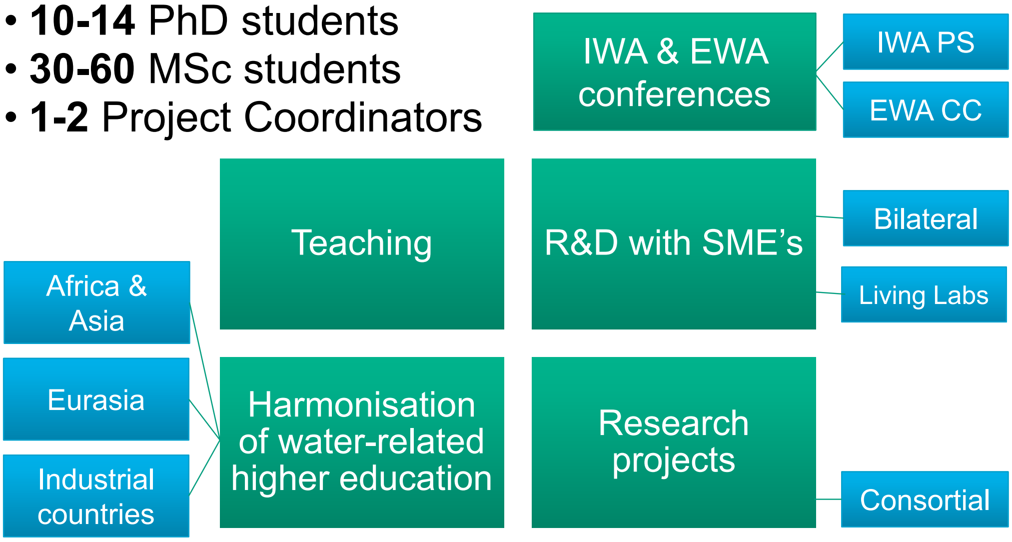
Work experience

- 20 years: Director of innovation & international projects at the Norwegian Institute for Water Research
- Since 2012, fulltime professor, NMBU (2001-2011 part-time) at the Faculty of Science & Technology
- Worked in all continents…also for the World Bank and UN ECE

- IWA Fellow (International Water Association)
- Member of the Norwegian IWA Board, Member of specialist groups steering committees
- Norwegian representative at the EWA (European Water Association), Council member
- Chairman/Board member of various Norwegian water association

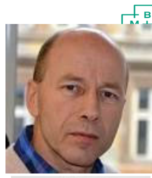
Water, Environment, Sanitation & Health - WESH

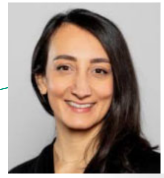
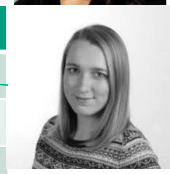
- **8-10** Teaching Members (Prof, Ass Prof)
- **2-3** Research Coordinators (Post Docs)
- **10-14** PhD students
- **30-60** MSc students
- **1-2** Project Coordinators







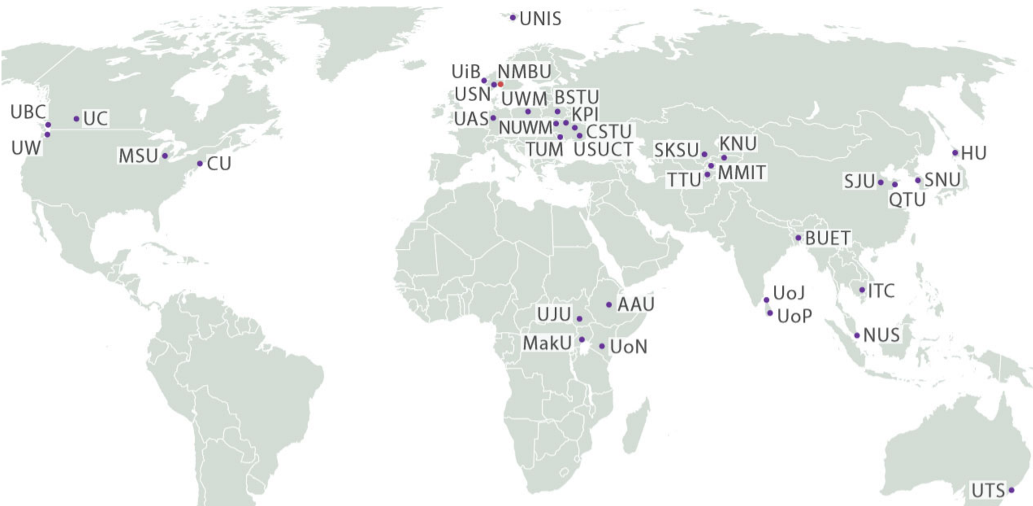




Lecturers

Name	Affiliation
Dr Zakhar Maletskyi	Associate Professor, NMBU
Prof Lars Hem	Adjunct Prof, Principal Engineer, Oslo Water
Prof Arve Heistad	Professor, Head of the Water group
Prof Jan Vermaat	Professor, Dean
Mr Haakon Thaulow	Former Director, NIVA
Dr Pelin Schumacher	Associate Professor, NMBU
Dr Agnieszka Cuprys	Postdoctoral fellow, NMBU
Dr Natalia Sivchenko	Project Engineer, DOSCON AS
Dr Goitom Weldehawaryat	Postdoctoral fellow, NMBU
Dr Abhilash Nair	Project Engineer, DOSCON AS

Susann Andersen, Course secretary

WESH projects



75 universities from 45 countries
www.WaterHarmony.net

International Summer School on Water

NMBU, Ås

A tradition since 2012

Course objectives

This course is an intensive course complimentary to THT 271, THT 310 or can be taken as an independent professional development course.

Learning outcome

After completion of this course, graduates will be able to:

- apply principles of the integrated water resource management
- recognise climate change impacts on water sector
- explain principles, opportunities and risks of digitalisation in the water sector
- implement bioeconomy principles in the water sector
- compare decentralised and centralised wastewater treatment solutions
- explain emerging water challenges
- develop research concepts and present results

WEEK 1: Day and topic	Norway time
Monday 14th June	
Course introduction (Ratnaweera) and group work structure	08:00-08:30
Module 1: Meeting the global challenges in the water sector	
Global challenges (Thaulow)	08:30-10:30
Meeting challenges in the water sector: Climate Change (Ratnaweera)	10:45-11:30
Group work: Groupmap exercise (Maletskyi)	12:00-14:00
Tuesday 15th June	
Module 2: Integrated water resources management & Water quality (Vermaat)	08:00-11:00
Groupwork (Playing serious game SIM4NEXUS) (Maletskyi)	11:30-14:00
Wednesday 16th June	
Module 3: Planning of water utilities for the future (Hem)	08:00-11:00
Groupwork (Playing serious game on Adaptive Planning) (Maletskyi)	11:30-14:00
Thursday 17th June	
Module 4: Water quality monitoring	
Sampling and online monitoring (Ratnaweera)	08:00-09:30
Advanced methods (Cuprys)	09:45-11:00
Groupwork on water quality: designing a monitoring plan for a DWTP/WWTP (Ratnaweera)	11:30-14:00
Friday 18th June	
Module 5: Digitalisation of the water sector	
Opportunities and threats (Weldehawaryat)	08:00-08:45
Introduction to simulation programs in the water sector (Ratnaweera)	09:00-09:30
Simulation program STOAT (Sivchenko)	09:45-11:30
Hands-on training on STOAT (Sivchenko)	12:00-14:00

WEEK 2: Day and topic	Norway time
Monday 21st June	
Module 6: Bioeconomy (Schumacher)	08:00-11:00
Group work: discuss and prepare a PPT presentation on given topics	11:30-13:00
Presentation in plenum (Schumacher)	13:00-14:00
Tuesday 22nd June	
Module 7: Research skills and visibility	
Research publication writing (Ratnaweera)	08:00-08:45
Increasing visibility: ResearchGate, Google Scholas, Scopus, LinkedIn etc (Maletskyi)	09:00-10:00
Managing scientific references – Mendeley and data bases (Sivchenko)	10:00-11:00
Group work: Hands-on literature search (Sivchenko)	11:30-14:00
Wednesday 23rd June	
Module 6: Digital tools in water utilities	
BIM and digital twins (Nair)	08:00-09:45
Virtual visit to a treatment plant (Ratnaweera)	10:00-11:00
Groupwork: design a treatment plant with videos from internet (Ratnaweera)	
Thursday 24th June	
Module 9: Decentralised water management and Eco Sanitation (Heistad)	08:00-11:00
Group work: discuss and prepare a PPT presentation on given topics	11:30-13:00
Group work /discussions in plenum (Heistad)	13:00-14:00
Friday 25th June	
Emerging water challenges (Cuprys)	08:00-10:00
Exam & discussion of question/answers	11:00-12:30
Closure	12:30

Introduction exam and to project work

THT311

Harsha Ratnaweera & Zakhar Maletskyi

Exam / ECTS / Marks

- THT311 course is a master level course with 10 ECTS (European Credits), which requires 300 hours of input from each student.
  - 80 hours: Lectures and self study during two weeks
  - 220 hours: Project work + self study

- Marks:
  - 50% for the online exam
  - 50% for the project report

Digital exam

- We will use a Google form based exam.
- Please test if your PC/login works? NMBU login not needed

- https://forms.gle/qiNoVRi6iSAASegB6

Project work: Process and deadlines

- 25.06.2021: Selection of the topic
- 30.07.2021 and 30.08.2021 open consultation/discussion sessions on zoom
- 10.09.2021: Submission of the final draft
- 19.09.2021: Comments to the final draft by teachers
- 30.09.2021: Submission of the report

- Only single reports (no group submissions)
- Prepare as a journal manuscript of 5000 words + figures+ tables etc.
- You may involve a teacher from your university and/or from NMBU as co-supervisors to develop the paper.

12 topics to select from

1. Meeting the global challenges in the water sector
2. Climate Change Impacts on the water sector
3. Integrated water resources management & Water quality
4. Planning of water utilities for the future
5. Water quality monitoring
6. Digitalisation of the water sector
7. Bioeconomy
8. Decentralised water management and Eco Sanitation
9. Emerging water challenges
10. Solving water treatment challenges in my country
11. Solving wastewater treatment challenges in my country
12. Water and wastewater legislations in my country compared with EU

Structure

- Introduction/Background: why this is a challenge or/and important to focus on. Use literature references
- Method: how did you collect information (data bases, contact resources persons, surveys, books etc)
- Results: what has been done so far and to which degree they are solved (references, examples)
- Discussion: how to proceed further/what can be /need to be done? Your thoughts from the lectures and other studies.
- Conclusions
- Recommendations: what can be done to improve work on this topic which I did not had time or resources, but still important to focus on
- List of references

Marking structure: 20% to each section

- Coverage of scientific literature
- Coverage of other information sources
- Comprehensiveness of the subtopics (Intro and results)
- Own reflections on the topic (discussions and recommendation part)
- Format of the manuscript

After submission

- We will consider including them in a printed proceedings book
- The best papers will be encouraged to develop as manuscripts for international journals and/or conferences. Such papers can be jointly developed with co-supervisors (but not as a part of the assignment for the evaluation of the subject).
- All will get an opportunity to present their findings at a seminar/workshop when you are in Norway (if the travelling will eb permitted).

Special course with SUNY-SB USA and NMBU

- State University of New York at Stoney Brook and NMBU collaborates in an R&D project “Managing nanoparticles and use of nanotechnology in water”.
- A special joint course with 4-6 joint lectures + project report is planned
- Postponed to Oct/Nov 2021
- A course completion certificate: jointly from SUNY.SB & NMBU
- NMBU 3 ECTS course certificate

- Registration in Oct 2021- you will be invited to join

Arctic Summer school

- 3 ECTS NMBU
- Certificate from IAS-HIT
- Registration end of June. You will be invited.

Modern analysis techniques for water pollutants

THT311 – 17 June 2021

Agnieszka Cuprys, Zakhar Maletskyi

Norwegian University of Life Sciences

Content

1. Challenges in water pollution
2. Sampling and sample preparation
3. Mass spectrometry
4. Separation techniques
5. Spectroscopic techniques
6. Other techniques – future trends

Challenges in water pollution

Persistent Organic Pollutants (POPs)

POPs
- carbon based organic chemicals
- highy soluble in lipids
- disperse to long distance in an atmosphere

Intentionally
- wanted products are produced
- highly lipophilic and neurotoxic

Unintentionally
- unwanted products are produced as byproducts

Organochlorine pesticides
- DDT
- DDE
- Dicofol
- Methoxychlor
- Lindane
- Aldrin
- Mirex

Industrial chemicals (PCB)
- 2-chlorobiphenyl
- 2,2',3,4'-tetrachlorobyphenyl
- 3-chlorobiphenyl

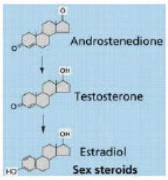
Polycyclic aromatic hydrocarbons (PAH)
- Anthrone
- Benzanthrone
- Benzo[A]pyrene

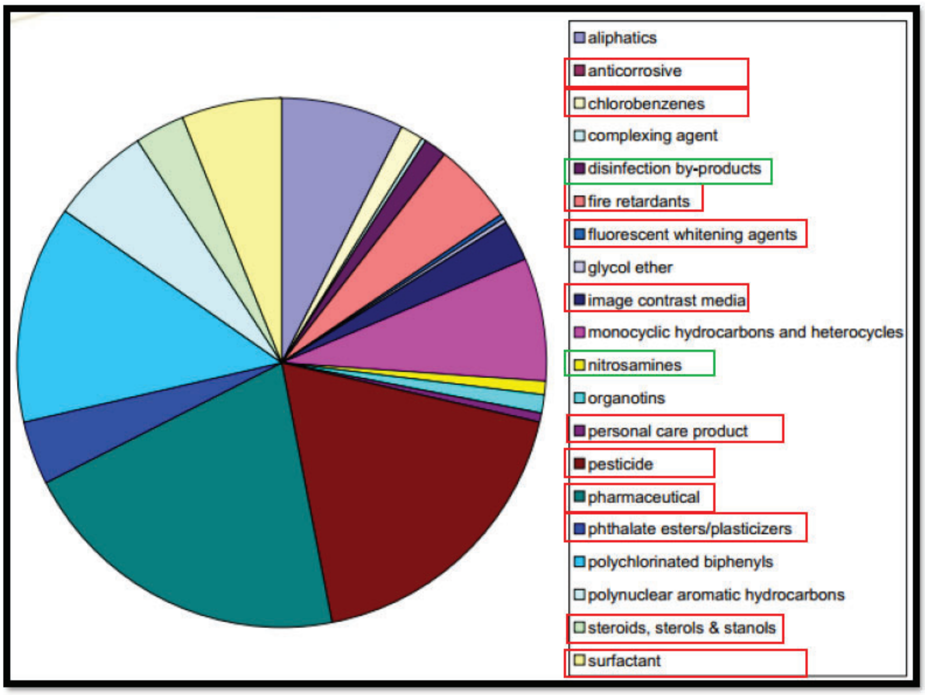
Furans compounds
- 2,3,7,8-tetrachlorodibenzofuran
- 1,2,3,7,8-pentachlorodibenzofuran

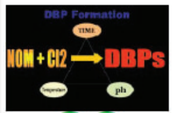
Dioxin compounds
- 2,3,7,8-tetrachlorodibenzodioxin
- 1,2,3,7,8-pentachlorodibenzo-p-dioxin

Credit: Gaur, N.; Narasimhulu, K.; PydiSetty, Y.. *J. Clean Prod*. 2018, 198, 1602-1631

Trace Organic Compounds







GC

WERF (2008)

Trace Organic Compounds

Pharmaceuticals lurking in U.S. drinking water

AP probe found traces of meds in water supplies of 41 million Americans

Painkillers found in drinking water of 15 Ontario cities, study reports

Study: India's Water Contains Highest Levels of Pharmaceuticals in World

Published January 26, 2009 / Associated Press

Third of male fish in rivers are changing sex

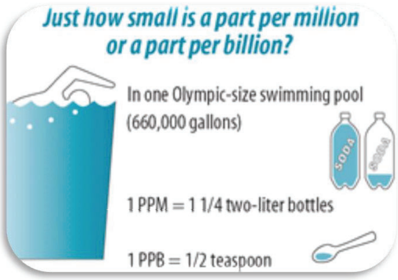
By FIONA MACRAE, Daily Mail
Last updated at 19:36 19 July 2006

A third of male fish in English rivers are changing sex due to 'gender-bending' pollution, alarming research shows.

Inorganic pollutants: drinking water regulations

To meet the needs of all standards at the required detection limit, a lab requires:ICP-OES; GFAAS; HGAAS; CVAFS; Fluorimetry

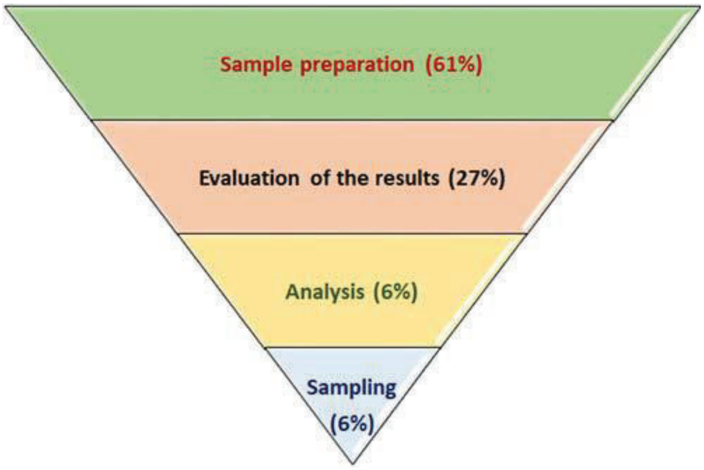
El	water								China		
Ag	----	ppb			10[z]				<50	<1	GFAAS
As	0.1 - 50	ppb	10[a]	10	10	10	50	50	<50	<1	HGAAS;GFAAS
B	50 - 200	ppb	500[z]	1000		1000		300	<300	<30	ICP-OES
Be	----	ppb			4				<2	<0.2	ICP-OES
Cd	0.05 - 0.5	ppb	3	5	5	10	10	5	<10	<0.3	GFAAS
Co	----	ppb							<1000	<100	ICP-OES
Cr	0.1 - 5	ppb	50[a]	50	100		50 (VI)	50 (VI)	<50 (VI)	<5	ICP-OES
Fe	1 - 10,000	ppb		200	300[z]	300	500	300	<300	<20	ICP-OES
Hg	0.01 - 0.05	ppb	1	1	2	0.5	2	1	<1	<0.05	CVAFS
Mn	10 - 1000	ppb	50[a]	50	50[z]	50	300	300		<5	ICP-OES
Mo	20 - 70	ppb	70						<500	<7	ICP-OES
Ni	1 - 20	ppb	20[a]	20	20[z]	10			<20	<1	ICP-OES
Pb	1 -30	ppb	10	10	15	50	50	50	<50	<1	GFAAS
Sb	0.1 - 1	ppb	5[a]	5	6	2			<50	<0.2	GFAAS
Se	0.1 - 0.5	ppb	10	10	50	10	10	10	<10	<1	HGAAS;GFAAS
Ti	----	ppb							<100	<10	ICP-OES
Tl	----	ppb			2				<0.1	<0.01	GFAAS
U	0.01 - 1	ppb	2[a]		30	2				<0.2	Fluorimetry
V	----	ppb							<50	<5	ICP-OES
Al	0.01 - 100	ppm		0.2	0.02-0.2[z]	0.2		0.2	<0.2	<0.02	ICP-OES
Ba	0.01 - 10	ppm	0.7		2		1		<0.7	<0.07	ICP-OES
Ca	1 - 500	ppm					75			<7.5	ICP-OES
Cu	0.01 - 1	ppm	2[a]	2	1.3	1	1	1	<1	<0.1	ICP-OES
Mg	1 – 50	ppm					50		<20	<2	ICP-OES
Na	10 – 100	ppm		200		200				<20	ICP-OES
Zn	0.005 – 1	ppm			5[z]		5	1	<1	<0.1	ICP-OES

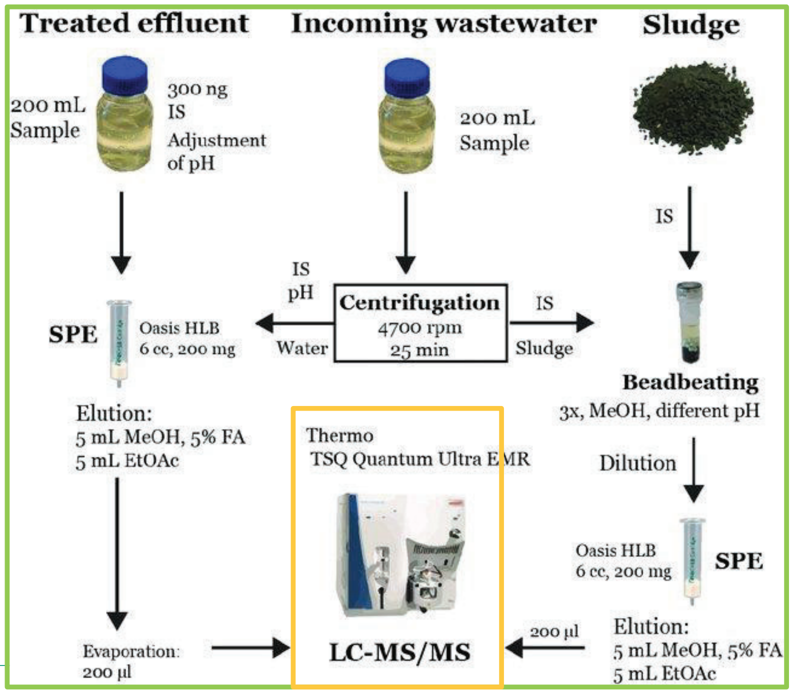


Credit: Agilent Technologies

Sampling and sample preparation

Environmental analysis

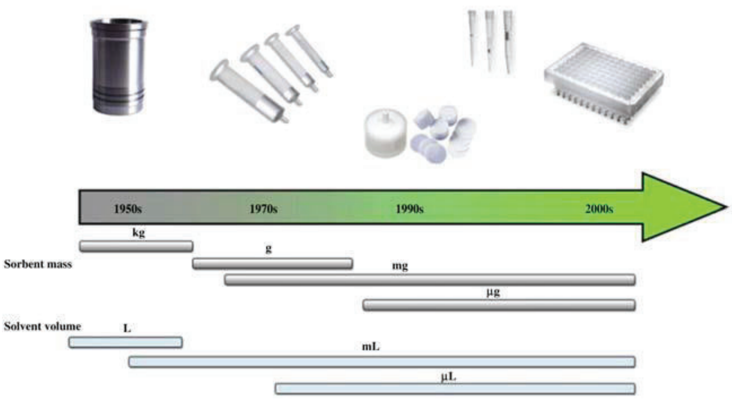


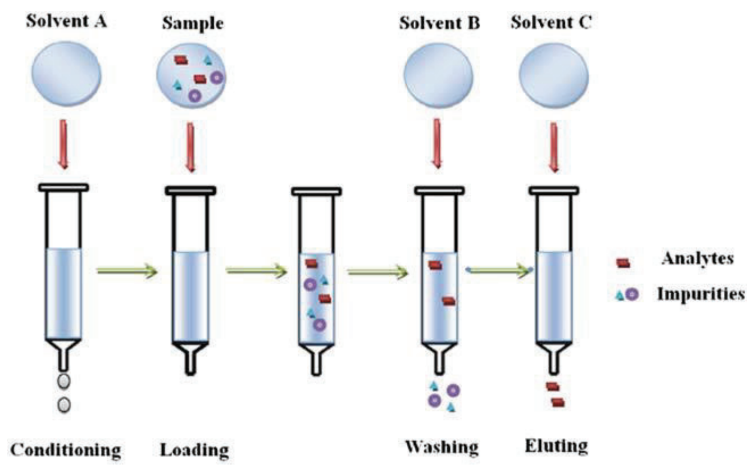


Credit: DOI: https://doi.org/10.1016/B978-0-12-816934-6.00004-7

Credit: DOI: 10.13140/RG.2.2.30958.87367

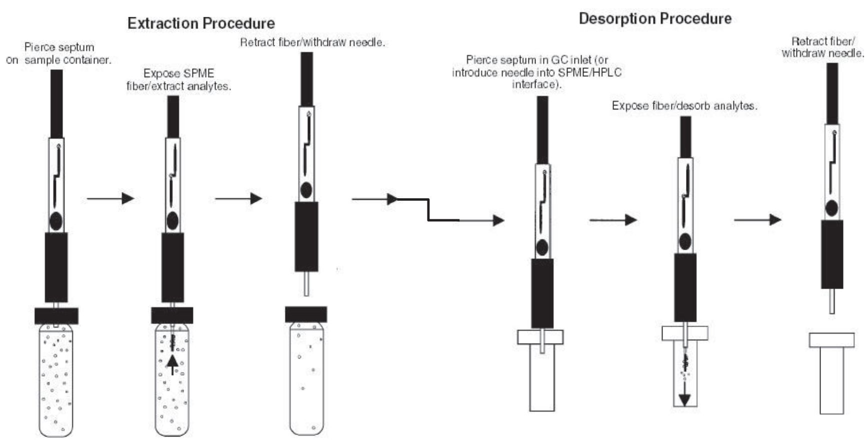
Solid-phase extraction



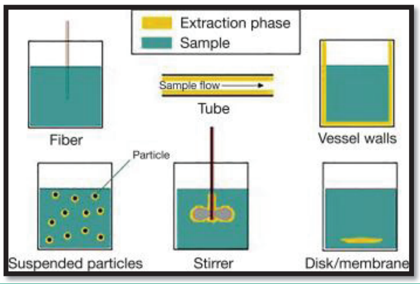


Credit: Płotka-Wasylka, J.; Szczepanska, N.; de la Guardia, M.; Namiesnik, J. Modern Trends in Solid Phase Extraction: New Sorbent Media. Trends Anal. Chem. 2016, 77, 23-43

Solid-phase microextraction



https://www.youtube.com/watch?v=Gno-S8FBpXM

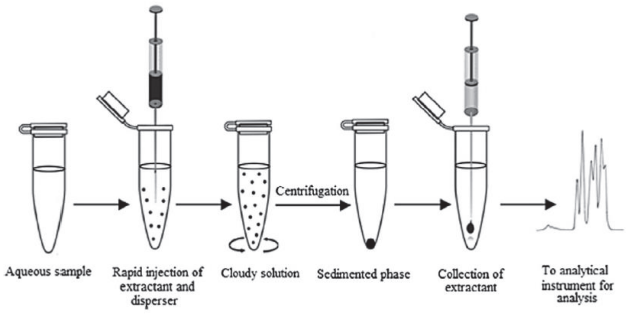


Credit: Vas, G., and Vekey, K. 2004. *Journal of Mass Spectrometry*, 39:233–54.
Credit: Xu, J., and Ouyang, G. 2019. *Encyclopedia of Analytical Science (Third Edition)*, 100-108.

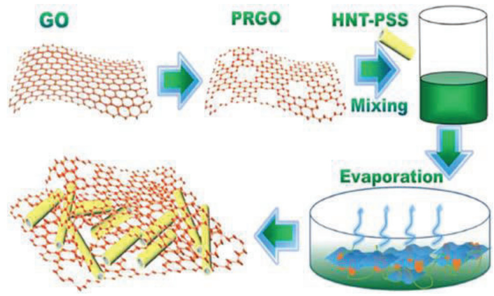
Solid-phase extraction – examples

Extraction technique	Adsorbent	Environmental pollutant	Sample	References
Solid-phase extraction (SPE)	Magnetic carbon nanotubes having nano-SiO_2 modified with octadecyl functional groups	Sulfonylurea pesticides and neonicotinoids	Water	[114]
SPE	Magnetic Fe_3O_4 nanoparticles-based-metal/organic framework	Heterocyclic pesticides (carbendazim, fenpyroximate, triadimefon, and chlorfenapyr)	Water	[115]
SPE	Amberlite XAD-2000	Pb(II) ions	Water	[116]
SPE	Magnetic metal/organic framework functionalized with graphene oxide (GO)	Triazole pesticides (myclobutanil, fenbuconazole, flusilazole, penconazole, and epoxiconazole)	Water	[117]
SPE	Polyamide nanofibers	Bisphenol A (BPA)	River water	[118]
SPE	Activated carbon	As(III), Cd(II) Cr (III), Cu(II), Fe(II), Mn(II) Ni(II), Pb(II), and Zn(II) ions	Wastewater	[123]
SPE	Magnetic Fe_3O_4 nanoparticles-based multiwalled carbon nanotubes (MWCNTs) composites	Polycyclic aromatic hydrocarbons	Industrial wastewater	[124]
Solid-phase microextraction (SPME)	Commercial SPME fibers (polydimethylsiloxane-divinylbenzene, divinylbenzenecarboxenpolydimethylsiloxane, polydimethylsiloxane, polyacrylate, polyethylene glycol, and carboxen-polydimethylsiloxane)	Hydrazine	Industrial wastewater	[129]

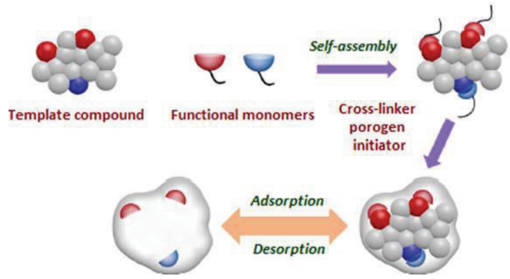
Other techniques



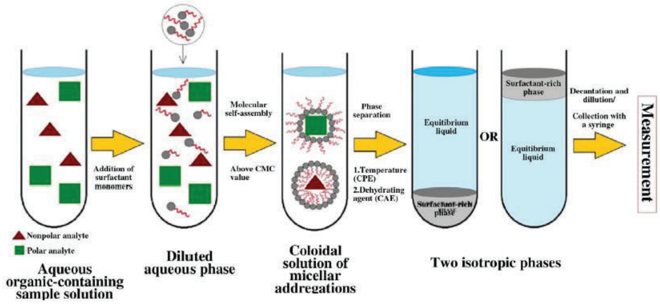
Dispersive liquid-liquid microextraction



Nano-based methods (membranes and particles)



Molecularly imprinted materials

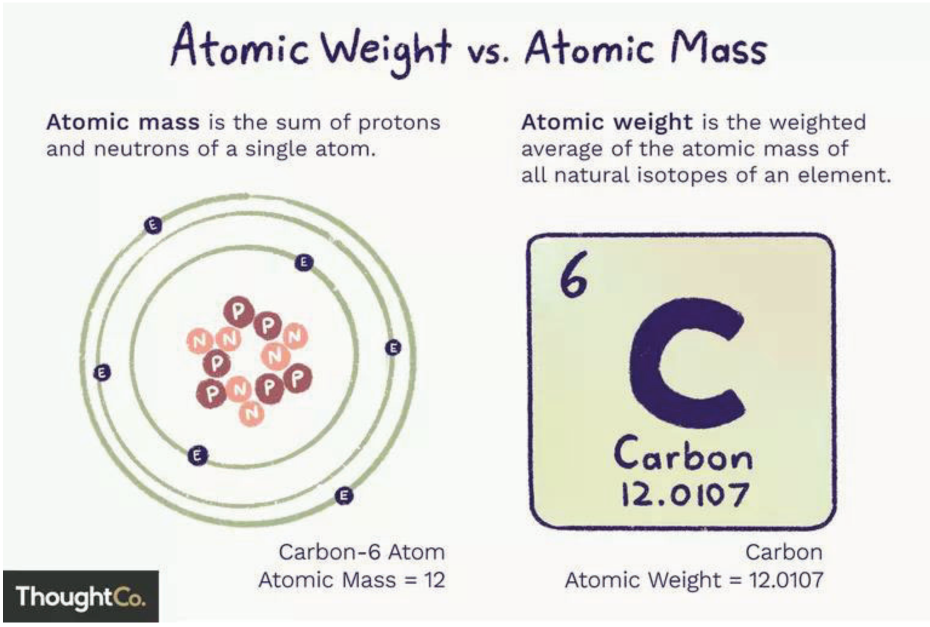


Cloud point extraction

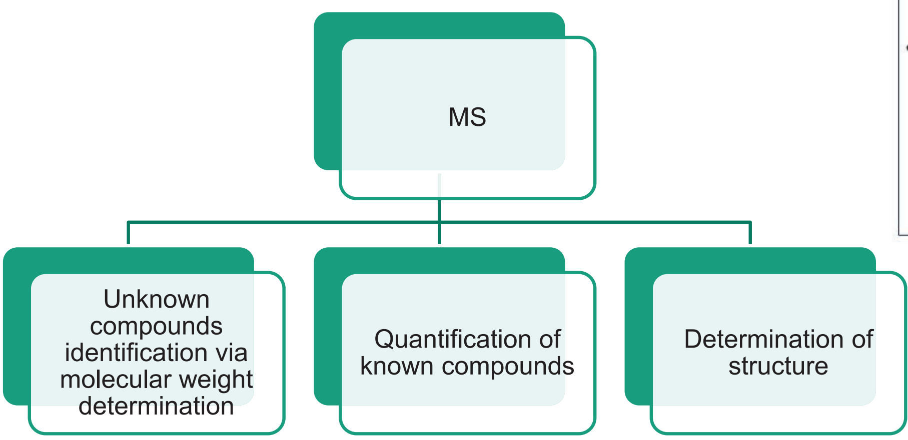
Credit: DOI: https://doi.org/10.1016/B978-0-12-816934-6.00004-7

Mass spectrometry

Weight and mass

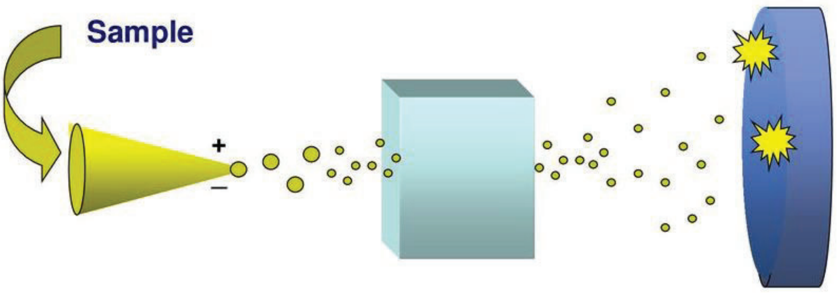


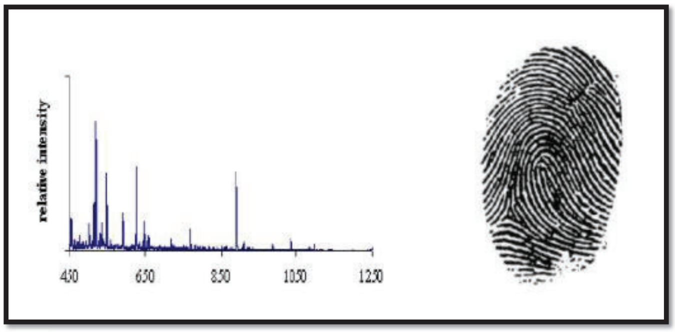
Mass spectrometry (MS)



- Mass spectrometry does not directly determine mass; it determines the *mass-to-charge ratio* (*m/z*) of ions.
- It is a fundamental requirement of mass spectrometry that the ions be in the gas phase before they can be separated according to their individual *m/z* values and detected.

Principle



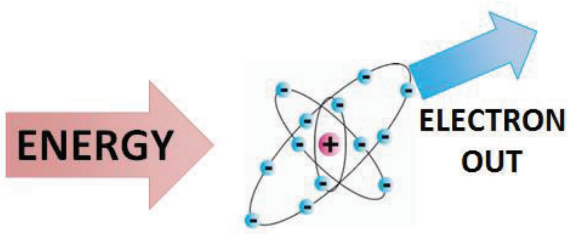


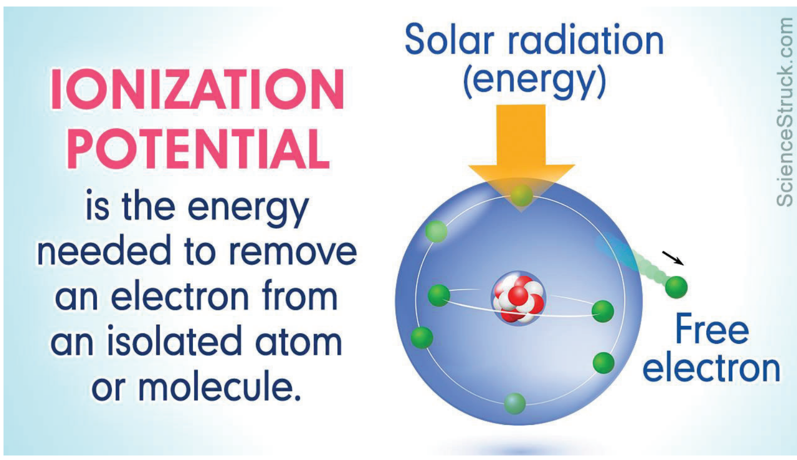
Ionizer
- MALDI
- Electro-Spray Ionization (ESI)

Mass Analyzer
- Time-Of-Flight (TOF)
- Quadrapole
- Ion-Trap

Detector
- Electron Multiplier (EM)

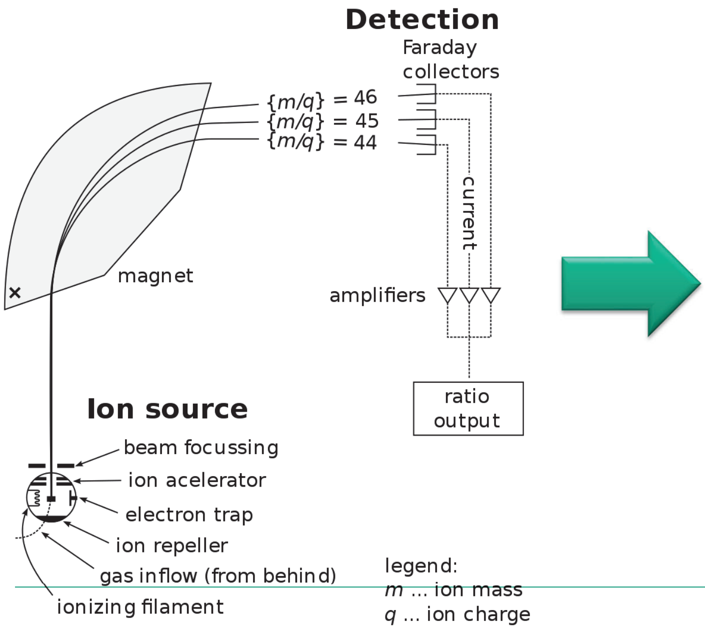
Ionization

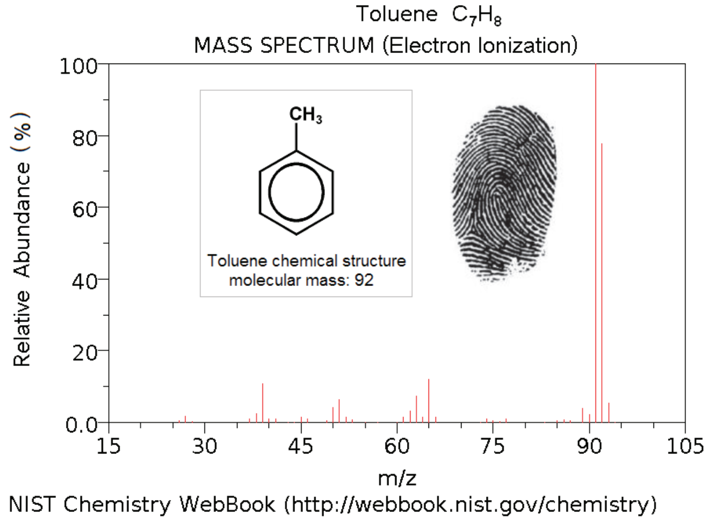




Mass spectrometry (**MS**)

- Measures the **mass-to-charge** ratio of **ions**





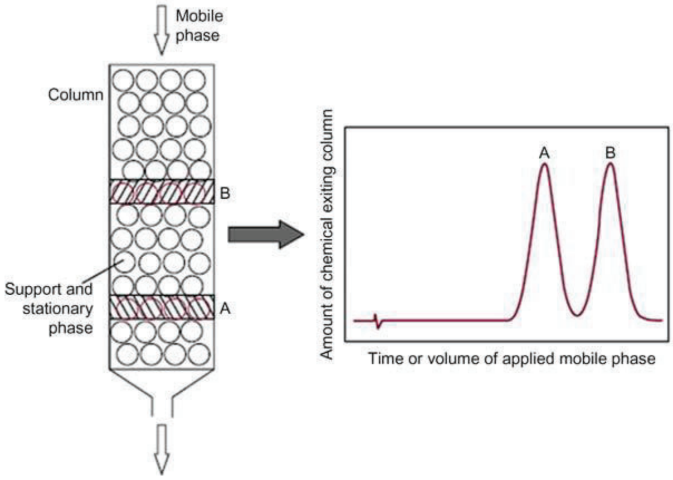
Mass analysers

- Quadropole: DC+RF are applied to two pairs of metal rods influencing trajectories of ions
- Time-of-flight: ions are accelerated in electric field, time of travel is measured
- Magnetic sector
- Electrostatic
- Quadrupole Ion Trap
- Ion Cyclotron

https://www.youtube.com/watch?v=DRo_VgIHWZg

Separation techniques

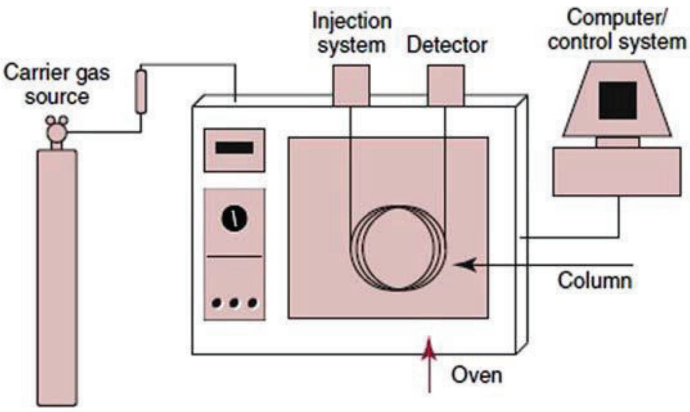
Chromatographic separation



Type of chromatography	Mobile phase	Stationary phase	Mechanism
Gas chromatography	Gas	Liquid adsorbed on the solid surface	Partition
		Solid	Adsorption
Liquid chromatography	Liquid	Liquid adsorbed on the solid surface	Partition
		Solid	Adsorption
		Ion-exchange resin	Ion-exchange
		Polymeric gel	Gel permeation
Supercritical fluid chromatography	Supercritical fluid	Solid	Partition

Credit: Hage, D. S., Principles and Applications of Clinical Mass Spectrometry. In Chromatography, 1st ed.; Rifai, N., Rita Horvath, A., Wittwer, C. T., Hoofnagle, A., Eds.; Elsevier, 2018; Chapter 1

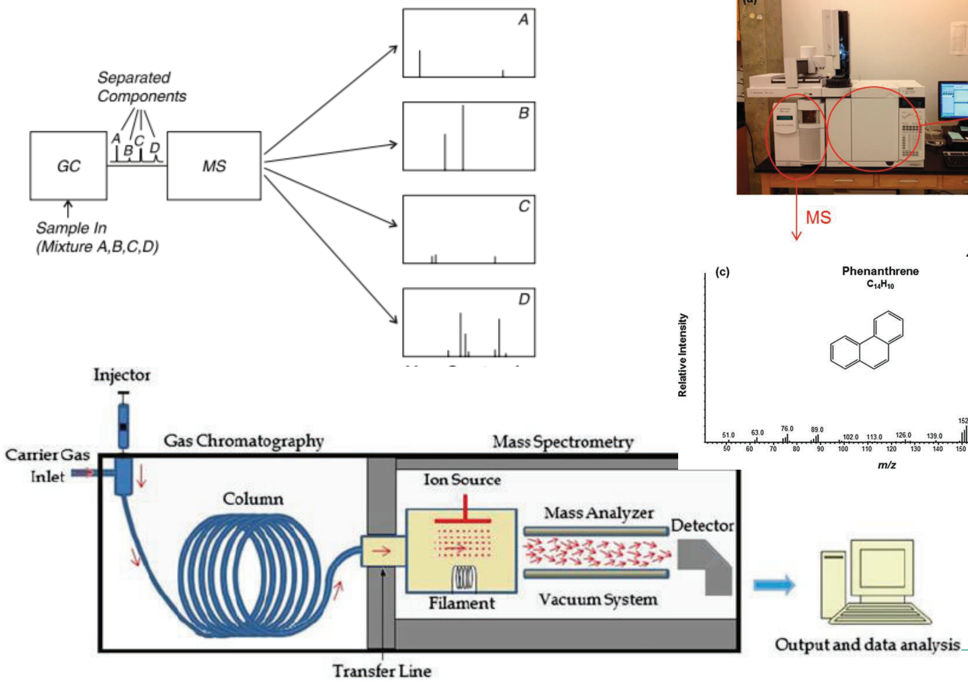
Gas chromatograph (GC)

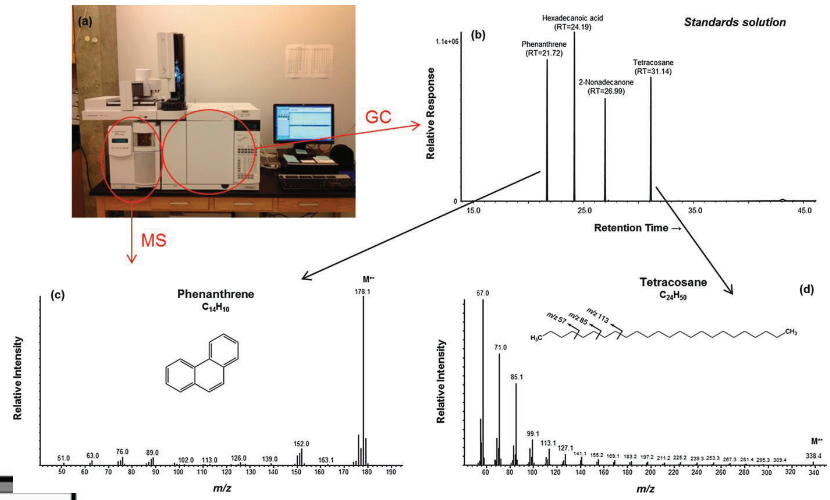


Detector type	Selectivity toward target compounds	Approximate detection limit	Dynamic range
Thermal conductivity detector (TCD)	Universal	1 ng	10^7
Flame ionization detector (FID)	Most organic compounds	100 pg	10^7
Electron capture detector (ECD)	Compounds having electronegative functional groups	50 fg	10^5
Photoionization detector (PID)	Aromatics, aliphatics, esters, aldehydes, organosulfurs, amines, heterocyclics, ketones, and some organometallics	2 pg	10^7
Electrolytic conductivity detector (ELCD)	Compounds bearing sulfur, halogen, and nitrogen functional groups	1 pg	10^6
Flame photometric detector (FPD)	Compounds having sulfur or phosphorus groups	100 pg	10^3
Nitrogen–phosphorous (thermionic selective) detector (NPD)	Compounds having phosphorus or nitrogen	10 pg	10^6
Mass selective detector (MSD)	Universal	1 pg	10^7

Credit: Hage, D. S., Principles and Applications of Clinical Mass Spectrometry. In Chromatography, 1st ed.; Rifai, N., Rita Horvath, A., Wittwer, C. T., Hoofnagle, A., Eds.; Elsevier, 2018; Chapter 1

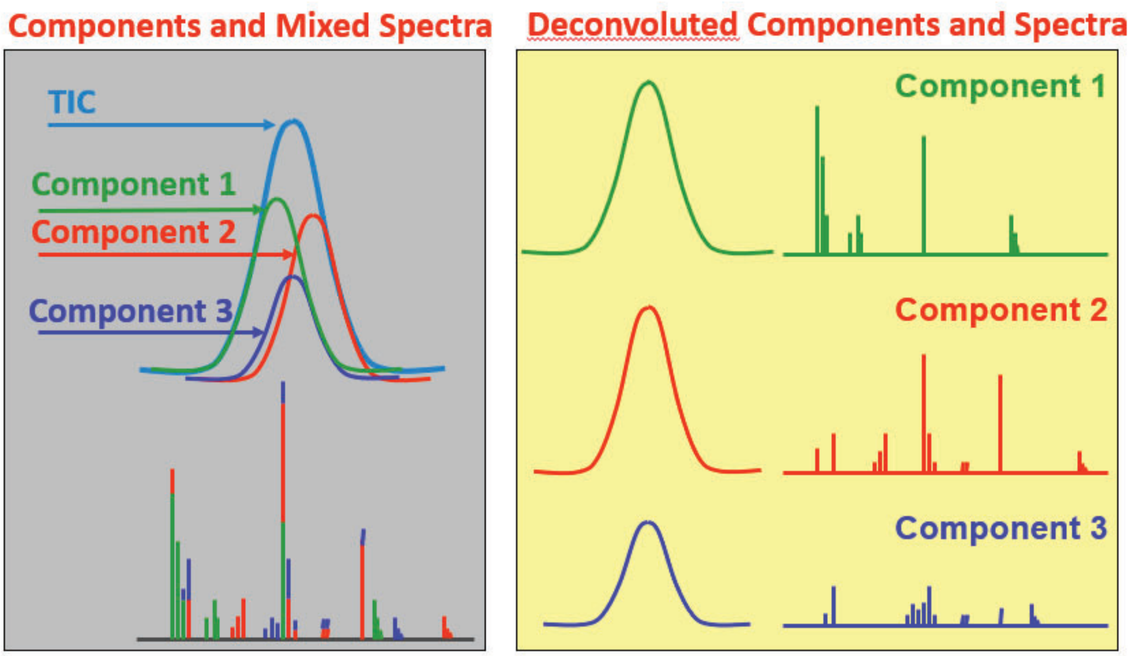
GC/MS – volatile compounds





Credit: https://doi.org/10.1007/978-3-319-39312-4_159

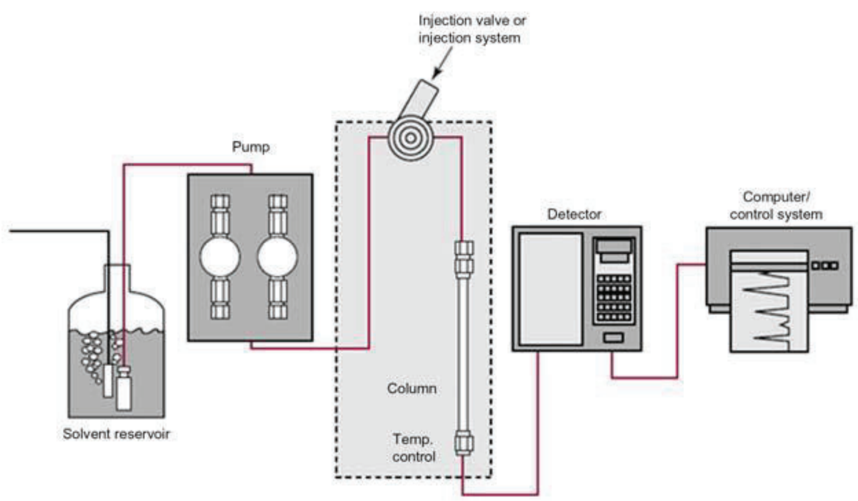
Spectra deconvolution with mass-spec



GC/MS – compounds

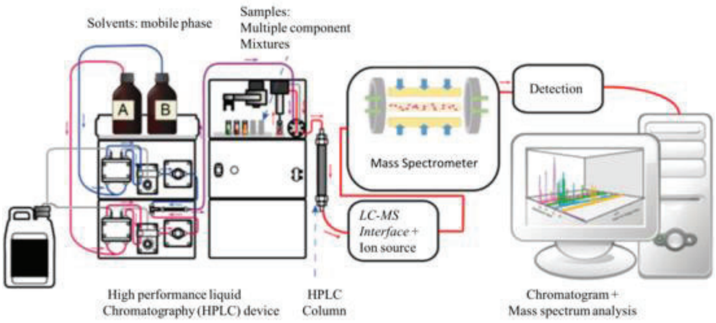
#		#		#		#	
1	Dichlorodifluoromethane	21	Carbon Tetrachloride	41	2-Nitropropane	61	n-Propylbenzene
2	Chloromethane	22	Methyl Acrylate	42	Tetrachloroethene	62	1,1,2,2-Tetrachloroethane
3	Vinyl Chloride	23	1,1,1-Trichloroethane	43	4-Methyl-2-pentanone	63	2-Chlorotoluene
4	Bromomethane	24	Tetrahydrofuran	44	cis-1,3-Dichloropropene	64	1,2,3-Trichloropropane
5	Chloroethane	25	1,1-Dichloropropene	45	1,1,2-Trichloroethane	65	1,2,4-Trimethylbenzene
6	Trichlorofluoromethane	26	1-Chlorobutane3	46	Ethyl Methacrylate	66	trans-1,4-Dichloro-2-butene
7	Diethyl Ether	27	2-Butanone	47	Dibromochloromethane	67	4-Chlorotoluene
8	1,1-Dichloroethene	28	Benzene	48	1,3-Dichloropropane	68	tert-Butylbenzene
9	Carbon Disulfide	29	Methacrylonitrile	49	1,2-Dibromoethane	69	1,3,5-Trimethylbenzene
10	Iodomethane	30	1,2-Dichloroethane	50	2-Hexanone	70	sec-Butylbenzene
11	Allyl Chloride	31	2,2-Dichloropropane	51	Chlorobenzene	71	p-Isopropyltoluene
12	Methylene Chloride	32	Fluorobenzene (IS)	52	Ethylbenzene	72	1,3-Dichlorobenzene
13	trans-1,2-Dichloroethene	33	Trichloroethylene	53	1,1,1,2-Tetrachloroethane	73	1,4-Dichlorobenzene
14	Methyl-t-Butyl Ether	34	Dibromomethane	54	m-,p-Xylene	74	n-Butylbenzene
15	1,1-Dichloroethane	35	1,2-Dichloropropane	55	o-Xylene	75	Hexachloroethane
16	Acrylonitrile	36	Bromodichloromethane	56	Styrene	76	1,2-Dichlorobenzene-d4 (SURR)
17	Propionitrile	37	Methyl Methacrylate	57	Bromoform	77	1,2-Dichlorobenzene
18	cis-1,2-Dichloroethene	38	trans-1,3-Dichloropropene	58	Isopropylbenzene	78	1,2-Dibromo-3-Chloropropane
19	Bromochloromethane	39	Chloroacetonitrile	59	4-Bromofluorobenzene (SURR)	79	Nitrobenzene
20	Chloroform	40	Toluene	60	Bromobenzene	80	Hexachlorobutadiene
						81	1,2,4-Trichlorobenzene
						82	Naphthalene
						83	1,2,3-Trichlorobenzene

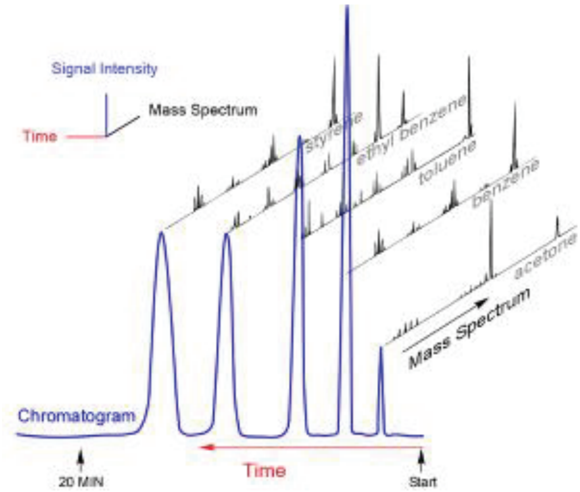
High-performance liquid chromatography (HPLC)

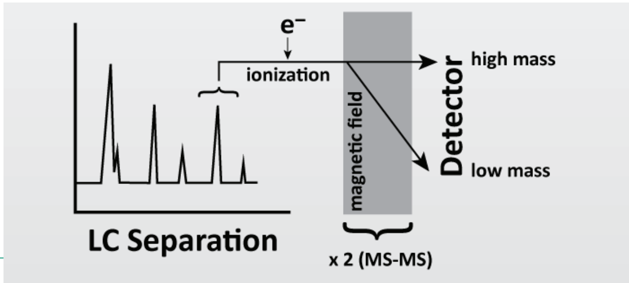


Credit: Hage, D. S., Principles and Applications of Clinical Mass Spectrometry. In Chromatography, 1st ed.; Rifai, N., Rita Horvath, A., Wittwer, C. T., Hoofnagle, A., Eds.; Elsevier, 2018; Chapter 1

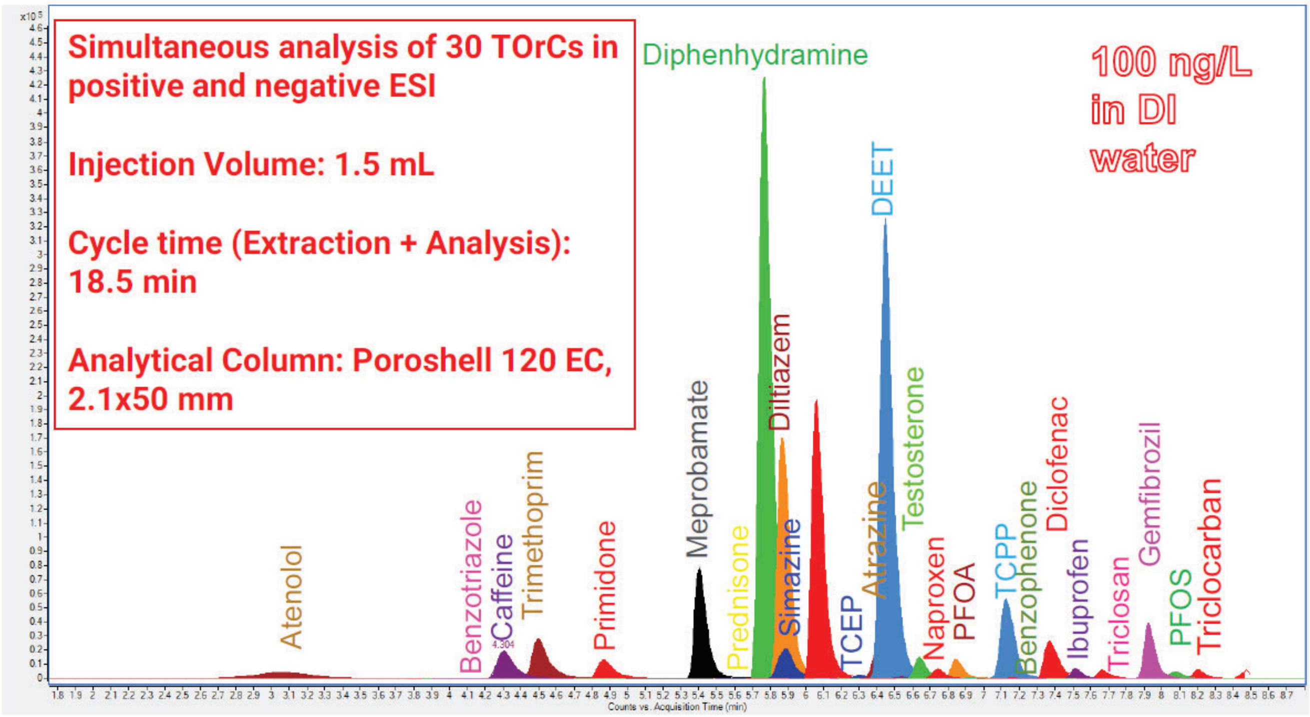
LC/MS





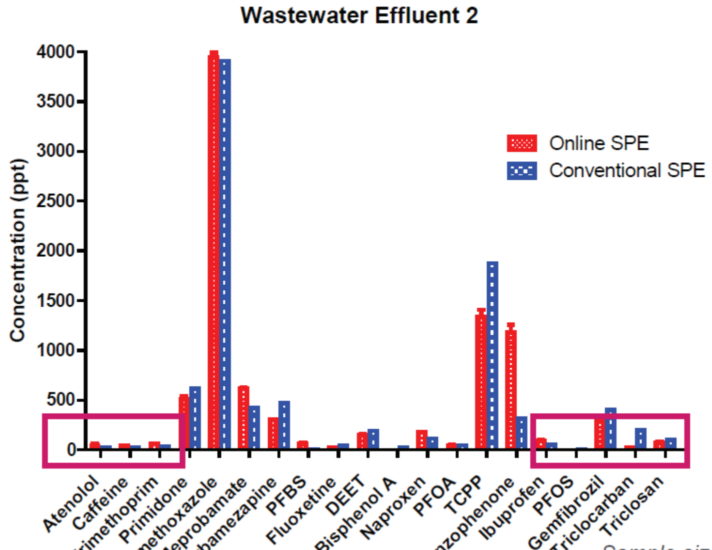


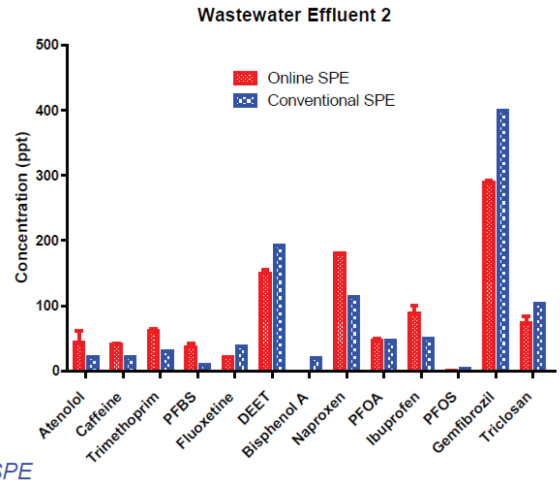
LC-MS – real examples



Credit: Agilent Technologies

LC-MS – real examples

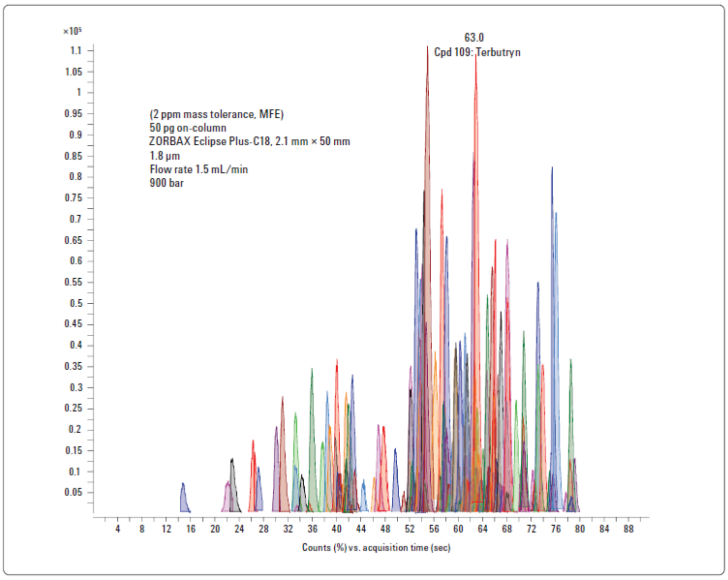




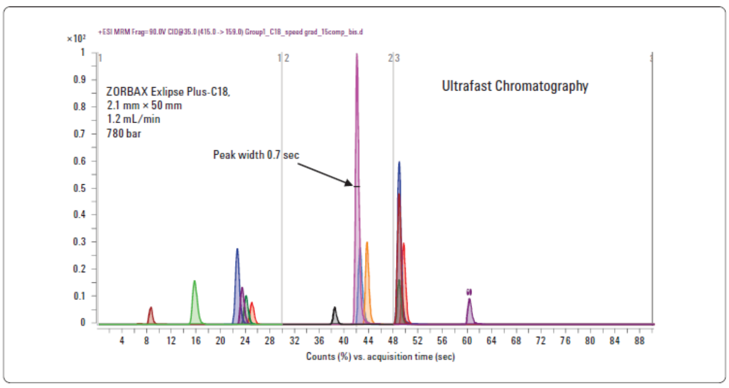
Sample size:
n=3 for online SPE
n=1 for conventional SPE

Credit: Agilent Technologies

LC-MS – real examples



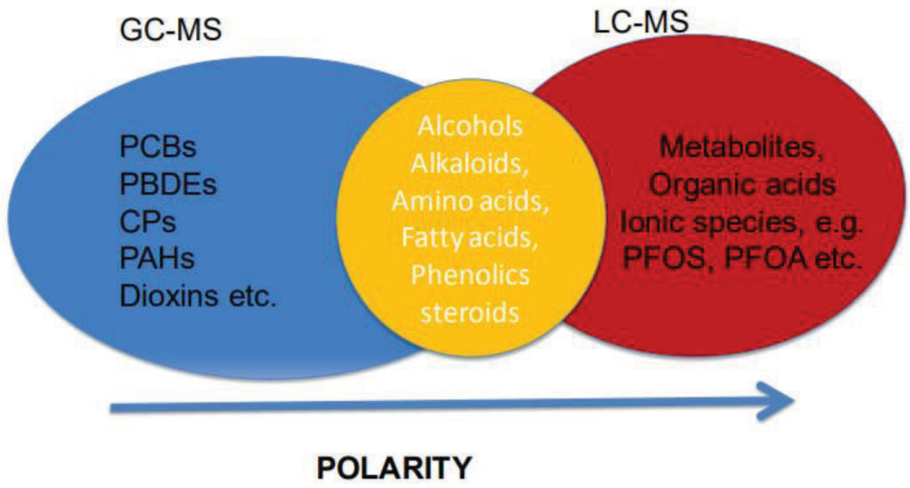
Pesticides



Pharmaceuticals

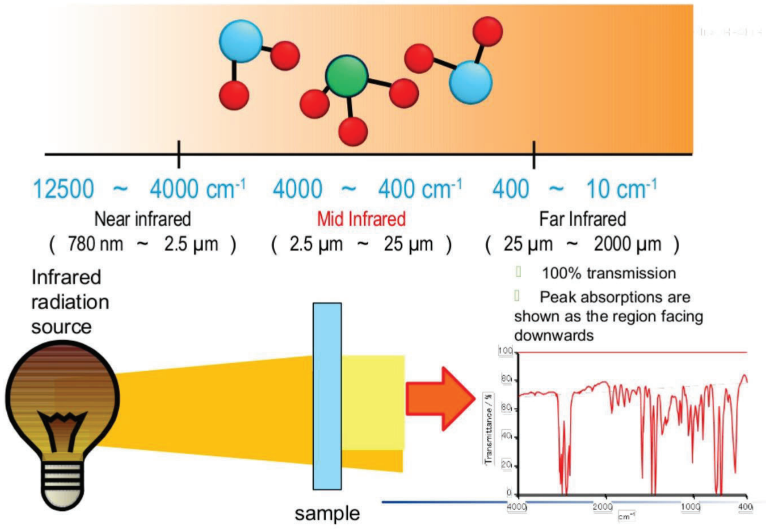
Credit: Agilent Technologies

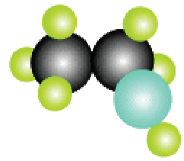
Summary for separation techniques

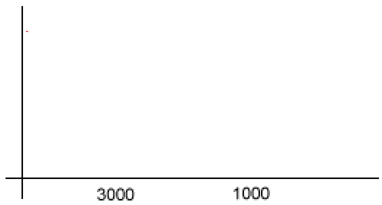


Spectroscopic techniques

Infrared spectroscopy



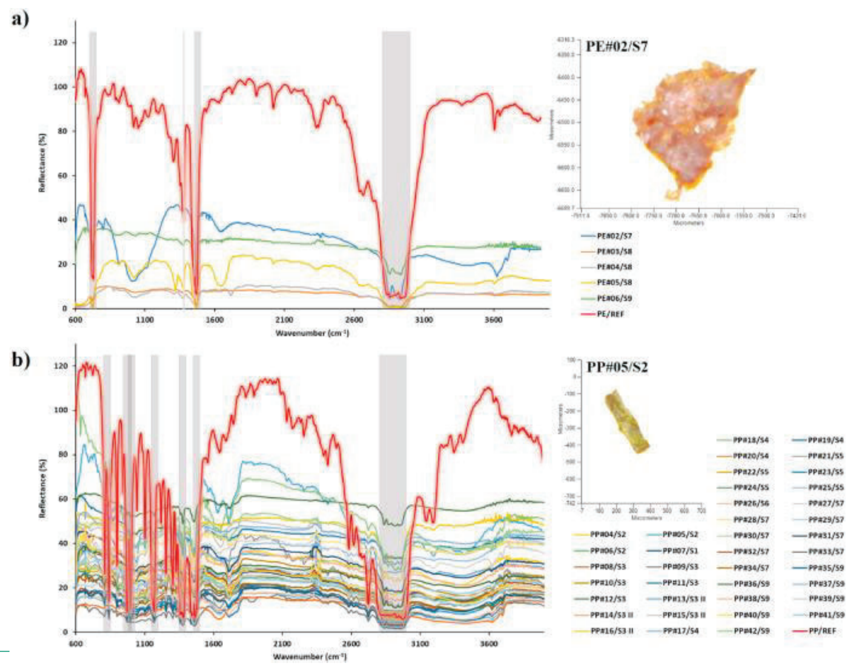




Infrared spectroscopy

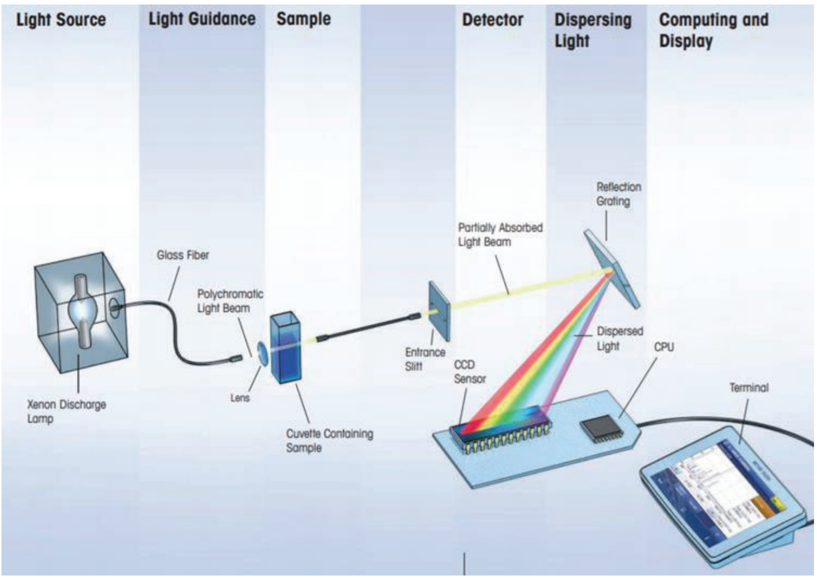
- Analysis of microplastics

Overlapped µFTIR spectra of microparticles from sediment aliquots manually identified as **a) polyethylene (PE)** or **b) polypropylene (PP)**



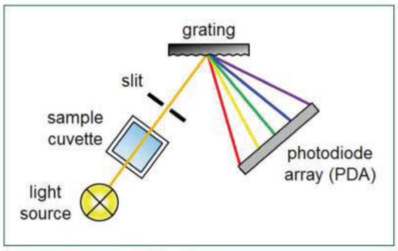
Credit: https://doi.org/10.1016/j.talanta.2020.121814

Ultraviolet-visible spectroscopy (UV-Vis)

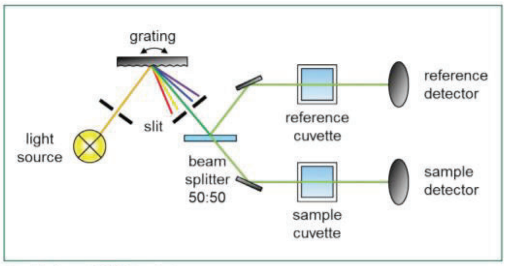


Absorbance is proportional to concentration

$$A = \varepsilon \, l \, c$$



Photodiode Array (PDA) Solution



Double-beam UV/Vis solution

Credit: House, J. E. Molecular Spectroscopy. In Fundamentals of Quantum Mechanics, 3rd ed.; Academic Press, 2018; Chapter 11, pp. 271-196

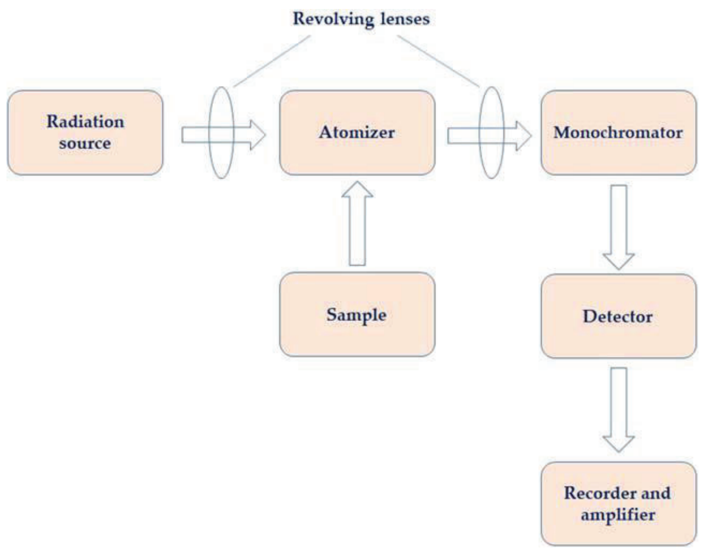
Spectrophotometric autoanalysers

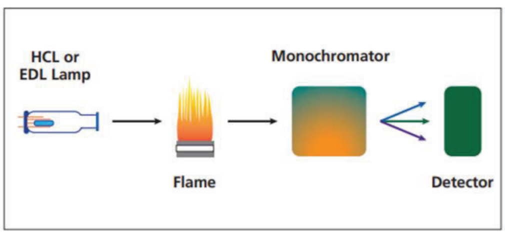
Main studies performed using UV–Vis spectroscopy

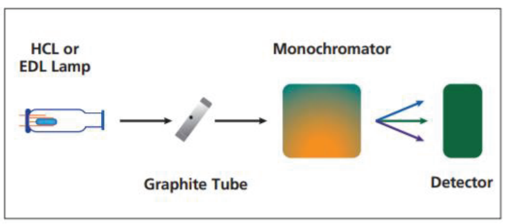
References	Sample source	Method	Wavelength range (nm)	Study
Ferree and Shannon (2001)	Full-scale WWT	UV	190–250	Application of a second derivative method for nitrate and total nitrogen determination
Muzio et al. (2001)	Full-scale WWT	UV	200–350	Attainment of reasonable prediction of influent BOD_5 and poor final effluent BOD_5 prediction
Azema et al. (2002)	Full-scale WWT	UV	200–350	Study of soluble and colloidal fractions in suspended solids
Roig et al. (2002)	Full-scale WWT	UV	200–350	Demonstration of the feasibility to measure organic mercaptans in wastewater
Vaillant et al. (2002)	Full-scale WWT	UV	200–350	Direct comparison, spectra differences and normalization showed the UV response to TSS, OM, inorganic particles and weather conditions
Sarraguça et al. (2009)	Lab-scale WWT	UV–Vis	230–700	Development of calibration models for COD, nitrate and TSS prediction
Drolc and Vrtovšek (2010)	Full-scale WWT	UV	200–250	Monitoring of nitrate and nitrite
Qin et al. (2012)	Pilot-scale WWT	UV–Vis	200–800	Combination of sensors to monitor COD, TSS, oil and grease with satisfactory prediction results
Kwak et al. (2013)	Full-scale WWT	UV	254	Prediction of wastewater BOD_5
Louvet et al. (2013)	Full-scale and lab-scale WWT	UV–Vis	200–600	Correlation of 416 nm absorbance with COD
Chen et al. (2014)	Full-scale WWT	UV–Vis	200–650	COD monitoring using variable pathlength
Zamora and Torres (2014)	Full-scale WWT	UV–Vis	200–700	Detection of outliers in the prediction of COD and TSS

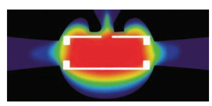
Credit: Mesquita, D.P., Quintelas, C., Amaral, A.L. *et al.* . *Rev Environ Sci Biotechnol* 16, 395–424 (2017).

Atomic absorption spectroscopy (AAS)









Credit: DOI: https://doi.org/10.1016/B978-0-12-816934-6.00006-0

AAS - examples

Comparison of various atomic absorption spectroscopic methods available for **nitrate and/or nitrite** detection

Reagent used	Sample	$\lambda_{max\ (nm)}$	Nitrate/Nitrite	Detection limit (µg/mL)	Detection range (µg/mL)	RSD%	Ref.
Bis(2,9-dimethyl-l,10-phenanthrolinato)-copper(I)	Food	328.1	Both	4.0×10^{-2} for both NO_3^- and NO_2^-	1.3×10^{-1}–2.20	NO_3^- – 3.7 NO_2^- – 4.1	Silva et al. [145]
Cadmium metal and 0.1 M hydrochloric acid	Inorganic and organic nitrates	228.8	Nitrate	N/A	3.1×10^{-2}–3.1	1	Hassan [146]
$[Ag(Phen)_2]$ solution	Fertilizer	328.1	Nitrate	N/A	3.1×10^{-2}–3.1×10^{-1}	0.45	Anwar and Haque [148]

Credit: https://doi.org/10.1016/j.talanta.2018.08.028

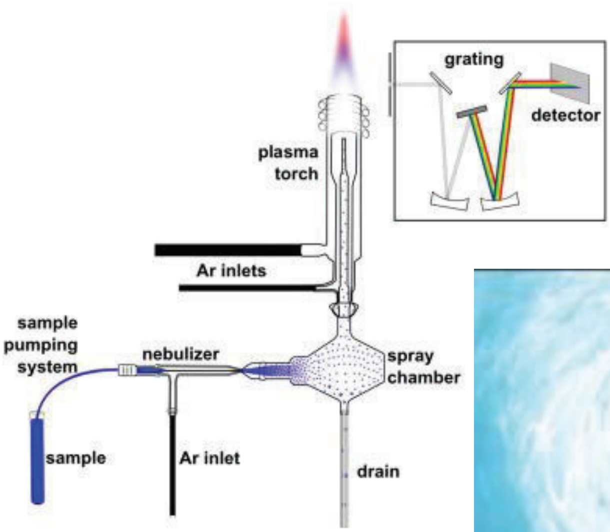
Analytical performance of the various systems for **Cd** determination

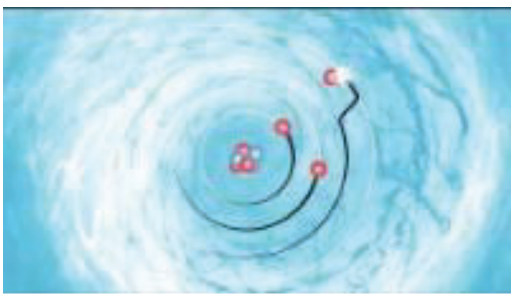
Method	LOD (µg L^{-1})	LOQ (µg L^{-1})	%RSD	Range (µg L^{-1})
FAAS	42	140	9.6	100–2000
SQT-FAAS	11.9	39.6	6.3	50–1000
DLLME-FAAS	1.3	4.4	7.6	5.0–100
DLLME-SQT-FAAS	0.5	1.5	8.2	1.0–17.5

Abbreviations: FAAS – flame atomic absorption spectrometry, SQT - slotted quartz tube; DLLME - dispersive liquid-liquid microextraction

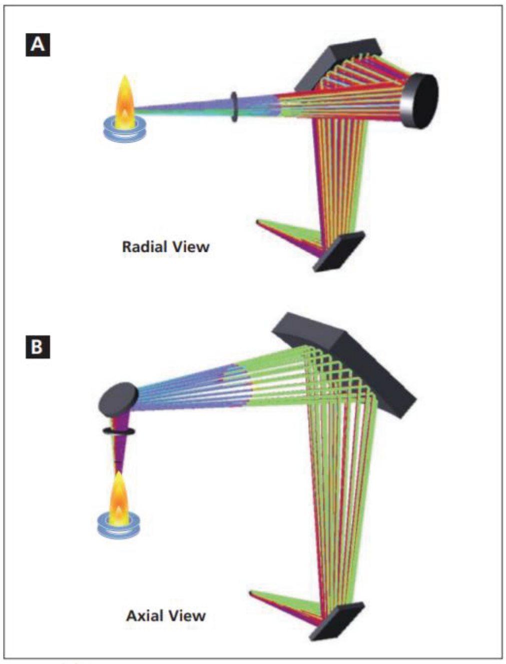
Credit: https://doi.org/10.1016/j.sab.2017.01.006

Inductively coupled plasma atomic emission spectroscopy (ICP-OES)



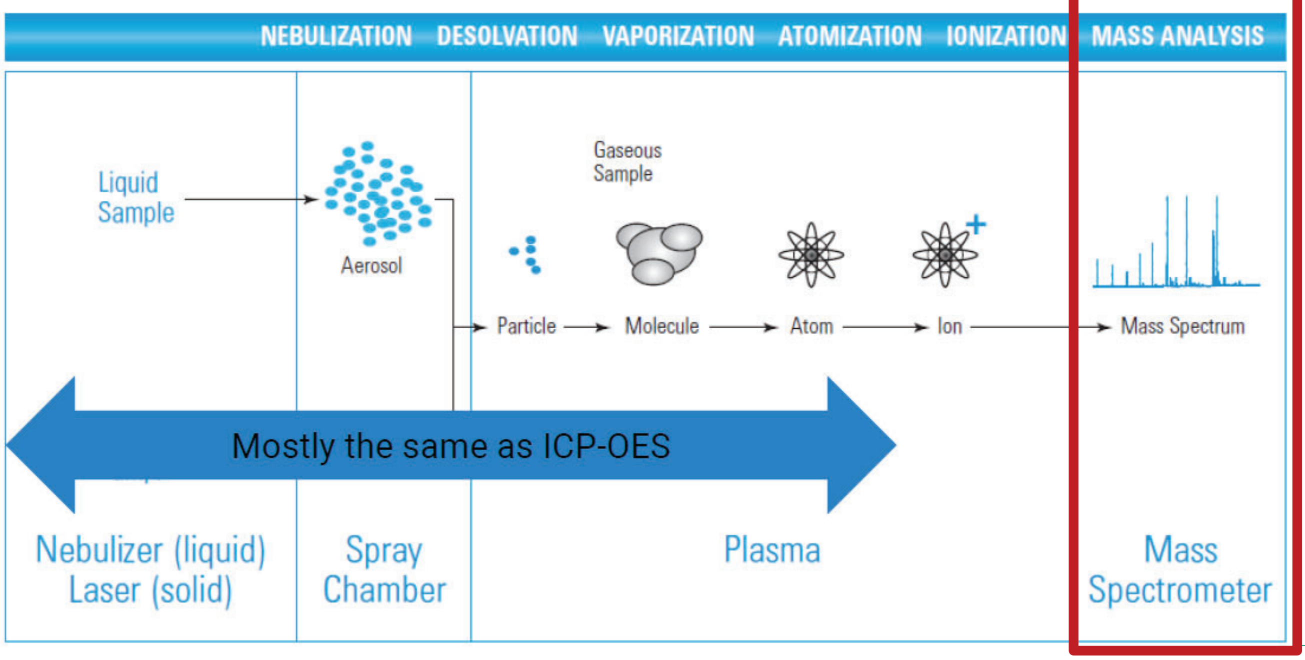


https://www.youtube.com/watch?v=aCi72rj0fYA



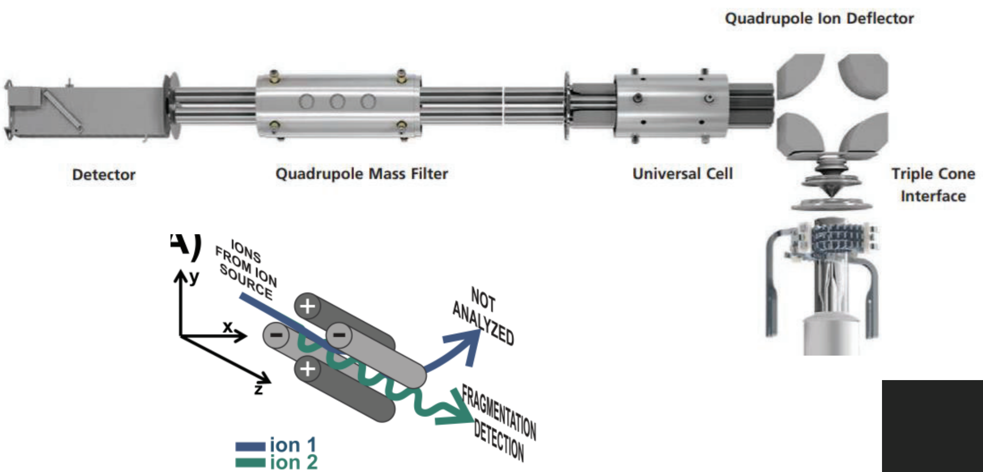
Credit: https://doi.org/10.1016/j.cemconres.2016.10.007

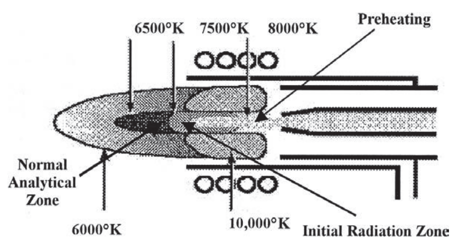
ICP-MS spectrometer

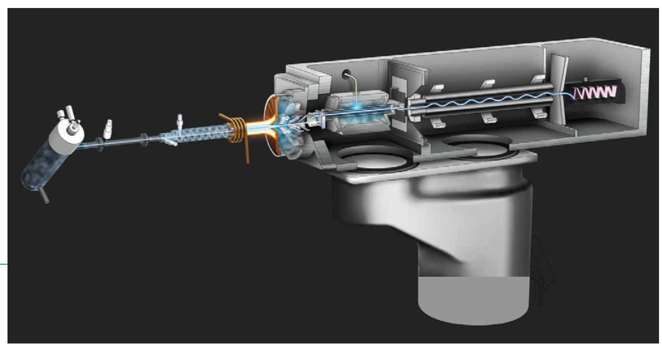


Credit: Agilent Technologies

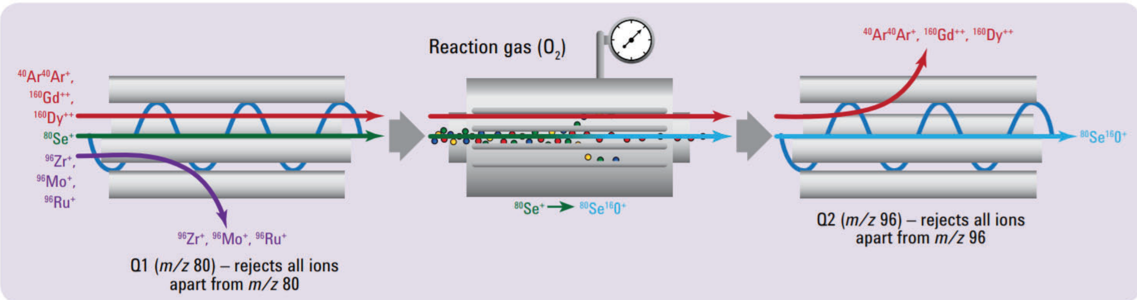
ICP-MS spectrometer



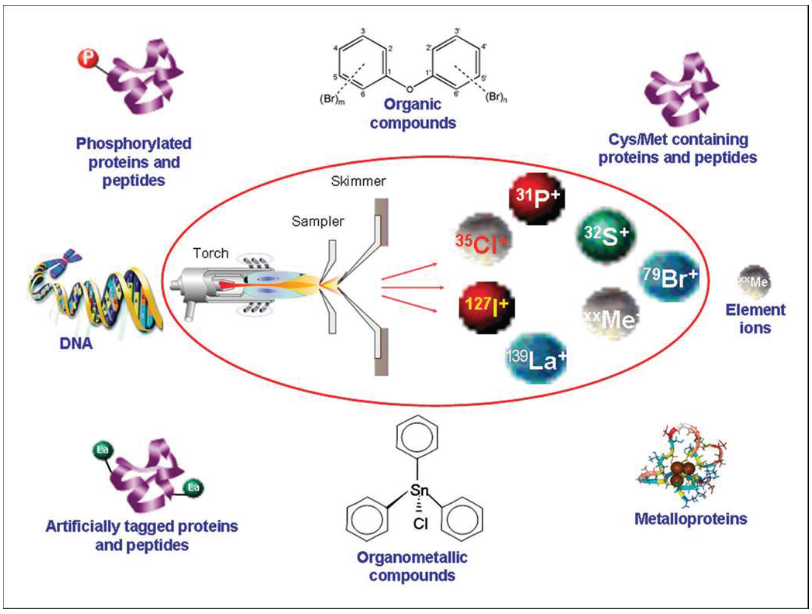




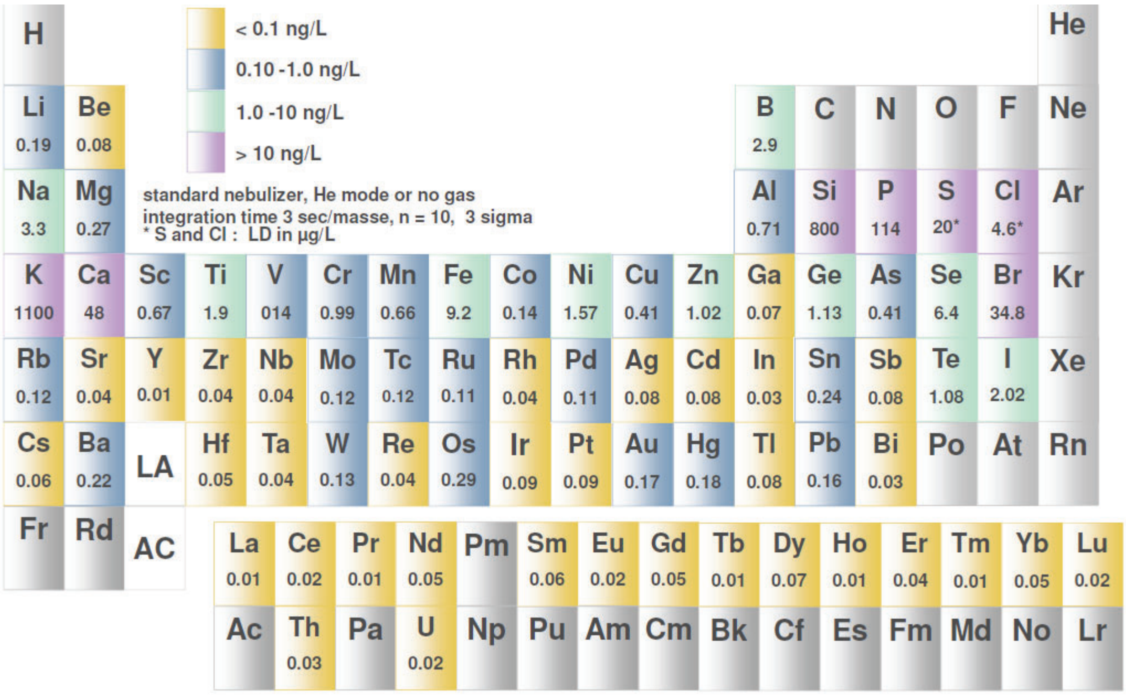
Commercial instruments



ICP-MS spectrometer

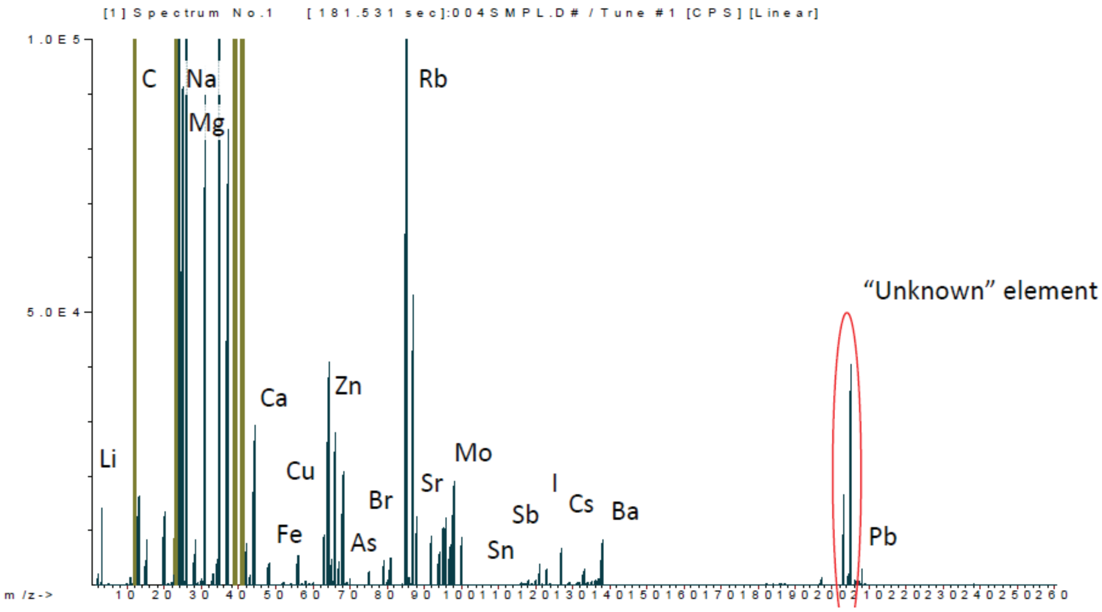


ICP-MS – detection limits



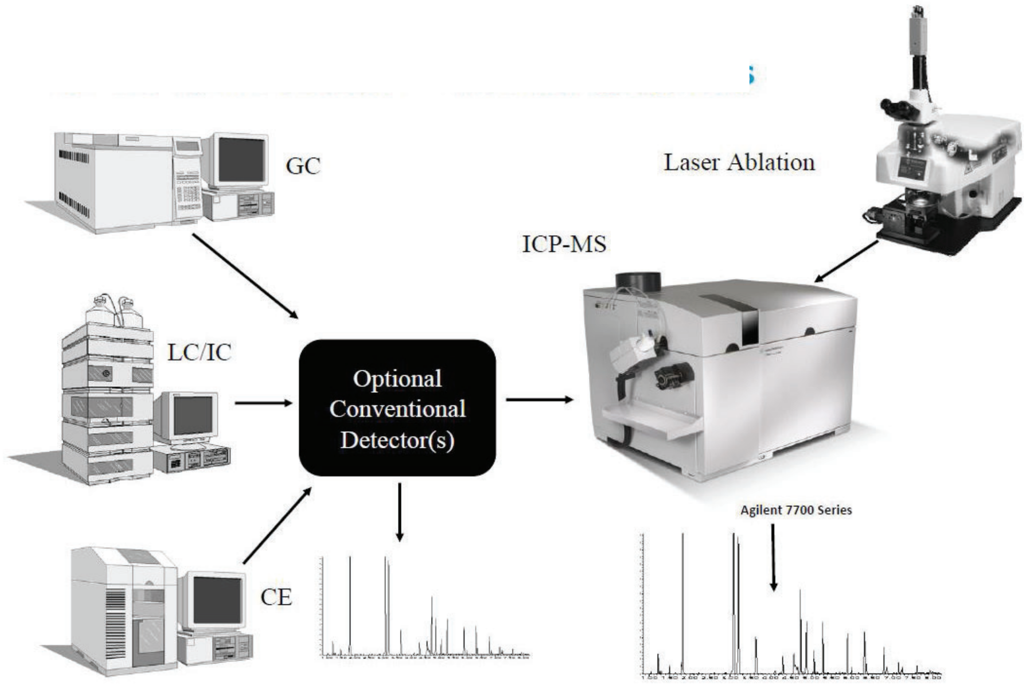
Credit: www.matriks.no

ICP-MS – real samples



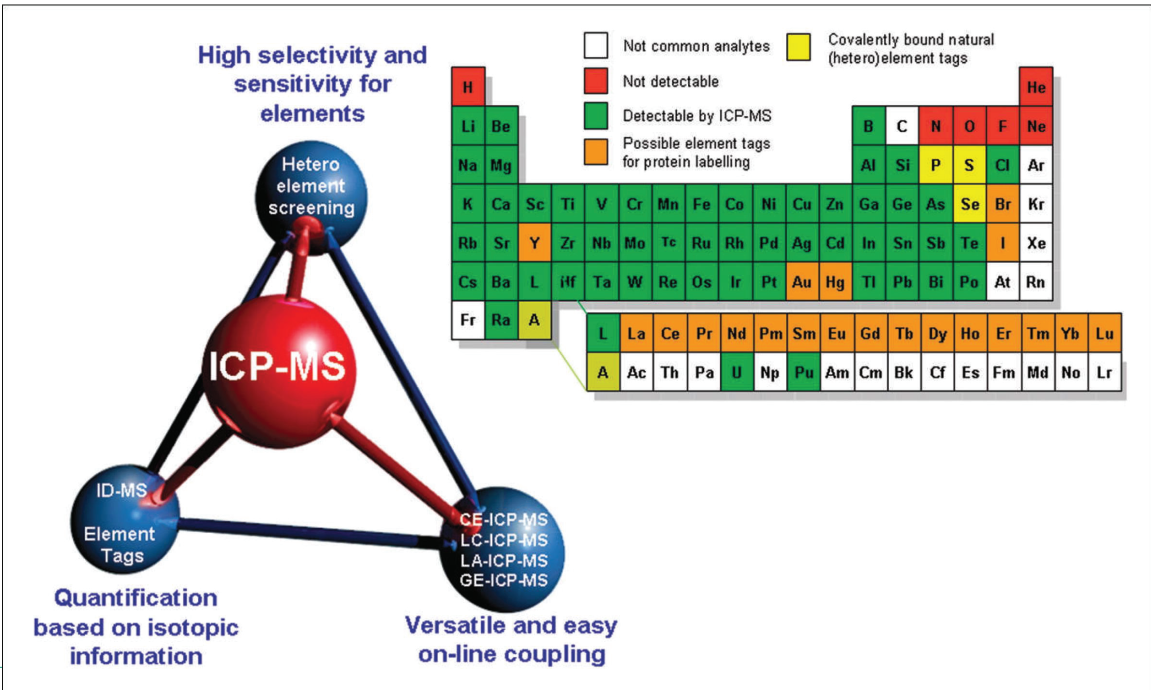
Credit: Agilent Technologies

Combined techniques

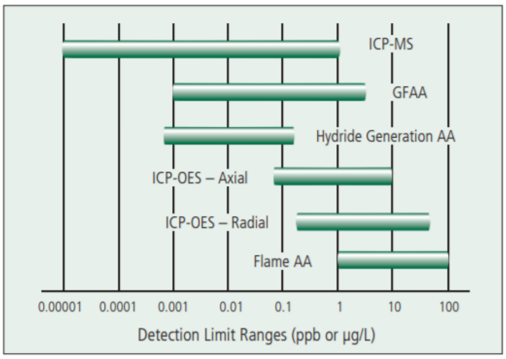


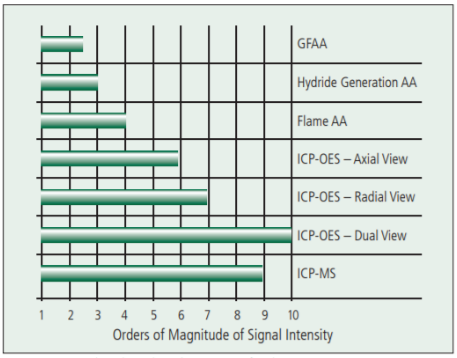
Credit: Agilent Technologies

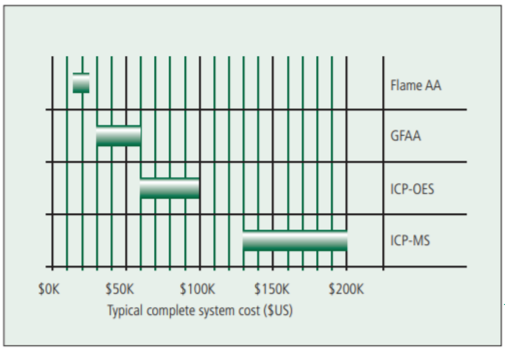
ICP-MS spectrometer



Summary of different techniques



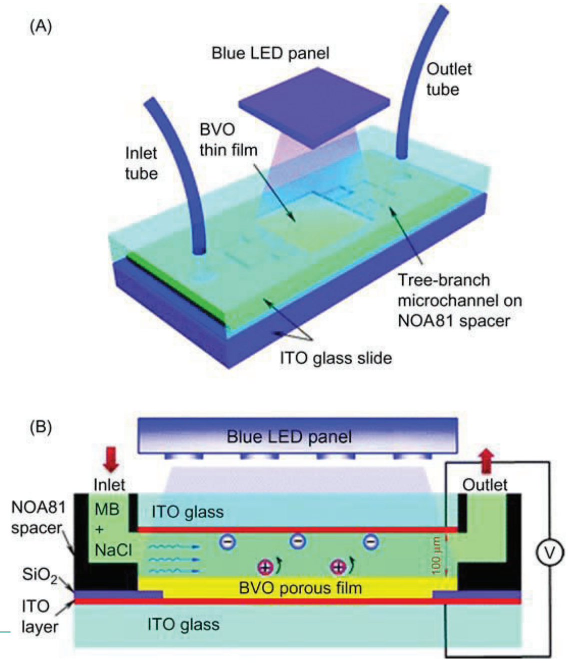




Other techniques – future trends

Total Analysis System (TAS) – "lab-on-a-chip systems"

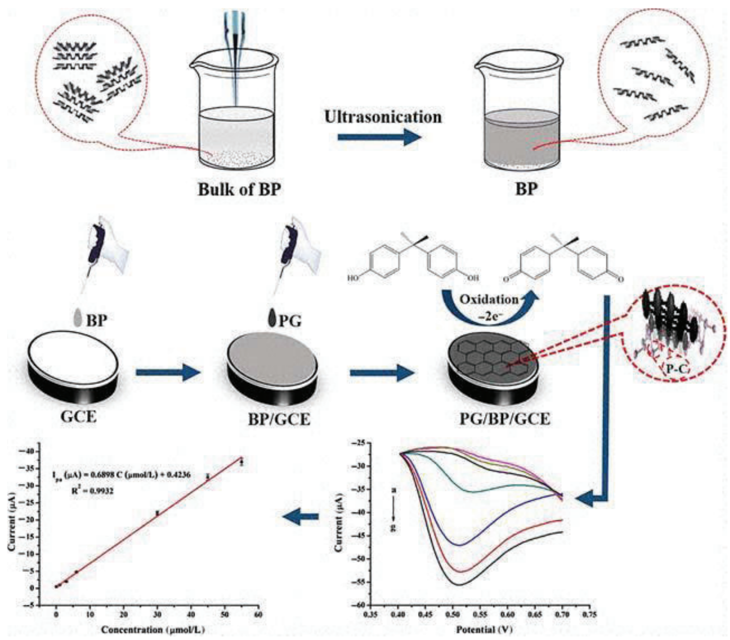
- Quick response in the target analysis
- No requirement for skilled researcher
- Small sample volumes



Photocatalytic reactor

Nanomaterial-based sensors

Porous graphene (PG) functionalized black phosphorus (BP) as electrochemical sensor platform for bisphenol A detection



Credit: https://doi.org/10.1016/j.jelechem.2019.01.003

Questions?

"Okay—who put my lunch through the mass spectrometer..?"

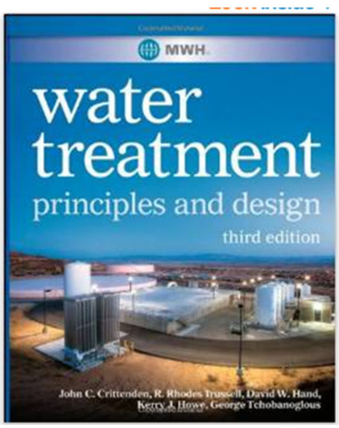
Water quality monitoring
Sampling and online monitoring

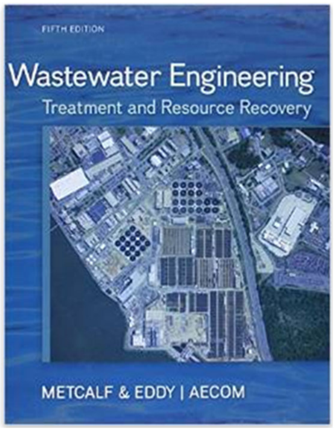
Harsha Ratnaweera
THT 311

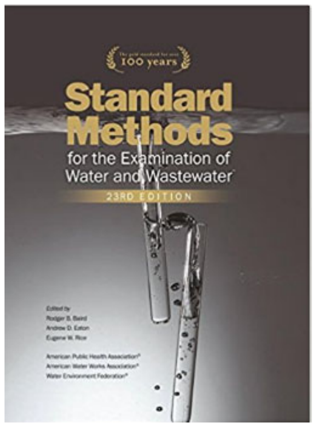
Outline

- Sampling-methods and error sources
- Status and need
- Online measurements and instruments
- Applications in surveillance and control

3 “bibles” in water treatment and analysis







- 1600-2000 pages; 100-400 USD each

Water Quality Analysis and Sampling

- We try to characterize the large amounts of water on the basis of a small sample volume.
- To:
  - Document the water quality to the customer / government (eg. meet the requirements for documentation in the Drinking Water Regulations)
  - Monitor water quality at special events
  - Monitor specific risk points and problem areas on the collection/distribution systems
  - Determine whether the treatment plant must be expanded
  - Calculate the load on the wastewater treatment plant
  - Calculate wastewater fees for businesses
  - Optimize treatment processes
  - Decide that could have major economic and environmental consequences

Type of samples

- Samples:
  - The entire sample volume is taken out at once.
- Mixed samples
  - A sample consisting of several random samples taken over a longer period of time, often over a day. The test is then called a 24-hour test or24-hour mixed test.. Other time intervals can also be used.
- Time-proportional test
  - One mixed samplewhich consists of equal samples taken at a constant time interval over a longer period, e.g. a sample every five minutes.
- Quantity proportional sample
  - One mixed sample consisting of random samples where the amount of sample taken is in a certain ratio to the amount of water that passes at any given time the sampling site.

– Grab sample?

Samplers
Ruttners water fetch

Wall-mounted samplers

- Pressure/vacuum principle
- Time and flow- proportional sampling
- Fully programmable
- Adjustable suction
- Follows ISO 5667
- Acidic environment

  Steel refrigerator

Uncertainty in an analysis result

- There is always some uncertainty associated with an analytical response. The uncertainty can be divided into two main components:
  - Uncertainty related to sampling
  - Uncertainty related to the chemical analysis

- The uncertainty contribution from the sampling is often significantly higher than the uncertainty contribution from the chemical analysis.

Sources of error in sampling

Systematic errors

Varying composition of water (particles of different composition and shape; too poor mixing at the sampling point)

Wrong sampling strategy (time proportional sampling instead of water volume proportional)

Random errors

Sampling is performed in different ways by different people

The function of the sampling equipment varies (sometimes pulls) the sampler up large particles, other times not)

The samples are treated differently from time to time

The uncertainty contribution from the sampling

- **The primary sampling** (sampling of the daily sample from the effluent):
  - Variation in the (wastewater) composition of the water (distribution of particles with different density, shape and size)
  - Flow conditions at the sampling point (degree of stratification in the effluent)
  - Function of the sampling equipment (will particles of a given density, shape and size be omitted from the sample?)
- **The secondary sampling**
  - Too poor stirring / shaking of the sample before taking a smaller sample volume
- Influence of the sample during transport and storage
  - Contamination of the sample from the material in the sample packaging
  - Influence of environmental factors (temperature and light)

Sources of error when processing samples

- Use of equipment that affects the sample
- Use of cork / container that affects the sample
- Incorrect marking of the sample
- Incorrect preservative / quantity / or no preservation
- No cooling / freezing of the sample
- Sampling for analysis from mixed sample can
- Degree of filling in bottles

Sample bottles

Cleanliness of sampling bottles

Sample volume

The sample volume must be sufficiently large so that the desired tests and analyzes can be performed. If the concentrations are low, the sample must be concentrated before analysis and for this larger sample volumes are needed

Storage (preservation) of samples

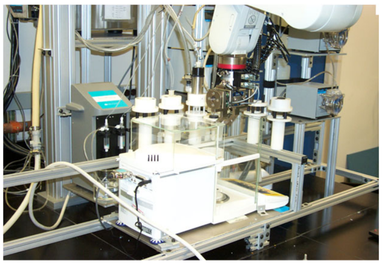
- The samples must be analyzed as soon as possible
- When it is impractical, should be preserved according to the provisions, which vary by parameter.

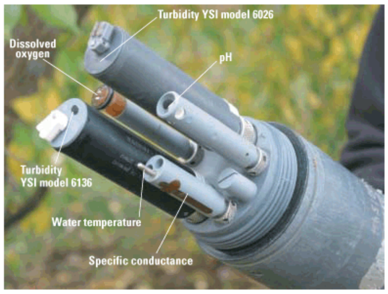
Outline

- Sampling-methods and error sources
- Status and need
- Online measurements and instruments
- Applications in surveillance and control

The status

- Daily, weekly or monthly monitoring
- Grab samples
- Often outlet only





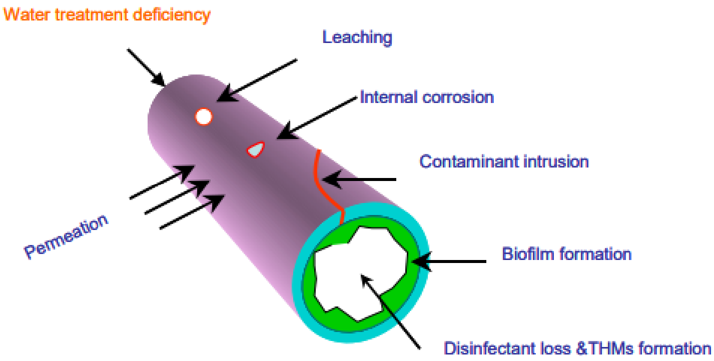
The need

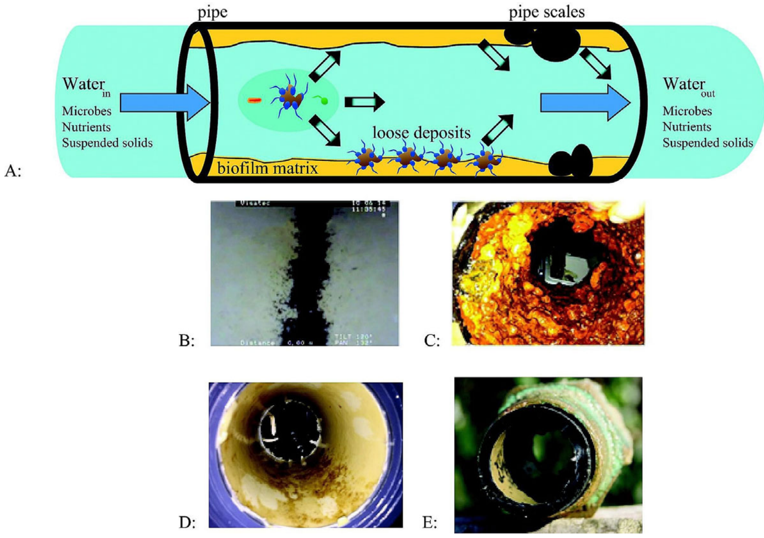
- Increasing treatment requirements
  - health reasons
  - environmental reasons
  - legal reasons

- Extreme treatment requirements
  - Micro-pollutants, nutrients
  - Footprint – cost of land
  - Process economy

- Operational requirements
  - Unmanned – lack of resources / cost

Water quality in the distribution pipes





Forbes

Norway Water Crisis: Thousands Fall Ill On Island Near Bergen

David Nikel Senior Contributor
Lifestyle
Travel and lifestyle in Europe with a focus on Norway & Scandinavia.

Askøy island municipality in Norway GETTY

Doctors are investigating the deaths of two people in Askøy near Bergen, Norway, following the contamination of the local water supply. Approximately 2,000 residents of the island municipality have suffered from sickness in the last week, according to the local authority, with symptoms including diarrhea, fever

62 municipalities in Norway asked to boil water before drinking: report

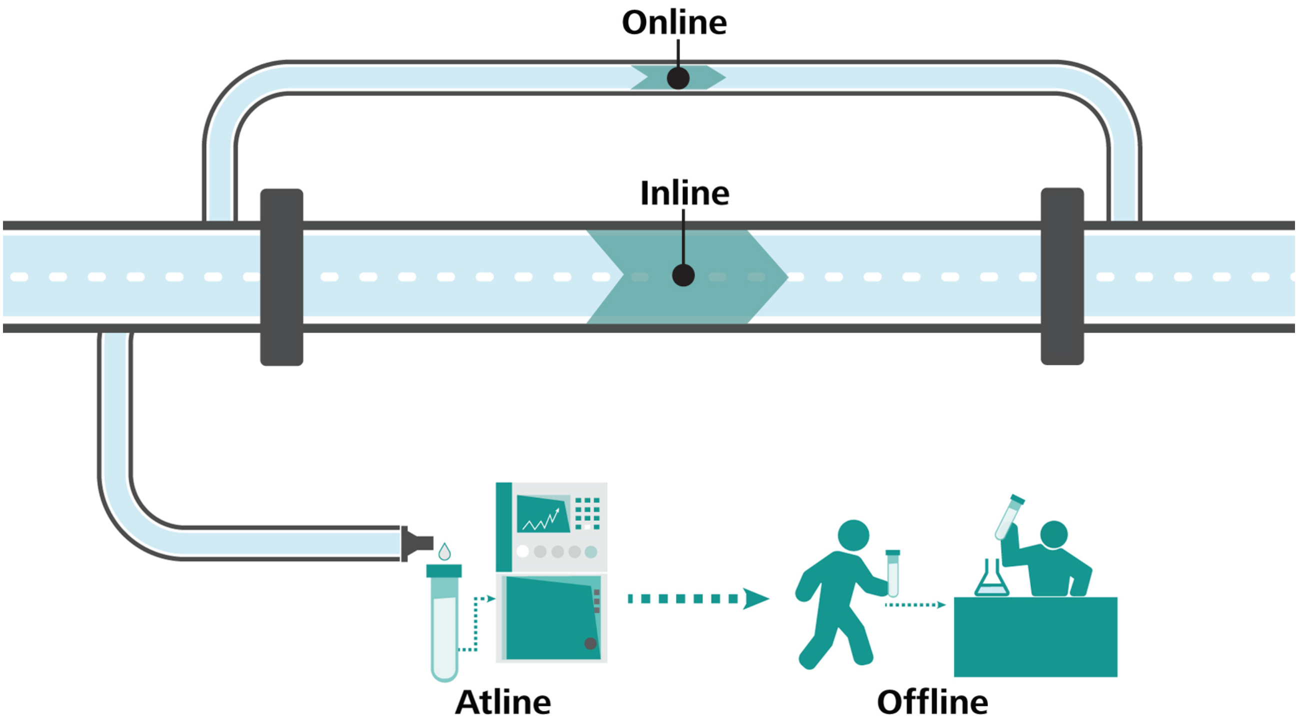
Source: Xinhua | 2019-06-17 22:50:05 | Editor: yan

OSLO, June 17 (Xinhua) -- Since 2018, residents of at least 62 municipalities in Norway have been asked to boil water before drinking, the newspaper Aftenposten reported Monday.

Outline

- Sampling-methods and error sources
- Status and need
- Online measurements and instruments
- Applications in surveillance and control

Online- inline –at line- off line



Type of surveillance systems

- **With chemicals at line or off line**
  - Automated lab analysis (Flow Injection Analysis (FIA) & Sequential Flow Injection (SIA))
- **Sensors "without" chemicals online or inline**
  - Ion selective electrodes
  - Photometric
    - Calorimetric
    - UV absorption (colour, DO)
    - UV-Vis absorption (COD, TOC, BOD)
- **Virtual sensors (soft sensors) online**

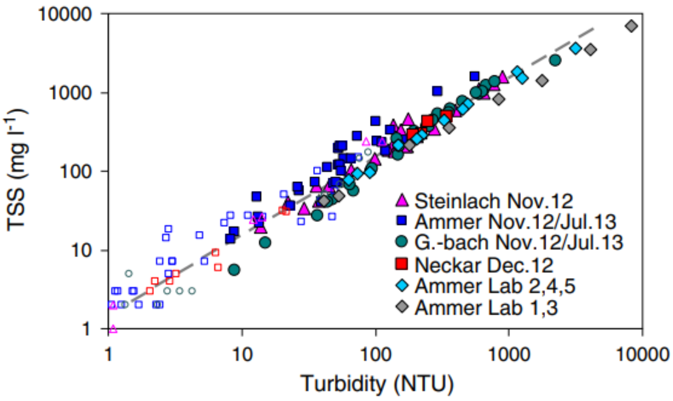
Various surveillance systems relevant for W&WWT

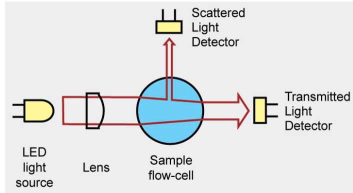
- Organic Loads (with emphasis on BOD and COD) ON/IN, AT, OFF
- Suspended Solids ON/IN, OFF
- Total Nitrogen AT, OFF
- Total Phosphorus AT, OFF
- Inorganics AT, OFF
- Heavy metals OFF
- Physicochemical parameters ON/IN, AT, OFF
- Microbiological contaminant indicators, such as E. Coli AT, OFF
- Pesticides OFF
- Endocrine Disrupting Compounds (EDCs) OFF
- Radioactive materials OFF
- Volatile Organic Carbons (VOC) and Trihalomethanes (THM) AT, OFF
- Haloacetic acids (HAA) AT, OFF
- Nitrosamines OFF
- Pharmaceuticals. OFF
- NH3-N, NO2, NO3: ON/IN, AT, OFF
- Sludge level ON/IN
- Water flow ON/IN,
- MLSS: ON/IN, AT, OFF

pH
Conductivity
RedOx
DO: Dissolved oxygen
TOC, DOC, COD; BOD
Colour
CEC: emerging contaminants

Virtual sensors (software sensors)

Typical example: measurement of SS via tuirbidity

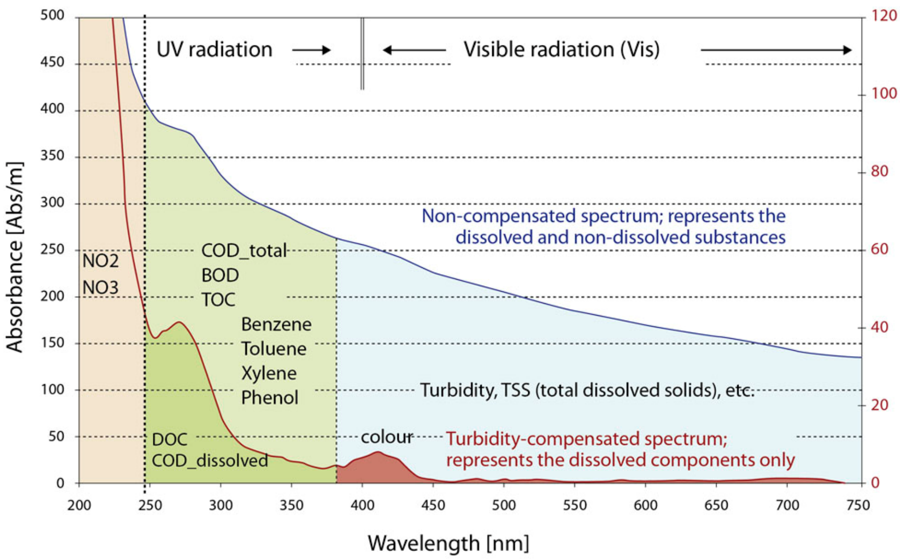




SS = *f* (Turbidity)

Scanning spectroscopy

TOC :: Color :: UV254 :: NTU :: FNU :: COD:: Alarm ..

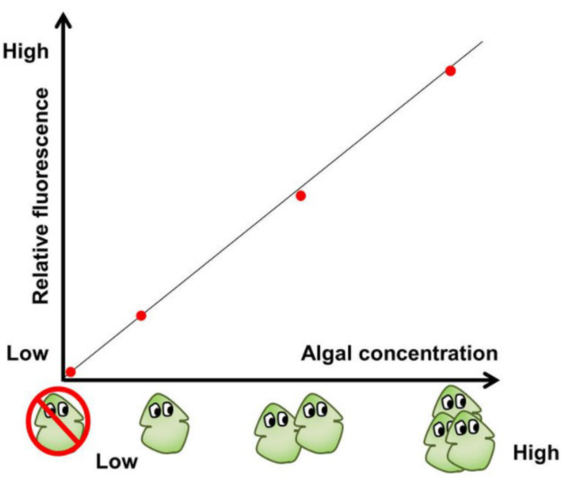


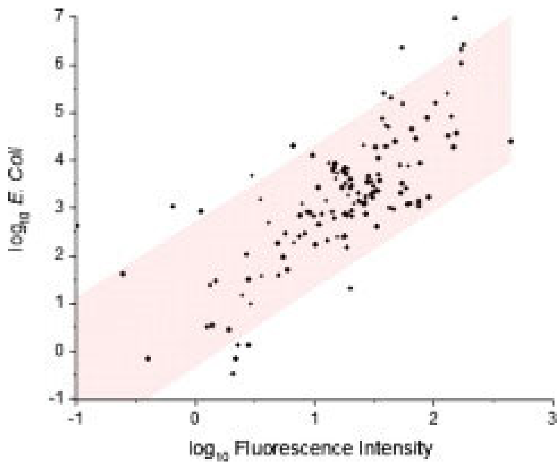
«Anything is possible»

	Drinking Water		Environmental		Municipal Waste Water			Industrial			
	Drinking Water	Ground Water	River/Surface Water	Sea Water	Effluent Municipal	Aeration	Influent Municipal	Dairy	Paper Influent	Paper Effluent	Brewery
	D	G	R	O	E	A	I	M	P	Q	B
TSS			■		■		■	■	■	■	■
TS						■					
Turbidity	■	■	■	■	■						
Color app / true	■	■	■	■	■		■				
TOC	■	■	■	■	■		■				
DOC	■	■	■	■	■		■				
BOD			■		■		■				
COD / CODf			■		■	■	■	■	■	■	■
NO3-N / NO3	■	■	■	■	■	■	■	■	■	■	■
Chloramine	■										
HS-		■	■				■				
O3	■				■						
CLD	■										
Chl-a			■								
BTX		■	■								
UV254 t / UV254 f	■	■	■	■	■	■	■	■	■	■	■
UV436 t / UV436 f	■	■	■	■	■	■	■	■	■	■	■
Single wavelength	■	■	■	■	■	■	■	■	■	■	■
Temperature	■	■	■	■	■	■	■	■	■	■	■
Fingerprint	■	■	■	■	■	■	■	■	■	■	■
Fingerprint comp	■	■	■	■	■	■	■	■	■	■	■

WE MAKE LIQUIDS TRANSPARENT.

Fluorescence





Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation

Sensors for universal transmitters

- pH, Orp, conductivity
- Liquid Oxygen
- Turbidity / Dry Solids, Sludge level
- Ammonium, Nitrate
- Phosphate
- Oil in water
- New sensors are continuously developed

Universal transmitters

- Connects to multiple sensors.
- With 1 or 2 inputs, analogue or digital.
- Mounted on wall or Embedded in to a cupbord

Universal transmitters

- Upto 8 in/outputs per unit, multiple units connect to form a network
- Includes all sensor possibilities as SC200

pH meters

- pH meters in multiple modes:
- 1, 2 or up to 8-channel
- Armatures for immersion, or flow-through.
- 4-20mA, relays PID regulator

Accessories for pH meters

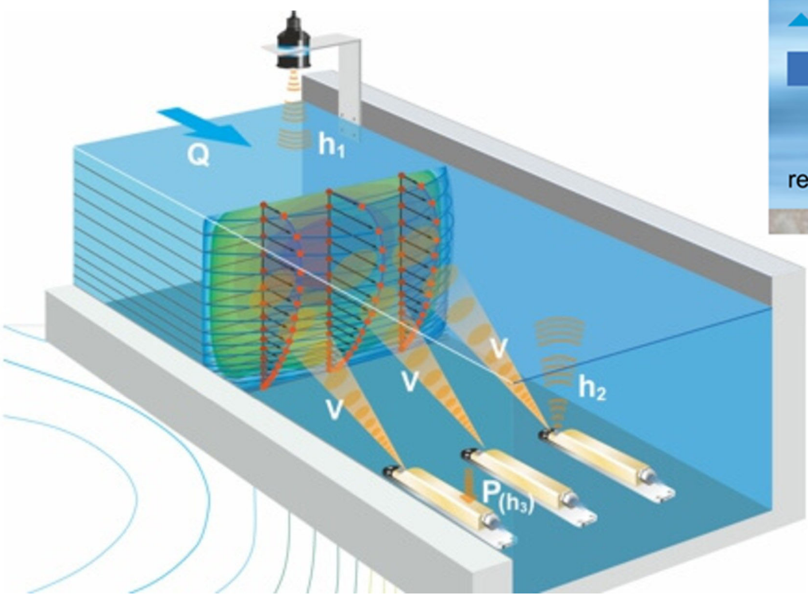
- Variety of calibrating buffers
- Powder for mixing
- 500mL bottles
- Disposable bags (Singlet)

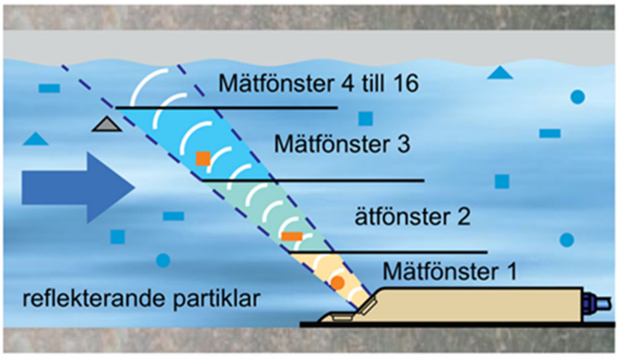
Flow measurements

- Flow measurements for open channels
- Ultrasound sensors
- Most Canal types re preprogarmmed, 10 point free-curve
- 4-20mA, 2 relays.

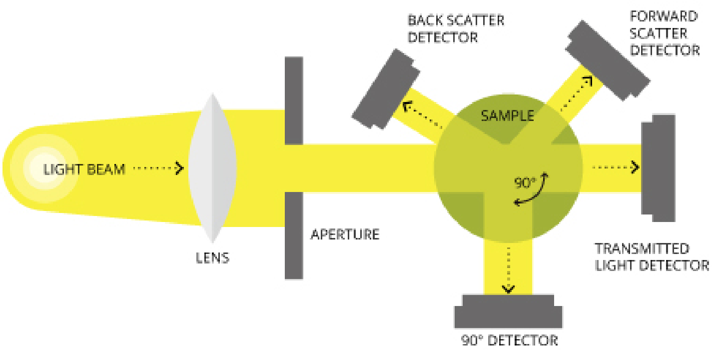
PROSESS-STYRING AS

Flow measurement in pipes



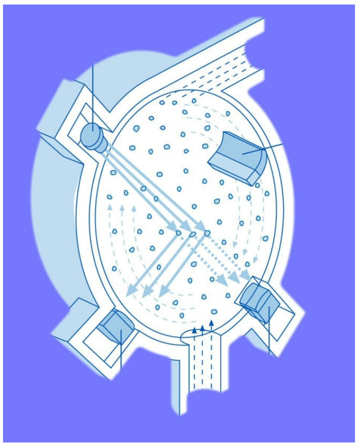


Turbidity meters for water supply



- Ready calibrated
- Light diode ensures stable measurements without needing calibration
- Delivered *with* or *without* automatic cleaning

Automatic cleaning system



Maintenance intervals can be stretched extensively when cleaning is installed, we have customers who refrain for 1 year…

A mechanical window cleaner ensures lenses, light source and all surfaces in the measurement chamber is cleaned.

Turbidity measurements in treatment plants

- Can be used for quality control of effluent.
- Contributes to optimisation of dosage

Cleaning system for turbidity and dry solids sensors

- Mechanical window cleaner which ensures longer life
- This image illustrates the efficiency of the method described above

Ultrasonic cleaning

Suspended Solids Sensor ViSolid®

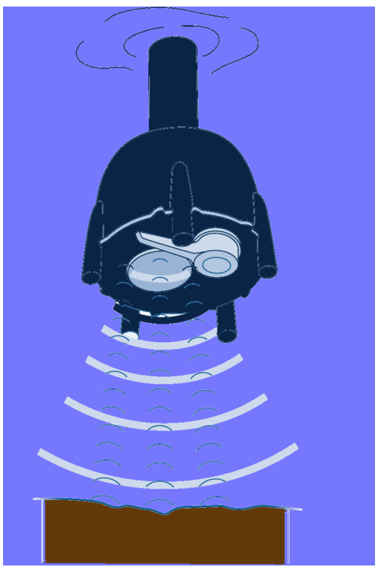
Blooper award from ICA2017

Where is the sensor?

It seems that cleaning the sensors is important…

Queralt Plana, model*EAU*, Université Laval

Sludge level measurement

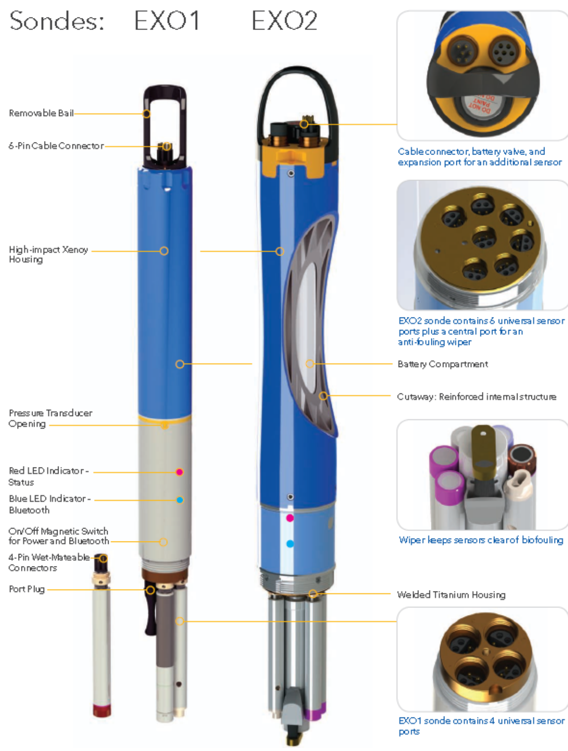


- No touch: time related measurements using ultrasound signals
- Universal: applicable in areas ranging from very low to very high dry solids content values
- Up to 12 meter tank depth: is also suitable for use in SBR reactors and special industrial applications
- Low maintenance: optimised automatic cleaner reduces maintenance need

Dissolved oxygen

- Optical system
- Does not require calibration
- No traditional membrane or electrolyte needing replacement/charging
- Sensor ”cap” normally changed once a year

Multi-parameter sensors

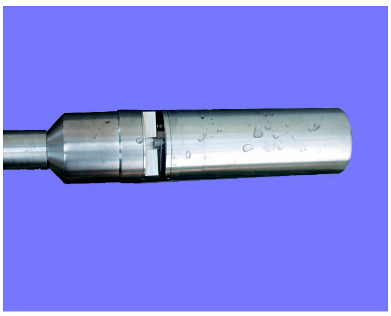


a xylem brand

Chlorine analyser for

- Colorimetric measuremetns ensures accurate results
- Self calibrates before each measurement
- Low maintenance

Nitrate measurements



- Sensor in acid resistant steel constructed for immersion
- Batch measurement frequency can be reduced to 1 measurement per minute
- Window cleaner keeps the sensor's measurement points clean, leading to a virtually maintenance-free product for customers
- Flow-through systems
- The sensor must connect to an SC family universal transmitter

Ammonium / Nitrate, ion seelctive electrodes

Typical life-span of sensor is 12 months.
Measurement range:
0 - 1000 mg/l NH4-N
0 - 1000 mg/l NO3-N

UV absorbtion

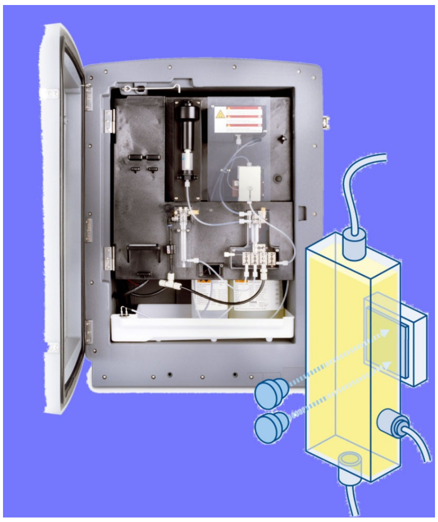
- UV absorption instrument, can perform various relation measurements on organic matter at 254nm

- TOC
- COD
- Colour
- SUM parameter
- Relation curves for the respective parameters must be made with lab measurements

Sample preparations

- Filtration units for samples used by e.g. Orthophosphate and ammoniums sensors.
- Continuously cleaned with air

Phosphate measurements



- Phosphax SC measures for orthophosphate through photometry, providing fast and realiable results

Microbiological quality

Colifast ALARM

Colifast ALARM™ is an online instrument for detection of indicator bacteria in drinking water by using the patented Colifast technology. 100 mL water samples are automatically collected at programmed intervals and analysed for total coliforms, thermotolerant coliforms or *E. coli*. The system can detect down to 1 cfu/100 mL, and results are obtained within 6-14/15 hours.

Outline

- Sampling-methods and error sources
- Status and need
- Online measurements and instruments
- Applications in surveillance and control

Terminologies

PLC - PROGRAMMABLE LOGIC CONTROLLERS

PAC - PROGRAMMABLE AUTOMATION COMPUTER

HMI - HUMAN MACHINE INTERFACE

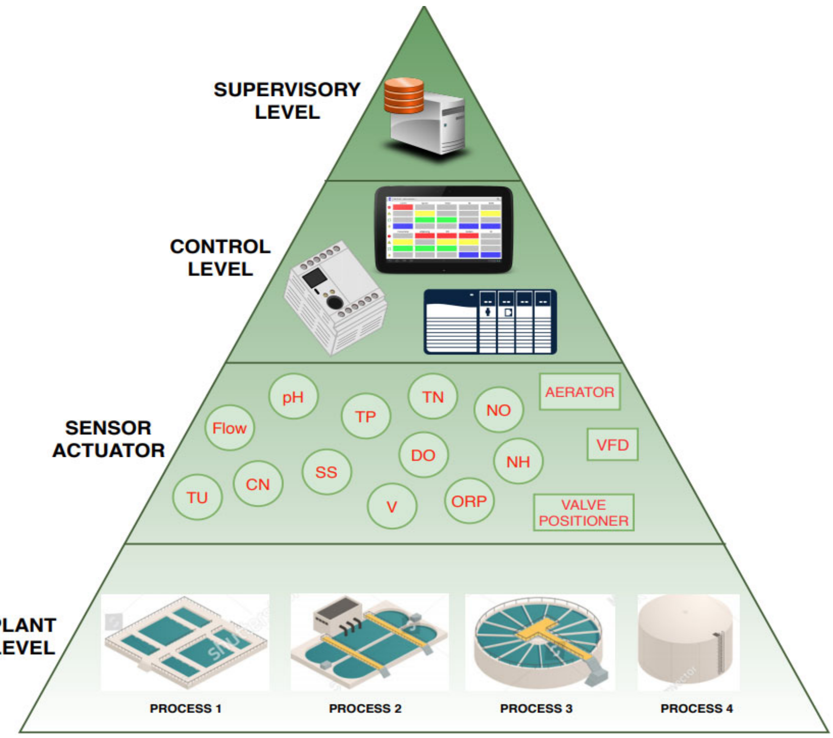
RTU - REMOTE TELEMETRY UNIT

I/O - INPUT OUTPUT MODULE

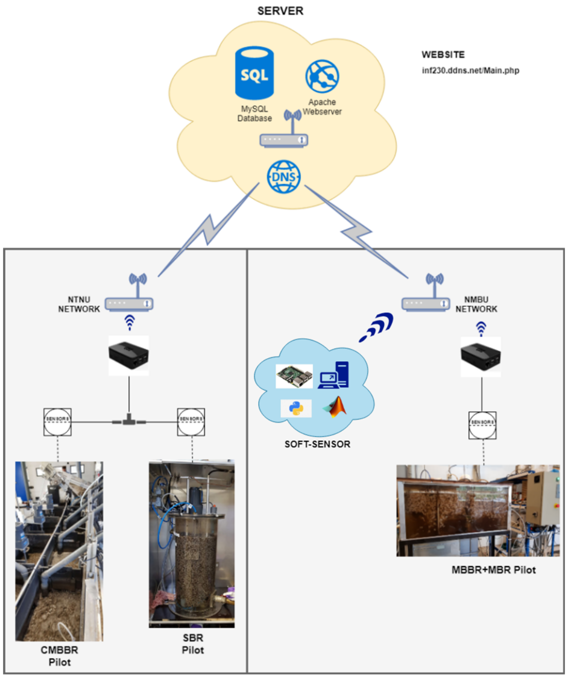
DCS - DISTRIBUTED CONTROL SYSTEM

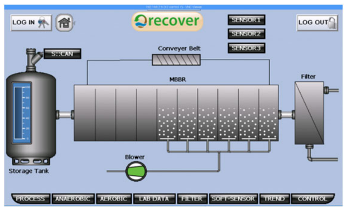
SCADA - SUPERVISORY CONTROL AND DATA ACQUISITION

Commercial SCADA architecture

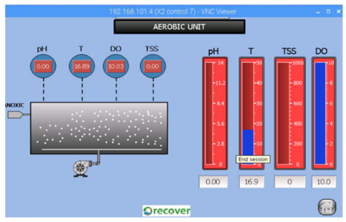


Network Architecture in SCADA

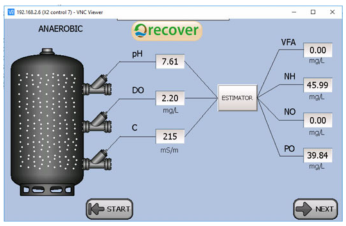




HMI Plant 1



HMI Plant 2

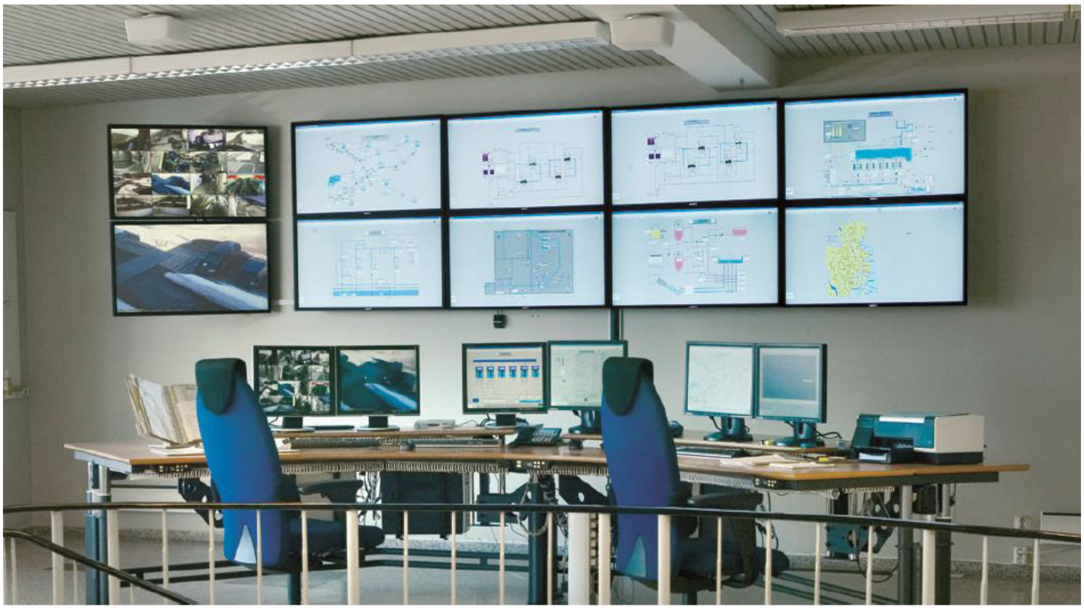


HMI Plant 3

Control Room – Pre Digital Era

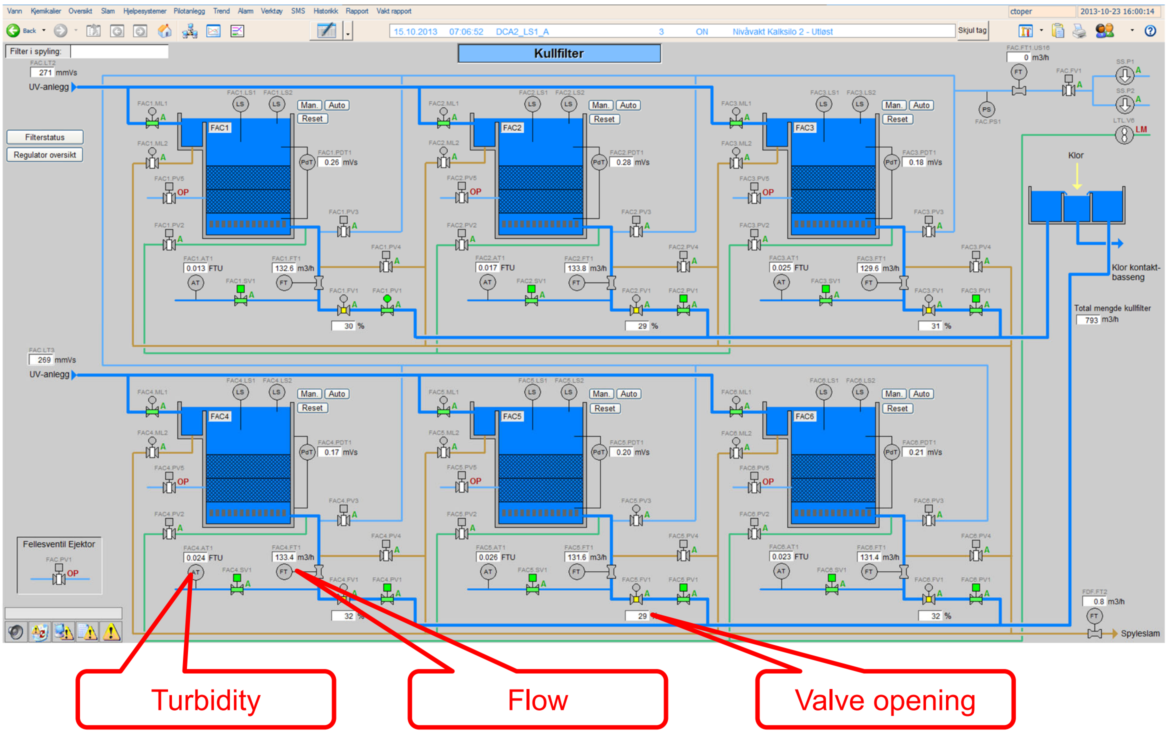
Coal Power Plant
Ref: http://power-controlsystem.com/

Control Room – Digital Era

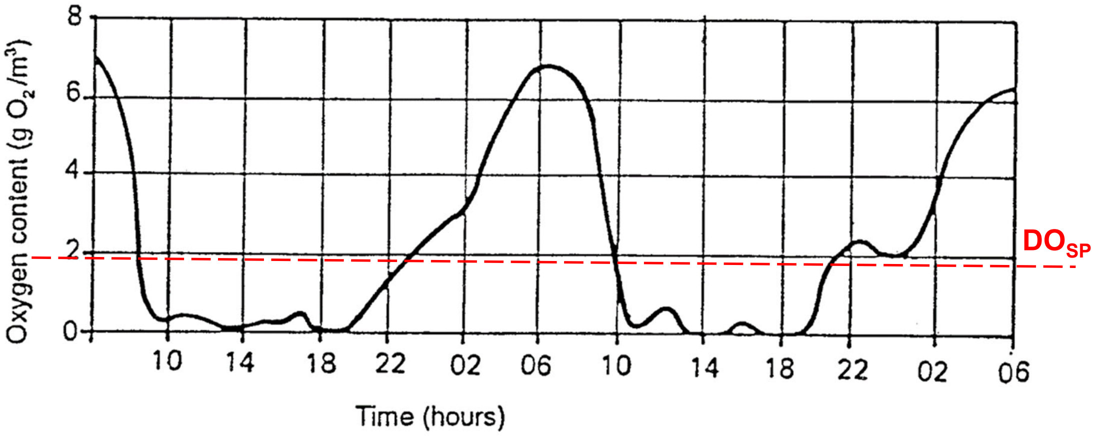


Ref: TS Electro

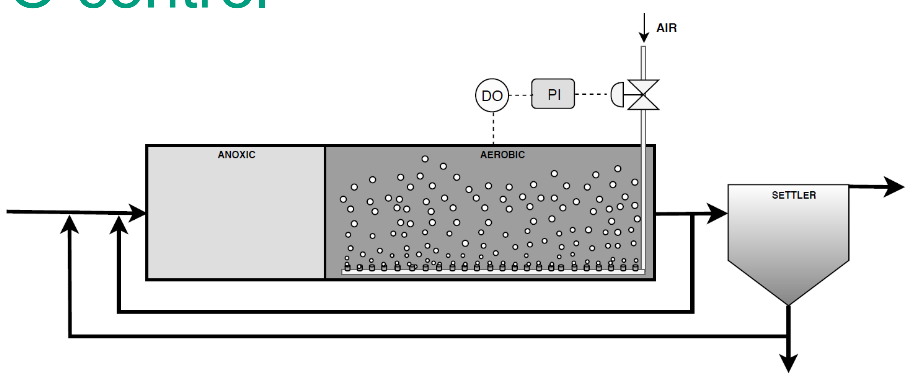
Example: use of online instruments at a drinking water plant: Activated Carbon filter

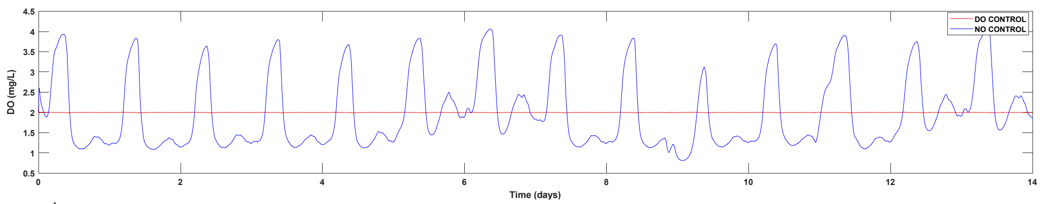


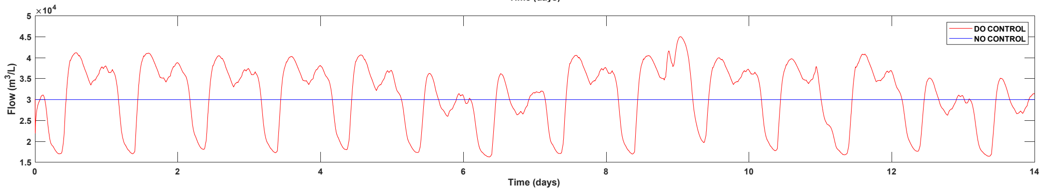
Aeration Basin without control



DO control



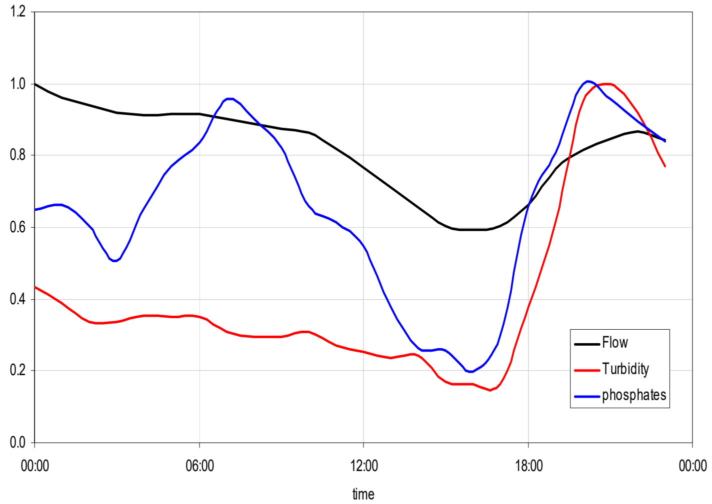




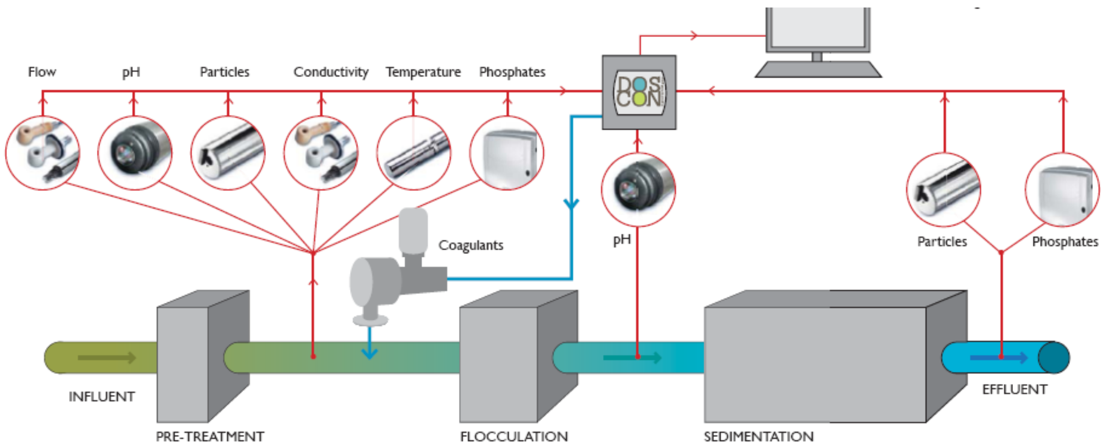
Flow Proportional Dosing

Most DWTPs and WWTPs use flow proportional dosing

… but water quality parameters vary not proportionally to each other

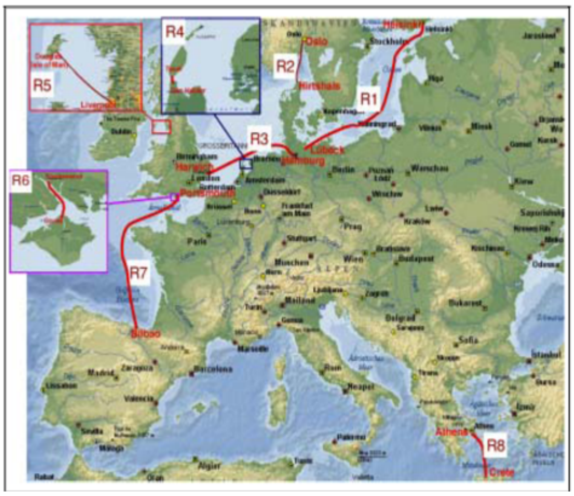


Multi-parameter based optimal dosing control

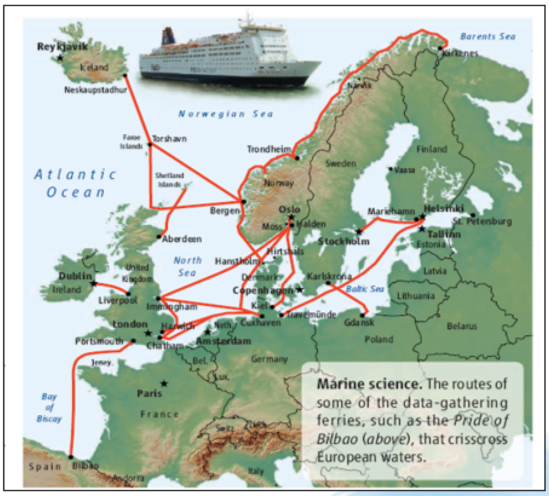


D=f(Q, pH, P, SS, temp, Cond, etc)

Ferrybox Network in Europe

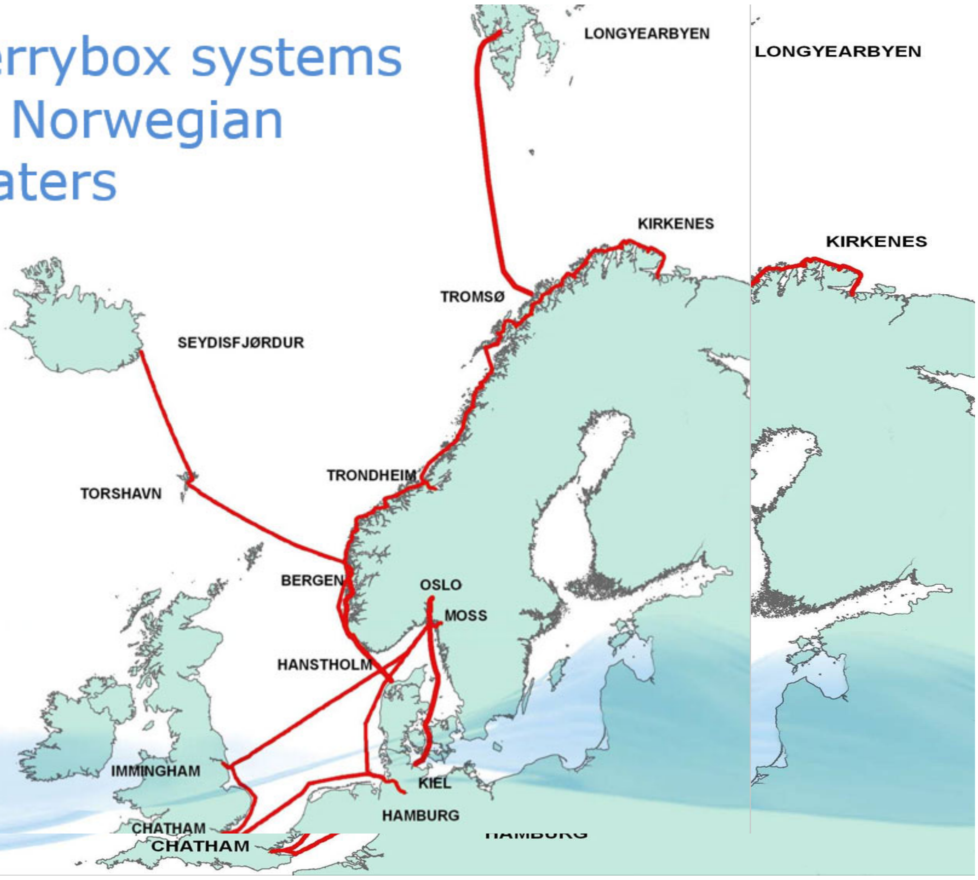


EU-Ferrybox project, 2002-2005



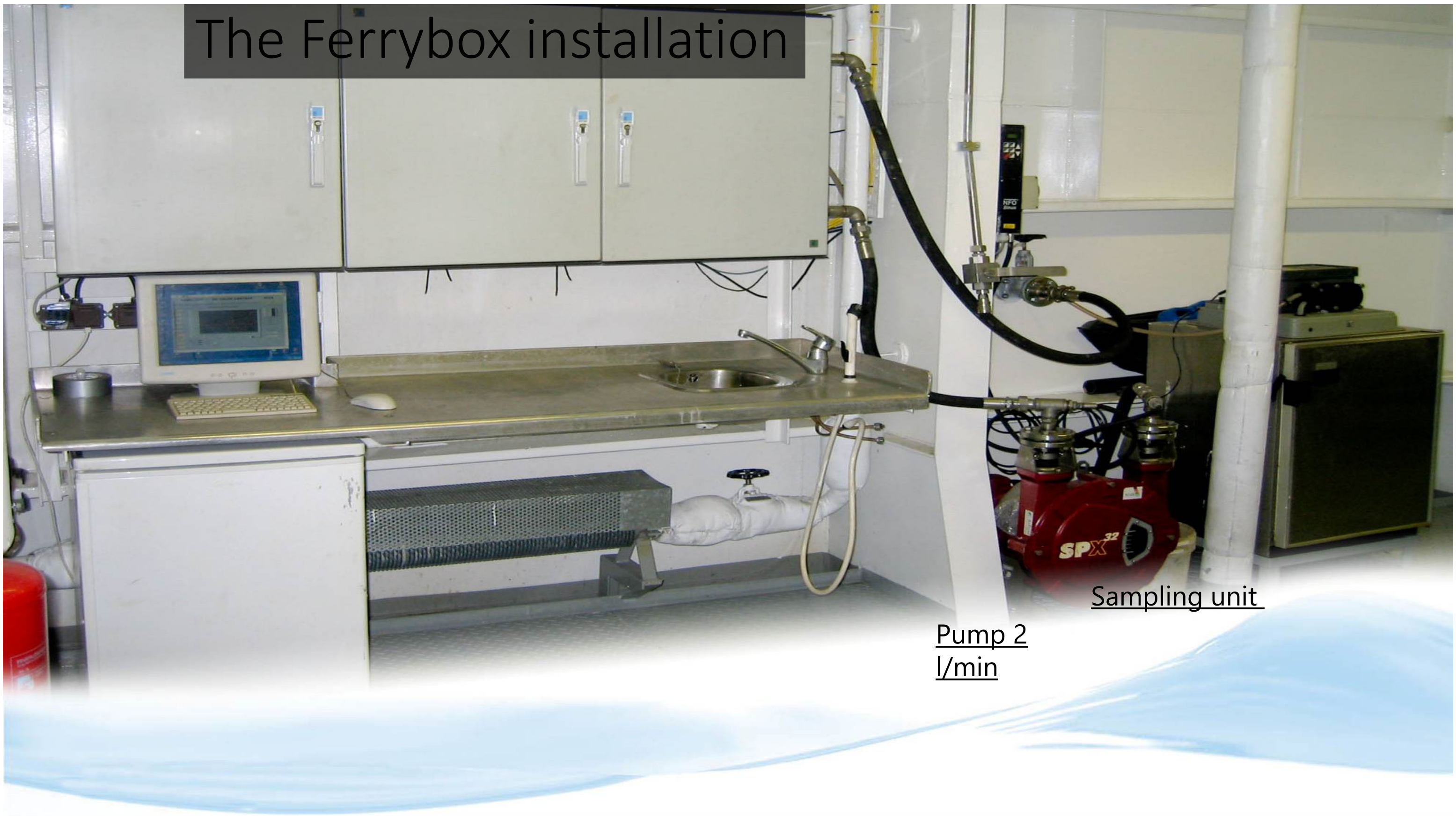
Updated Network, Science Vol 322, 2008

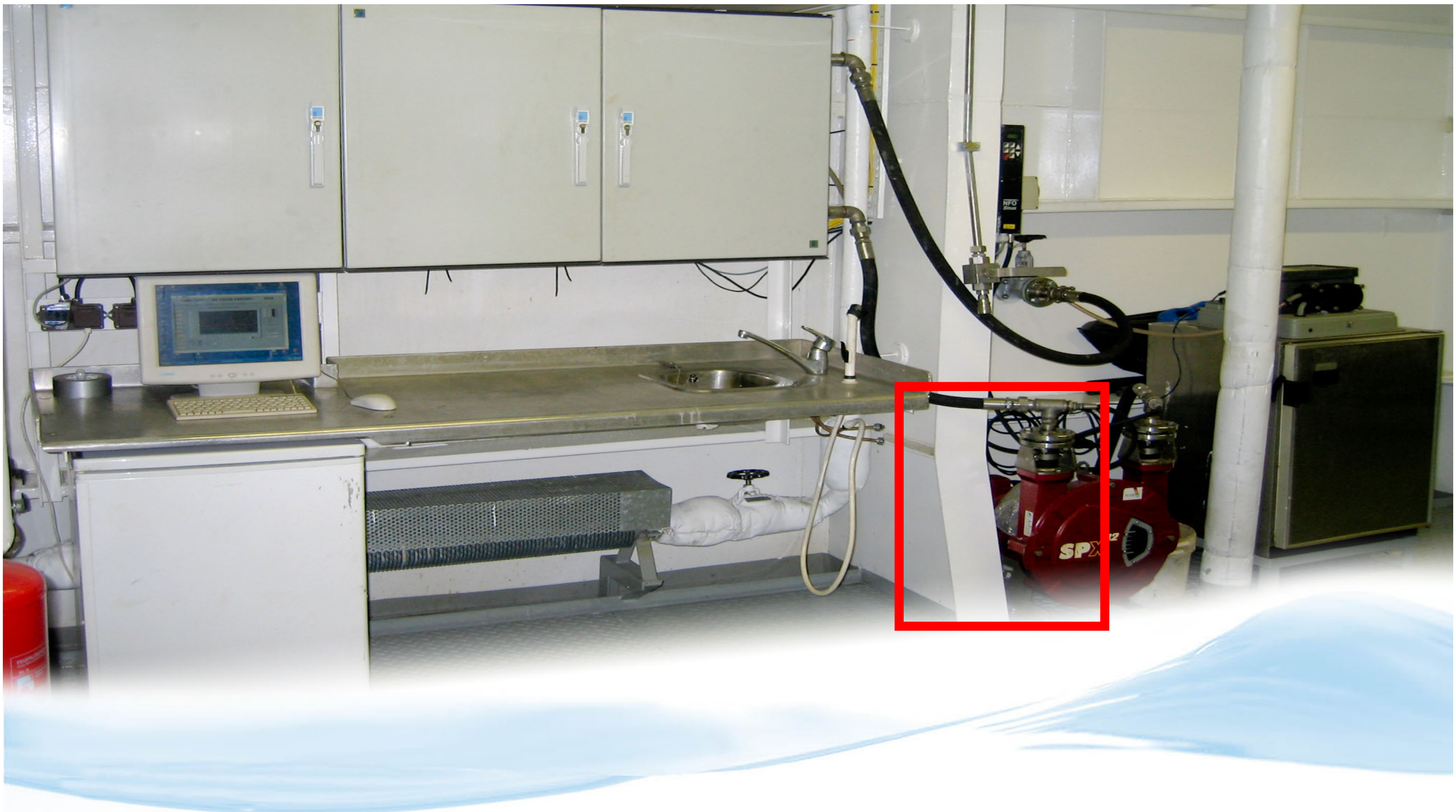
Ferrybox systems in Norwegian waters

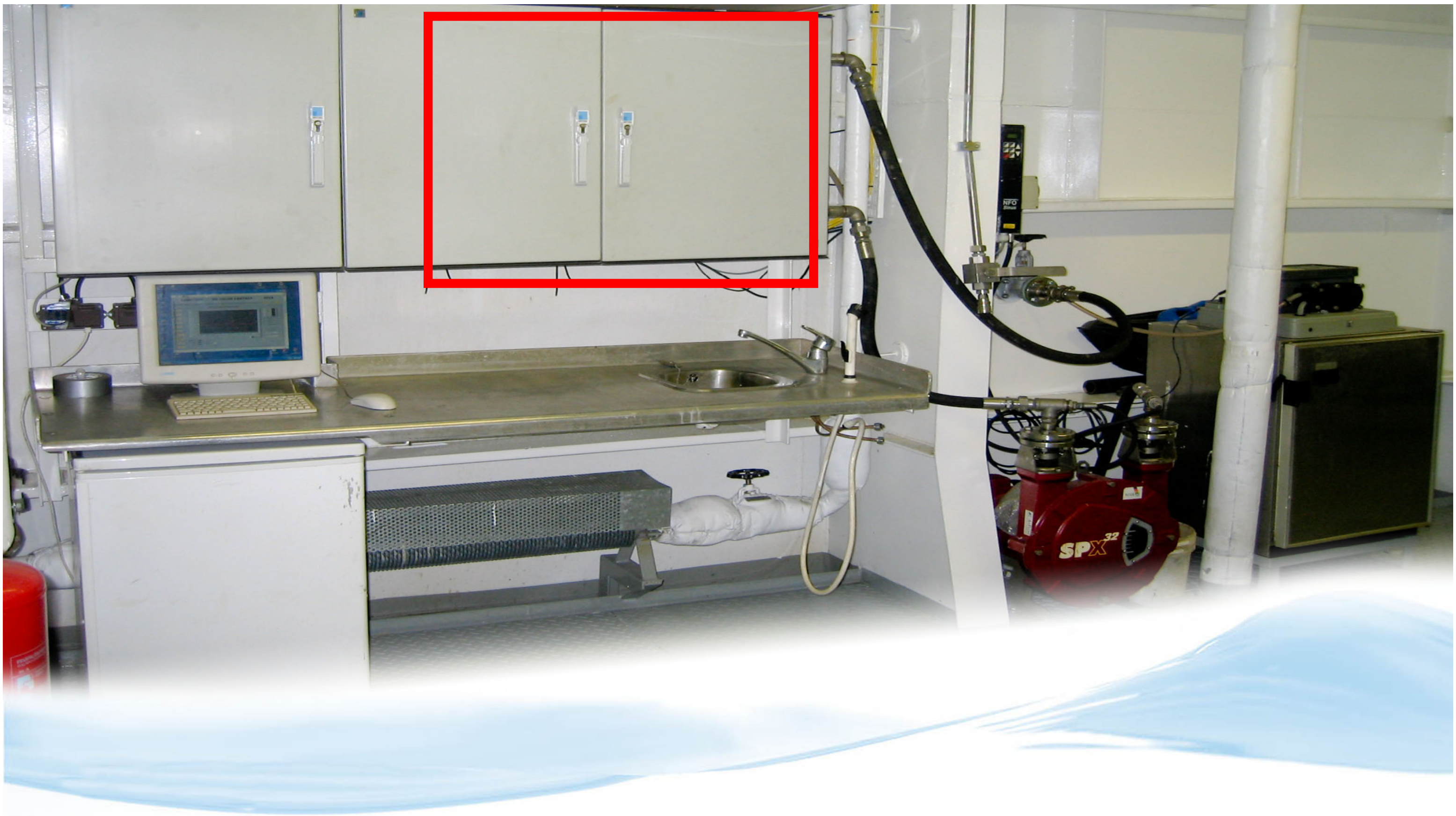


NIVA

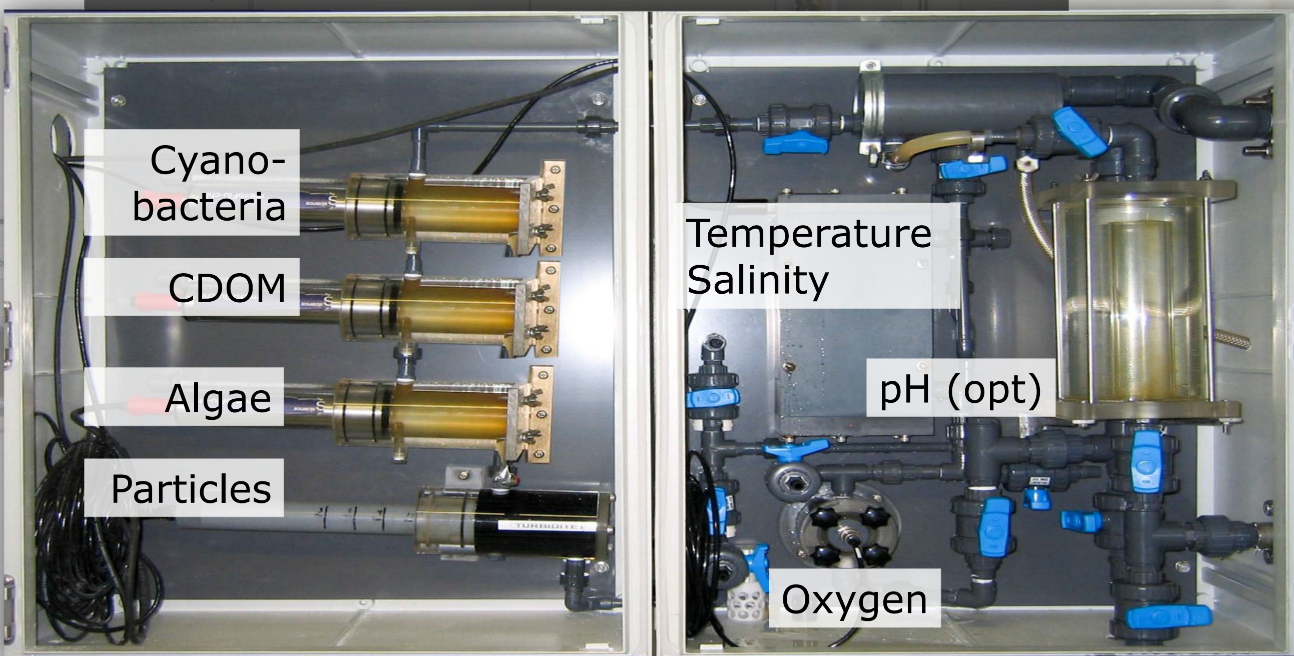
The Ferrybox systems on Color Fantasy between Oslo and Kiel


The Ferrybox installation
Sampling unit
Pump 2
l/min



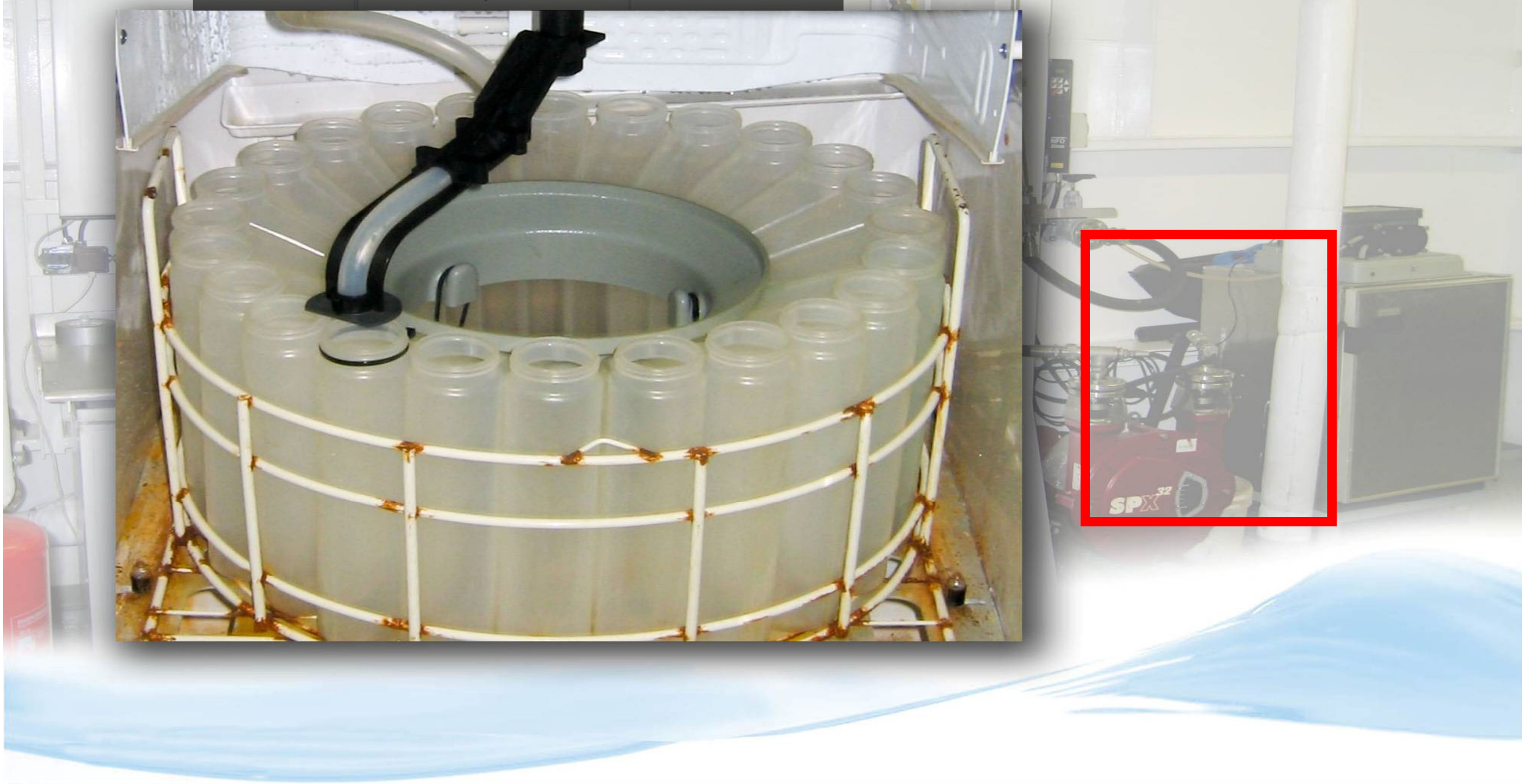


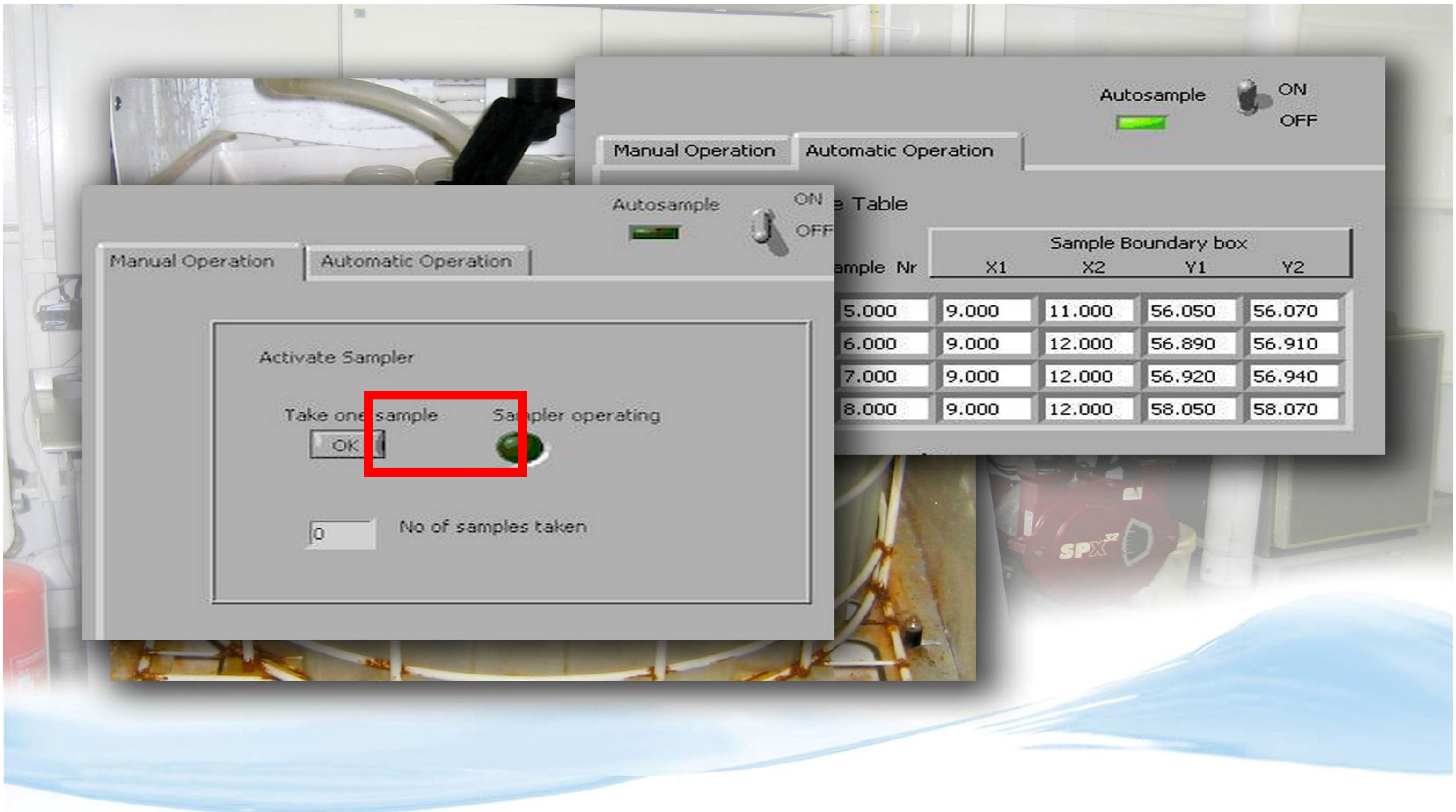
Ferrybox sensors on Oslo-Kiel



CDOM: coloured dissolved organic matter /phycocyanin,_

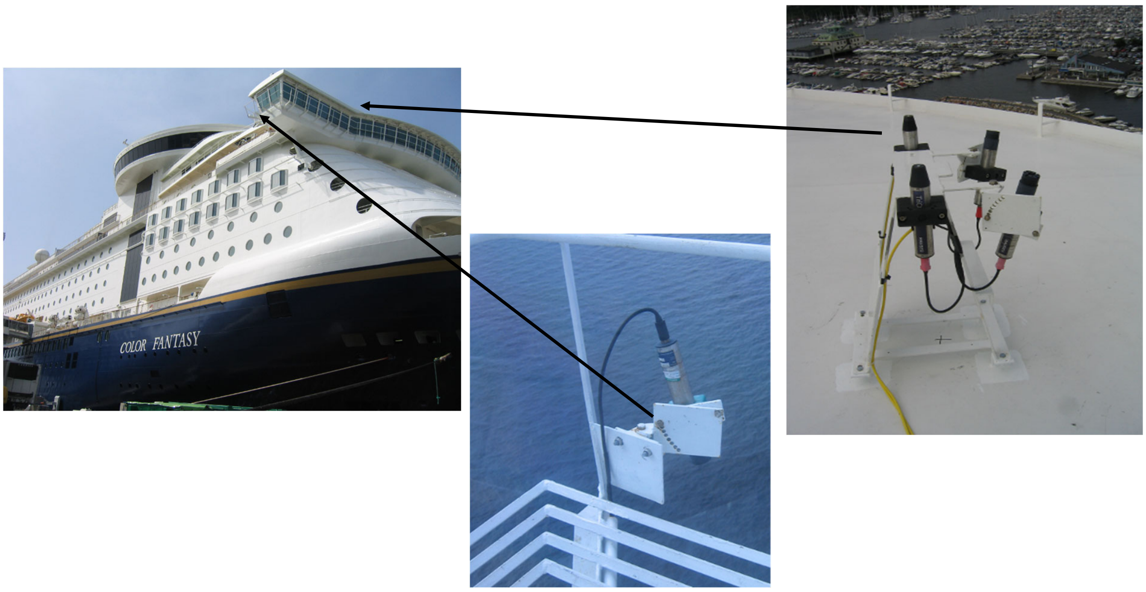
Water sampler



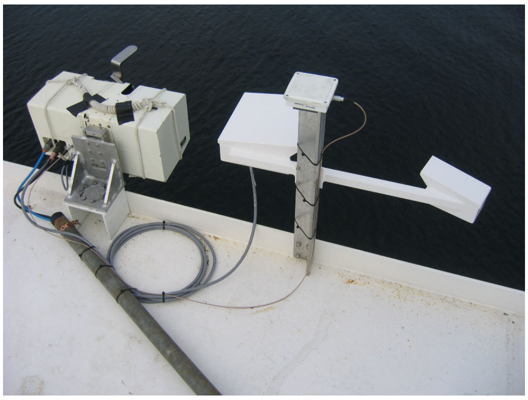


Sensors on the deck (colour, radiation, sea temperature)

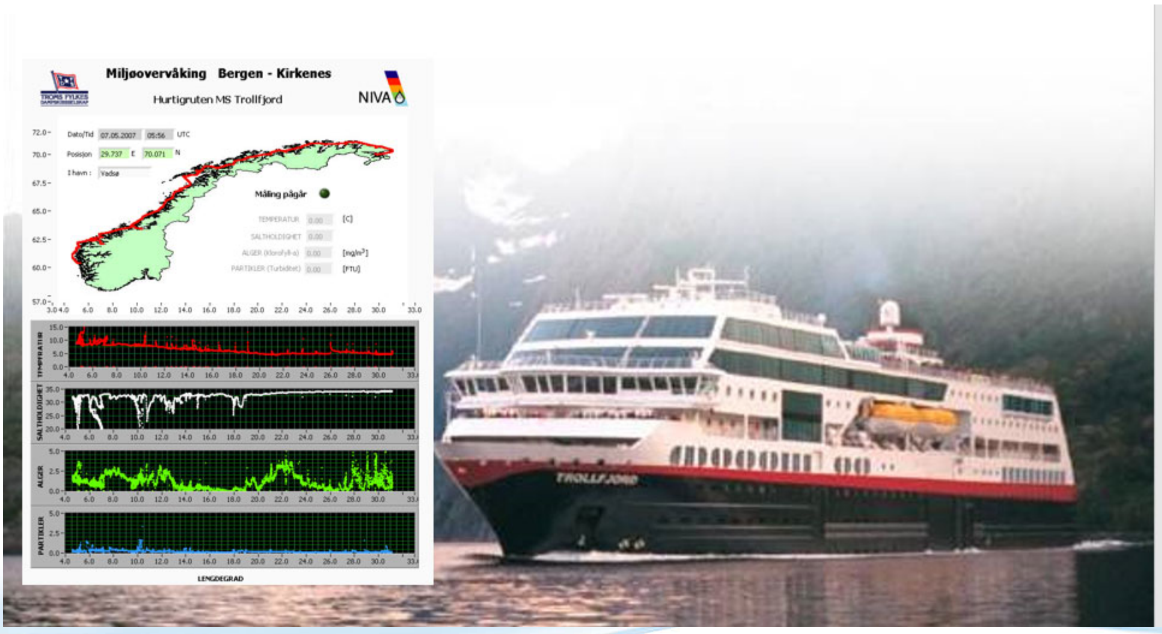
Sensors on the deck (colour & radiation)



Temperature measurements



Web site for the ship data www.ferrybox.no



Digitalisation in the Water Sector

Opportunities & Threats

Goitom Weldehawaryat and Harsha Ratnaweera

June 18, 2021

Outline

Introduction

Digitalisation in the water sector
- Opportunities
- Threats

Cyber attack incidents

Summary

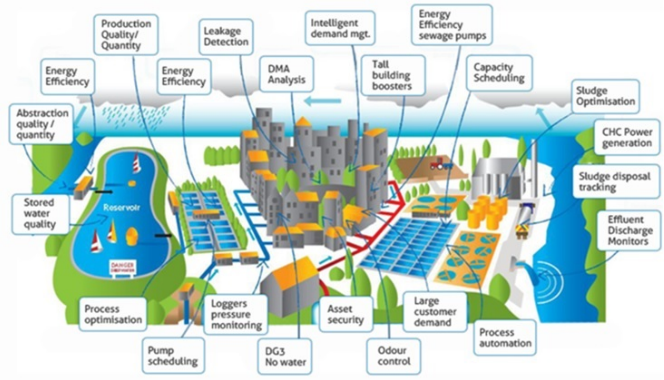
Introduction

Water utilities are **essential** for human society, life and health. However, water utilities and the population they serve are **facing a combination of water security and resilience challenges**.

These are caused by the cumulative impacts of

- population growth,
- increasing demand for water supply,
- declining resources,
- wastewater management,
- pollution and climate change

Use of digital data & concepts to meet the challenges



Smart by design - adaptive, distributed, advanced
Smart use - doing more with less, RRR (R3)
Smart control - sensors, analytics, OT-IT integration

Defining digital water

Digital water, Smart Water, Internet of Water, Water 4.0

The water sector's **value chain links** the environment and water resources to a utility, the utilities to their customers, and the customers back to their environment.

- Efficient collection and use of digital data for smart digital solutions to address the challenges in critical physical assets and their services (the water cycle)

Digital solutions for water & wastewater utilities

- **Remote watershed integrity** Proactive remote monitoring enables fewer callouts and surprises in headwater parameters, including monitoring of multiple parameters (Temperature, pH, Nitratets, etc)
- **Treatment process optimization** Water quality sensors combined with advanced logarithms to optimize the treatment processes, reducing operational costs (e.g. energy, treatment chemicals, etc)
- **Water network management** Sensors and algorithmic solutions provide monitoring of network pressure, failures, and overall asset condition
- **Combined sewer overflow management** Intelligent equipment and real time analytics to prepare for and prepare sewage and stormwater overflows, reducing the need for emergency call-outs

Digital solutions for water & wastewater utilities

- **Preventative & predictive maintenance** Connected equipment and maintenance solutions to reduce downtime and failures of critical equipment and pipelines, reducing the need for emergency call outs
- **Stormwater management and flood relief** Comprehensive range of on-site water capture and dewatering solutions – including emergency response capabilities – to mitigate and manage a range of stormwater and wastewater flooding events
- **Intelligent pumping & treatment equipment** Intelligent equipment – including pumps, mixers, diffusers, and other equipment- which is capable of self-optimizing for enhanced performance, lower maintenance, and lower total cost of ownership

Benefits of digitalisation

Community Benefits

INCREASED AFFORDABILITY

- Improved long-term affordability of rate structure
- Greater transparency in the use of proceeds from water tariffs
- Reduced likelihood of bill shock, non-payment and cut-offs

CUSTOMER EXPERIENCE

- Increased customer engagement and responsiveness to customer inquiries
- Reduced disruptions in water service
- Reduction in the volume of disruptive construction projects

ENVIRONMENTAL PROTECTION

- Reduced risk of sewage overflows into the environment
- Reduced GHG emissions from utility operations
- Improved conservation and management of critical water resources

Operational Benefits

PROCESS EXCELLENCE

- Data-driven operations and decision making reduces errors
- Speed in decision making due to efficient data analysis and processing

PREDICTIVE MAINTENANCE

- Reduced number of emergency call-outs
- Reduced downtime of critical assets

REGULATORY COMPLIANCE

- Reduced incidences of failure and overflows
- Reduced risk of non-compliance resulting from network water quality issues

Benefits of digitalisation

Financial Benefits

REDUCED OPERATIONAL EXPENDITURE

- Optimised operations reduce energy and maintenance costs
- Reduction in costs and risks associated with ad-hoc field maintenance

INCREASED CAPITAL EFFICIENCY

- Improved cash flow as a result of targeted rehabilitation of faulty infrastructure
- Reduced liability and costs from unexpected water main breaks and sewage overflows

INCREASED REVENUE

- Targeted interventions with faulty meters increases revenue
- Value-added digital services available to bulk water customers

Long-term Resiliency Benefits

INCREASED RESILIENCE

- Improved operational flexibility from changing climate and demographics
- Increased safety through rapid customer engagement on public safety concerns

WORKFORCE DEVELOPMENT

- Improved cross-department collaboration through systems integration
- Reduced safety risk to workforce through fewer emergency call-outs

BRAND AND INNOVATION

- Elevates utility brand and engagement in the water industry
- Enables the utility to more easily pilot and adopt latest technologies

Threats

The transition to smart water systems provides invaluable opportunities for *enhancing operational efficiency* in utility sectors. However, it results in increased risks posed by adversaries and threat actors

- Threats may potentially disrupt the normal operation of the water sector in a number of ways.
- Threats may either be triggered or *exploited* by nature, unintentionally by a human, or deliberately by a malicious actor

- System failures
- Natural phenomena
- Human errors
- Malicious actions – cyber attacks
- Third-party failures

Threats

- **Natural phenomena** (earthquakes, floods, landslides, tsunamis, heavy rains, heavy snowfalls, heavy winds,electromagnetic impact (lightning, geo-magnetically induced current (GIC)), explosion, fire (e.g., bush fire, forest fire))
- **External human activities** (e.g. disruption of communication links due to mechanical force and bomb threats, theft of (copper) lines and equipment, the deliberate use of force to create damage including pistol shots at communication lines)
- **Internal** (insufficient training of water sector operators and engineers, human error, lack of awareness about organisational, physical, cyber, and personnel security, unpreparedness and lack of critically needed supplies)

Threats

- **System failures/ malfunction** –failure of devices or systems, failure or disruption of communication links (communication networks), failure or disruption of main supply, failure or disruption of service providers (supply chain), malfunction of equipment (devices)
- **Malicious actions** – cyber attacks (malware, denial-of-service attack, Man-in-the-Middle,jamming attack, phishing attack, false data injection attacks, etc)

Vulnerabilities

- Types of vulnerabilities

  cyber, cyber-physical, and physical vulnerabilities
- Causes of vulnerabilities

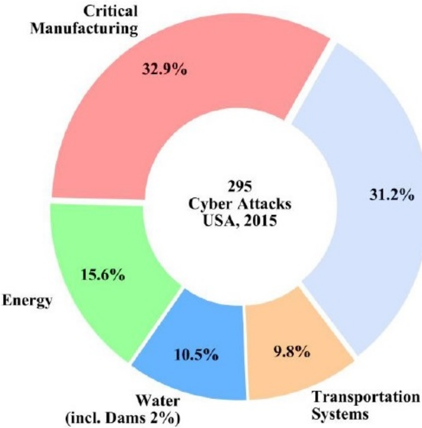
  Isolation assumption
  Increased connectivity
  Easier escalation from a single unit failure to system collapse
  Cascading effects between critical infrastructure (e.g. water and energy)

Vulnerabilities

- Communication vulnerabilities in cyber components
  - Vulnerable protocols
  - Direct access to remote field devices such as RTUs and PLCs
  - PLCs directly connected to the Internet
- Software vulnerabilities
  - Applications that are used for controlling and monitoring field devices are running on general-purpose OS
  - Vulnerabilities in Internet exposed devices that are connected to the local network (e.g. servers in the control center, employees' portable devices)
  - Smart meters provide a potential access point for malicious attackers
  - Weak authentication mechanisms
  - Improper credentials' storage
  - Unauthorized firmware update
- Physical exposure of many ICS components, such as RTUs and PLCs - insufficient physical security

The attackers are also interetsed in the water sector

- Already a prominent target (**3rd most targeted**)
- Many cybersecurity incidents go either **undetected** and **unreported, or undisclosed** (reputation+ customers trust)
- **Cybersecurity** is of course already part of the agenda for water companies
- **Physical security** has been part of the agenda for some time



Cyber attack incidents in USA, 2015 (DHS, 2016)

What can cyber attacks do?

- Interfere with operations – over/under dosage
- Unauthorised changes to programmed instructions; reduced pressure, overflow of sewage, malfunction of unit processes
- Modify control systems to produce unpredictable results
- Block data or send false information to operators
- Change alarm thresholds or disable them
- Prevent access to account information
- Ransomware
- Access to personal information (GPDR directive)

Cyber attack incidents

Incidents	Year	Target	Attribution	Infection Vector	Details	Impact
Israel's water system	2020	OP	Hacktivist/ Nation state	Unknown	Israeli government reported cyber-attacks against water supply and treatment facilities and urged these facilities to change passwords.	Unknown.
Northern Colorado	2019	OP	Cybercrime	Ransomware	Locked access to technical and engineering data.	Disruption, took about three weeks to unlock data.
Kemuri water	2016	OP	Hacktivist	Remote access	Accessed PLC responsible for controlling water treatment chemicals.	Engineers were able to identify and reverse the changes made to process control parameters.
Bowman Avenue Dam	2016	OP	Hackers/ Nation state	Remote access	According to US authorities, hackers linked to Iranian Armed Forces infiltrated ICS of Bowman Avenue Dam and accessed the SCADA for the dam.	Data exfiltration and over $30k on remediation costs. Physical damage was not possible due to disconnected sluice gates.
Florida Wastewater	2012	IT	Ex-Employee	Remote access	Stolen login credentials were used to access district's computer system.	Deleting and modifying information. Ex-employee was arrested on account of computer crime.

Cyber attack incidents

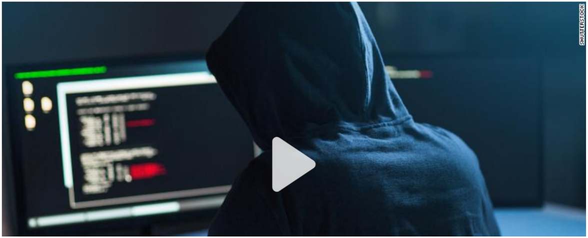
edition.cnn.com/2021/02/10/us/florida-water-poison-cyber/index.html

CNN US Crime + Justice Energy + Environment Extreme Weather Space + Science Edition

Florida water treatment facility hack used a dormant remote access software, sheriff says

By Alex Marquardt, Eric Levenson and Amir Tal, CNN

Updated 2203 GMT (0603 HKT) February 10, 2021



Florida water treatment cyber attack incident

Summary of the incident

- In February, 2021, attackers accessed the control system's software at the **Oldsmar water-treatment facility in Florida**, and attempted to increase the levels of sodium hydroxide (commonly referred to as lye) that is used in water treatment to regulate acidity levels by adjusting the control setting to **more than 100 times its normal levels** (100ppm to 11,100ppm)
- The change was immediately detected by a plant operator, who changed the setpoint levels back before the attack had any impact on the system
- The attack used **stolen credentials** that were shared between multiple users and devices to remotely login to the HMI station controlling the water systems

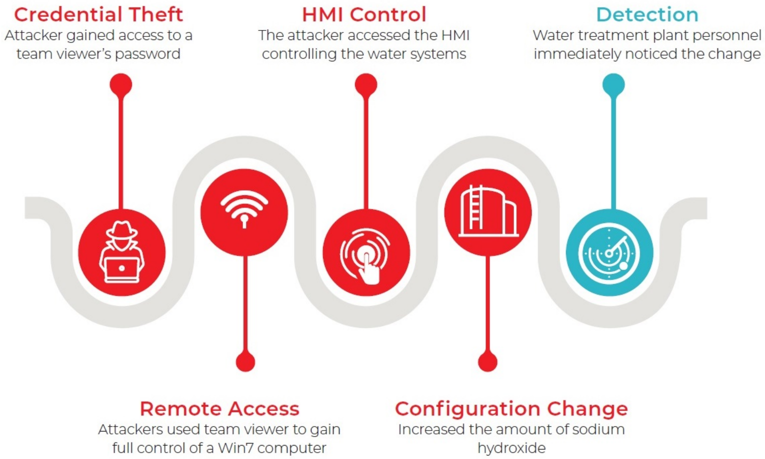
Florida water treatment cyber attack incident

Attack highlights

- The attackers accessed the Oldsmar water-treatment facility's OT control system via **TeamViewer**, which is a remote access software
- All computers used by the facility personnel were connected to the OT control system that used an **outdated operating system (Windows 7)**
- All computers shared the same password for remote access.
- All computers appeared to be connected directly to the Internet without any type of firewall protection.

Florida water treatment cyber attack incident

Attack timeline



What are the potential impacts of the incident?

- This specific incident did not result in any public health impacts, however the attack highlights potential vulnerabilities for systems that use networked industrial control systems and outdated operating systems
- This incident may inspire similar attacks seeking to exploit such vulnerabilities at municipal water treatment plants
- Tampering with water treatment chemicals, by either increasing or decreasing the concentration delivered, could cause public health impacts

NIS directive

The **Directive on security of network and information systems** (the NIS Directive) is the first piece of EU-wide legislation on cybersecurity. The NIS Directive was adopted in 2016, and it provides legal measures to boost the overall level of cybersecurity in the EU by ensuring:

- **Member States' preparedness**, by requiring them to be appropriately equipped. For example, with a Computer Security Incident Response Team (CSIRT) and a competent national NIS authority
- **cooperation among all the Member States**, by setting up a Cooperation Group to support and facilitate strategic cooperation and the exchange of information among Member States
- **a culture of security across sectors** that are vital for the economy and society and that rely heavily on ICTs, such as energy, transport, water, banking, financial market infrastructures, and healthcare

Revised NIS directive (NIS 2 directive)

Greater capabilities

- More stringent supervision measures and enforcement are introduced
- A list of administrative sanctions, including fines for breach of the cybersecurity risk management and reporting obligations is established

Cooperation

- Establishment of European Cyber crises liaison organisation network (EU- CyCLONe) to support coordinated management of large scale cybersecurity incidents and crises at EU level
- Increased information sharing and cooperation between Member State authorities with enhanced role of the Cooperation Group
- Coordinated vulnerability disclosure for newly discovered vulnerabilities across the EU is established

Revised NIS directive (NIS 2 directive)

Cybersecurity risk management

- Strengthened security requirements with a list of focused measures including incident response and crisis management, vulnerability handling and disclosure, cybersecurity testing, and the effective use of encryption.
- Cybersecurity of supply chain for key information and communication technologies will be strengthened.
- Accountability of the company management for compliance with cybersecurity risk-management measures.
- Streamlined incident reporting obligations with more precise provisions on the reporting process, content and timeline.
- Expanded scope to include more sectors and services as either essential or important entities. **Waste water and waste management, Space, etc**

Cybersecurity framework

The **NIST Cybersecurity Framework** (NIST CSF) provides a policy framework of cybersecurity guidance for **how private sector organizations can assess and improve their ability to prevent, detect, and respond to cyberattacks**

- Version 1.0(1.1) was published by the US NIST in 2014(2018), originally aimed at **operators of critical infrastructure**
- It can be used by a wide range of businesses and organizations, and helps shift organizations to be **proactive about risk management**

Cybersecurity framework

The Framework provides an assessment mechanism that enables organizations to **determine their current cybersecurity capabilities**, **set individual goals for a target state**, and establish a plan for improving and maintaining cybersecurity programs

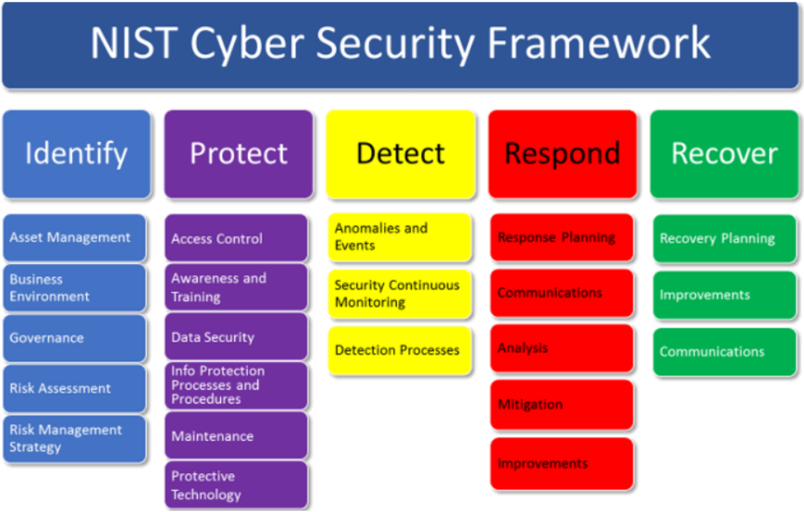
It allows organizations to:

- Describe current cybersecurity posture
- Describe target state for cybersecurity
- Identify and prioritize opportunities for improvement
- Assess progress towards target state

Cybersecurity framework

- **Identify** – Develop an organizational understanding to manage cybersecurity risk to systems, people, assets, data, and capabilities
- **Protect** – Develop and implement appropriate safeguards to ensure delivery of critical services
- **Detect** – Develop and implement appropriate activities to identify the occurrence of a cybersecurity event
- **Respond** – Develop and implement appropriate activities to take action regarding a detected cybersecurity incident
- **Recover** – Develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a cybersecurity inciden

Cybersecurity framework



Basic security measures to reduce vulnerabilities a

- Segregate networks and apply firewalls
- Use secure remote access methods
- Establish roles to control access levels and log users
- Require strong passwords & password management
- Avoid vulnerabilities, implement patches, updates
- Enforce policies on the security of mobile devices
- Have an employee cyber security training program
- Involve utility executives in cyber security
- Monitor network intrusions and have a response plan
- Report and share information on incidents for developing coordinated common actions (NIS directive, etc)
- Employ defense-in-depth strategies

Defense in Depth Strategy Elements	
Risk Management Program	· Identify Threats · Characterize Risk · Maintain Asset Inventory
Cybersecurity Architecture	· Standards/ Recommendations · Policy · Procedures
Physical Security	· Field Electronics Locked Down · Control Center Access Controls · Remote Site Video, Access Controls, Barriers
ICS Network Architecture	· Common Architectural Zones · Demilitarized Zones (DMZ) · Virtual LANs
ICS Network Perimeter Security	· Firewalls/ One-Way Diodes · Remote Access & Authentication · Jump Servers/ Hosts
Host Security	· Patch and Vulnerability Management · Field Devices · Virtual Machines
Security Monitoring	· Intrusion Detection Systems · Security Audit Logging · Security Incident and Event Monitoring
Vendor Management	· Supply Chain Management · Managed Services/ Outsourcing · Leveraging Cloud Services
The Human Element	· Policies · Procedures · Training and Awareness

References

References will be added here

IWA
Digital Water: Industry Leaders Chart the Transformation Journey
.

DHS
Recommended Practice: Improving Industrial Control System Cybersecurity with Defense-in-Depth Strategies
.

Thank you!

Simulation and modelling programs for water resource management (WRM) and W&WW treatment

Harsha Ratnaweera, RealTek NMBU

18.06.2021

Need for simulation programs

- A decision making tool
- Provides a basis for design alternatives reducing need for physical tests - avoids costly mistakes in full-scale
- Plant operators may simulate operational conditions for process optimisation
- A learning tool for plant operators, students
- Researchers and Consultants: wider opportunities to find more economical and efficient process alternatives
- Guidance under extreme conditions

WEAP

Water
Evaluation
And
Planning

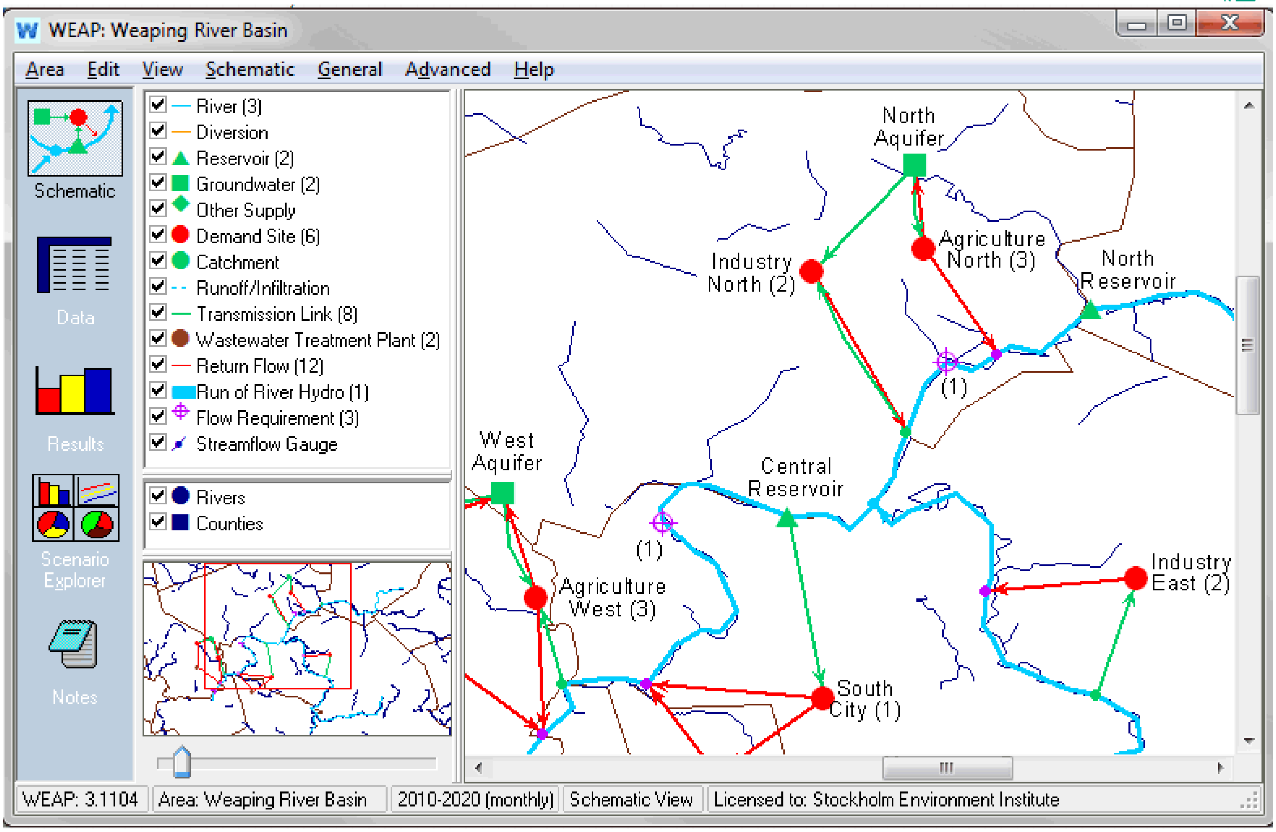
- A tool for integrated water resources planning that attempts to assist rather than substitute for the skilled planner.
- a comprehensive, flexible and user-friendly framework for planning and policy analysis.
- Many water professionals are finding WEAP to be a useful addition to their toolbox of models, databases, spreadsheets and other software

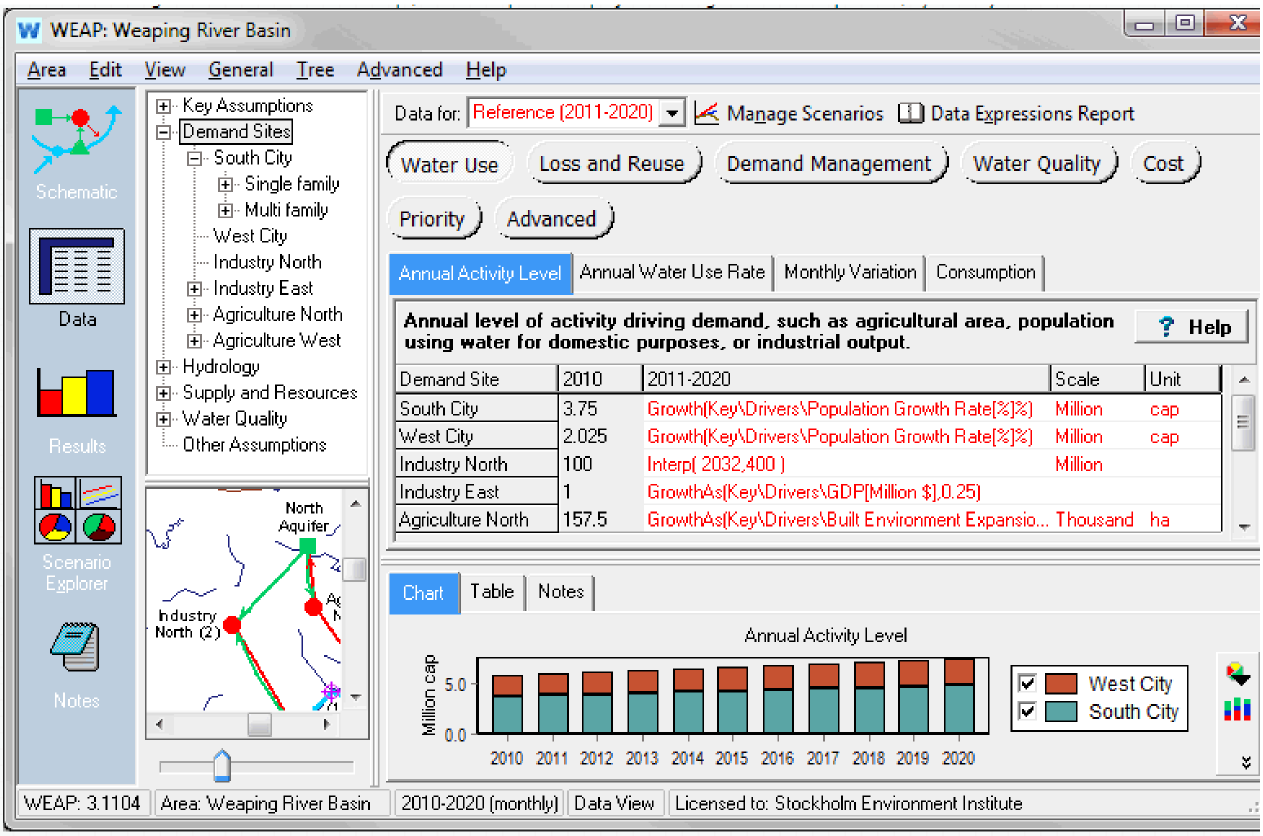
Main functions

- **Water balance database:** WEAP provides a system for maintaining water demand and supply information.
- **Scenario generation tool:** WEAP simulates water demand, supply, runoff, streamflows, storage, pollution generation, treatment and discharge and instream water quality.
- **Policy analysis tool:** WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems

Examples

- What if population growth and economic development patterns change?
- What if reservoir operating rules are altered?
- What if groundwater is more fully exploited?
- What if water conservation is introduced?
- What if ecosystem requirements are tightened?
- What if a conjunctive use program is established to store excess surface water in underground aquifers?
- What if a water recycling program is implemented?
- What if a more efficient irrigation technique is implemented?
- What if the mix of agricultural crops changes?
- What if climate change alters demand and supplies?
- How does pollution upstream affect downstream water quality?
- How will land use changes affect runoff?





- Free download from www.weap21.org
- Install in your PCs so we can run simulation exercise.

- Before downloading you need to register

Simulation of drinking water treatment

- SimEau
- WatPro
- WaterSPOT

WATPRO

Hydromantis
Environmental Software Solutions, Inc.

Home / Products

WATPRO

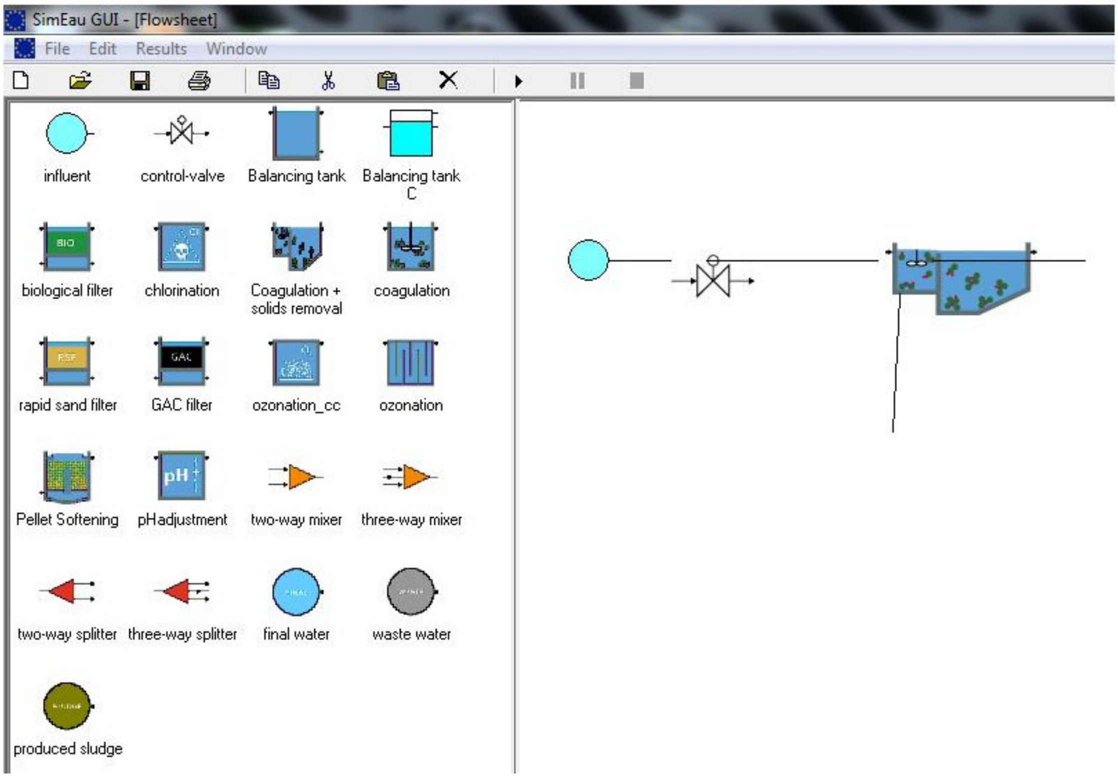
Water Treatment Simulator for Predicting Water Quality

WatPro is a sophisticated tool to allow for simple evaluation of the performance of a drinking water treatment facility from a microbial and chemical standpoint.

This software allows for the steady-state analysis of disinfection by-product (DBP) formation, inactivation of Giardia and viruses, removal of organic matter, the decay of disinfectants, and pH.

https://www.hydromantis.com/WatPro.html

SimEau



Simulation software for wastewater treatment

- STOAT
- WEST
- GPS-X
- Simba
- Enviorsim

DET L

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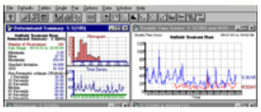
AARDVARK
Plan-It STOAT
STOAT
STORMPAC
UPM-RAT

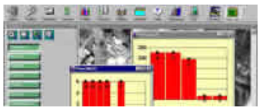
Software

WRc has over thirty years' experience of development and application of models for wastewater treatment processes and is recognised internationally for its software development.

AARDVARK



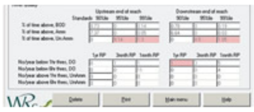
Plan-it STOAT



STOAT

STORMPAC

UPM-RAT



www.wrcplc.co.uk

News

WRc's response to Industry consultations
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Versión Espagñole

Software

Process simulation modelling is a valuable tool that is used to provide a better understanding of the biological and chemical processes that determine the performance of wastewater treatment works. With advances in the power of computers, the use of process modelling has grown widely in the Water Industry over the last 10 years. Process models are commonly used to prove the performance of new wastewater treatment plant configurations at the design stage or explore opportunities for improving the performance of existing plants without risk of impairing effluent quality that might occur with full-scale testing.

WRc has over thirty years experience of development and application of models for wastewater treatment processes and is recognised internationally for its software development. The models are:

- **STOAT** - a dynamic sewage treatment works modelling package.
- **Plan-It STOAT** - a steady-state sewage treatment works model.
- **Mastar** - assists in determining the Best Practical Environmental Option (BPEO) for the treatment and recycle/disposal of sewage sludge.
- **STOP** - predicts the odour emission rate from sewage and sludge treatment processes at greenfield sites.

The tools can be used for:

- Designing new sewage treatment works and extensions to existing works;
- Developing new operational practices;
- Testing 'What-If' scenarios;
- Assisting process audits.

How to share STOAT files

hello everyone,

i would like to know if it is applicable to share my work with my college, i use STOAT V5. I tried "save as work" button, but it save it internally in the program and I need an external file,so is it applicable???
Thanks in advance.

3 · 2 Comments

jeremy dudley • 1st 2y ...
engineer at WRc plc

Easiest way is to share the entire database, along with the influent files and, optionally, the result files.

If you only want to share one works, then run the 'Database Copy' tool that comes with STOAT - select the works that you want to copy. It will copy result files as well, if you create the new database in a new folder. However, I don't think we checked that it copies influent files - you will need to check and copy by hand. I will look at that as an upgrade.

Having handed over your STOAT database, the influent files will be looked for the in the hard-coded location of your computer. So if you saved the files in C:\STOAT\Influents, then your colleague will need to keep the influents there.

However, if they put the influents wherever they want they need, when creating a new simulation, to use Edit/Influents and that will allow them to reset the file location.

From LinkedIn STOAT group page: https://www.linkedin.com/feed/update/urn:li:activity:6357986316965150720

MIKE 2019 Areas of application Products Download Support Pricing DHI

WEST

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OUR CONTACT

MIKE Powered by DHI
Customer Success team
mike@dhigroup.com

APPLICATIONS

- Design of wastewater treatment plants
- Optimisation of wastewater treatment plants
- Advanced control strategies
- Integrated urban water systems
- Monitoring and troubleshooting of treatment plant operation

WEST

Modelling and simulation of wastewater treatment plants

WEST is a **powerful and user-friendly** modelling software for **dynamic modelling and simulation of wastewater treatment plants** (WWTP) and other types of water quality related systems. It is designed for operators, engineers and researchers interested in studying **physical, biological or chemical processes** in WWTPs, sewer systems and rivers.

BENEFITS

- User-friendly and intuitive graphical tools
- Extensive and transparent default model library
- Limitless flexibility for developing customised model libraries
- Easy implementation of control strategies
- Customisable project documentation through inclusion of rich text notes and automated report generation
- Fully customisable objective functions

https://www.mikepoweredbydhi.com/products/west

www.intelligen.com

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Pharmaceuticals
Specialty Chemicals
Consumer Goods

Water Purification
Wastewater Treatment
Mineral Processing
Pulp and Paper
Microelectronics
Air Pollution Control

Competencies

Process Simulation
Cost Analysis
Scheduling & Planning
Debottlenecking
Cycle Time Reduction

Environmental Impact
Wastewater Treatment
Water Purification
VOC Emissions
Air Pollution Control

EnviroPro Designer®

EnviroPro Designer is an environmental process simulator designed to enhance the productivity of engineers and scientists engaged in the design, development, and assessment of integrated water purification, wastewater treatment, and waste disposal processes.

EnviroPro Designer is a valuable tool for environmental consulting engineers, process designers, and treatment/disposal plant engineers and managers. It enables the user to efficiently develop, assess, and optimize environmentally beneficial technologies. It provides under a single umbrella modeling of end-of-pipe treatment processes, project economic evaluation, and environmental impact assessment. Its rigorous and versatile biological reactor models can be used to represent and optimize biochemical oxidation as well as nitrogen and phosphorous removal processes. Its VOC emission models (accepted by EPA) can be used to calculate emissions from treatment plants and track the fate of hazardous chemicals.

A superset of EnviroPro, SuperPro Designer, is also available to extend the modeling of pollution control processes to include chemical and biochemical manufacturing operations.

A detailed brochure file is available in MS Word format. The size of the file is 277 kb. Click here to download it (in zip format).

EnviroPro Designer is available for the MS Windows 95, 98, ME, NT, 2000, and XP platforms. It requires a Pentium PC (> 200 MHz) with at least 64 MB of RAM, and 200 MB of free hard disk space.

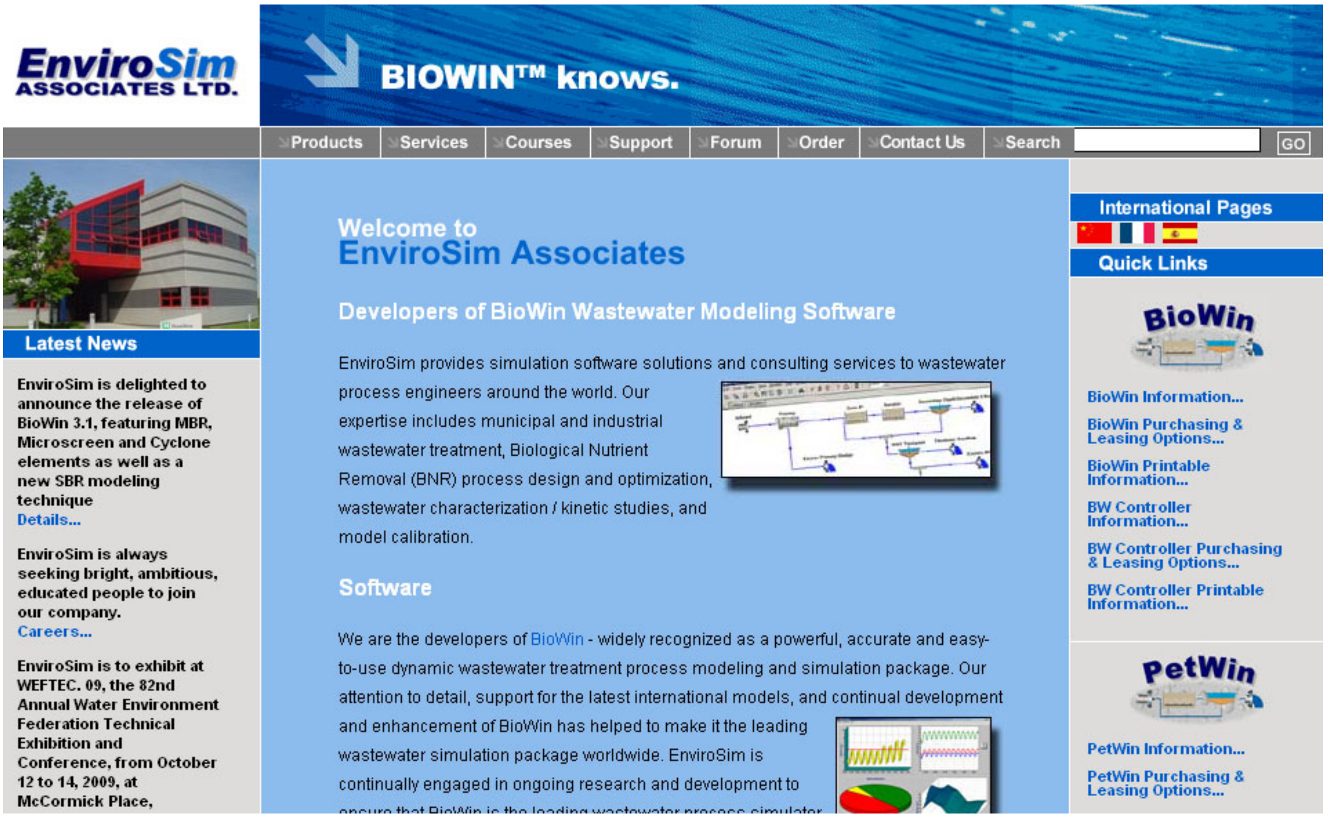
Key Features of EnviroPro Designer:

- Models for over 70 operations.
- Material and energy balances.
- Equipment sizing and costing.
- Thorough process economics.
- Rigorous VOC emission calculations from treatment plants.
- Chemical component fate prediction.
- Extensive chemical component and mixture database.
- Extensive equipment and resource databases.
- Waste stream characterization.
- Environmental impact assessment.
- Intuitive graphical user interface.
- Advanced hypertext help facility.
- OLE-2 support.
- PFD customization through addition of your own graphics and text.
- Compatibility with a variety of graphics, spreadsheet, and word processing packages.
- Option to export PFDs in DXF format (for incorporation into AutoCAD) and in WMF format.

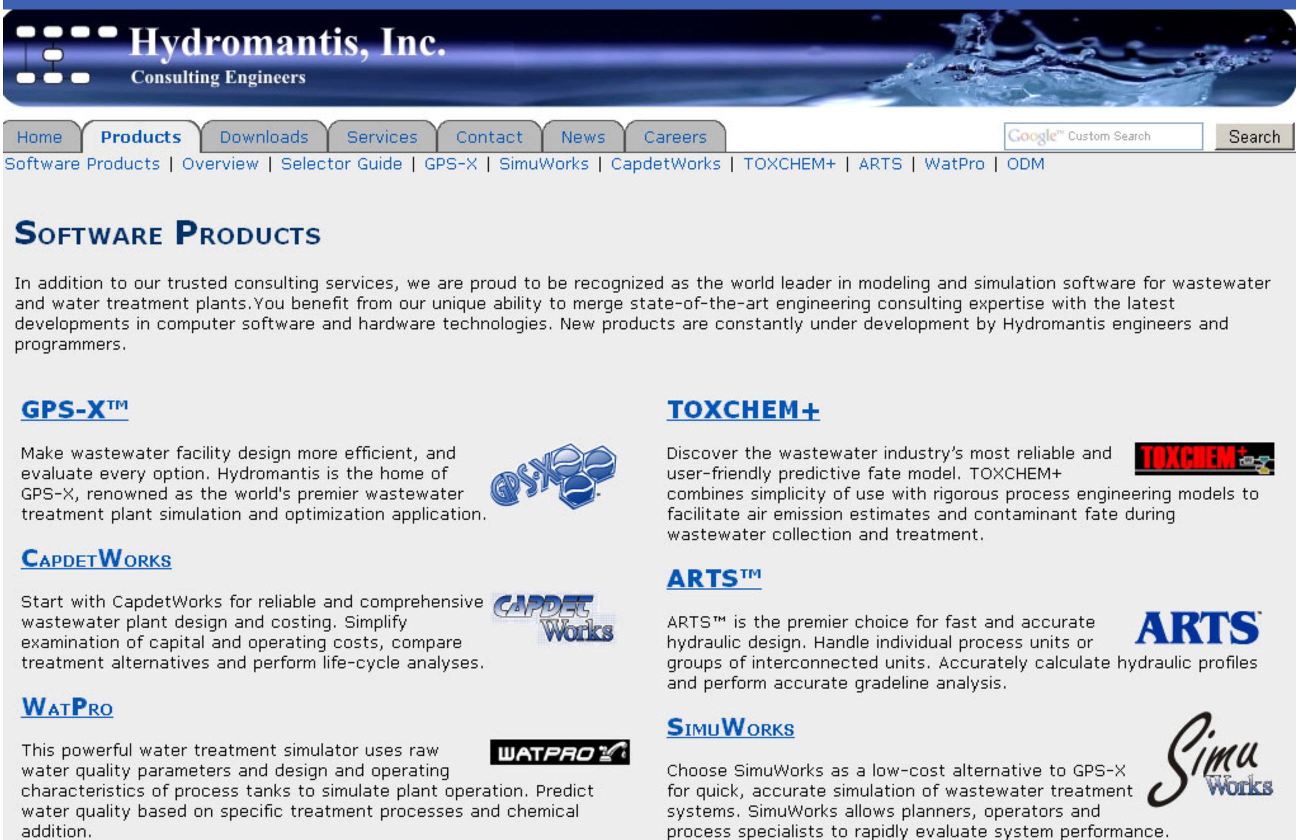
Unit Procedure Models in EnviroPro Designer

Reaction	**Solid/Liquid Separation**	**Pressure Change**
Aerobic BioOxidation	Decanter Centrifuge	Pumps
Plug Flow Aerobic	Hydrocyclone	Compressors
BioOxidation	Clarifier	Fan/Blower
Trickling Filtration	Thickener	
Anoxic Reaction	Flotation	**Drying**

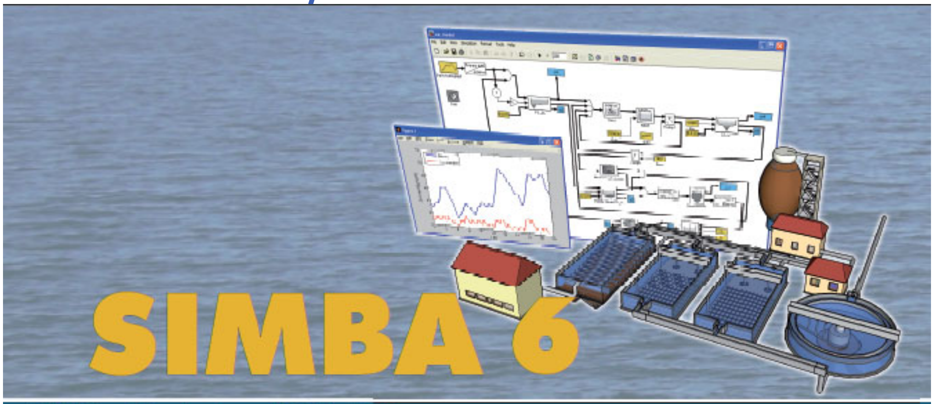
www.envirosim.com



hydromantis.com



simba.ifak.eu/simba



SIMBA - Simulation of biological wastewater systems

SIMBA is . . .

Magdeburg-Gerwisch WWTP, Photo: E. Neubert

... a dynamic simulation system for sewer systems, wastewater treatment plants (WWTPs), sludge treatment and receiving water bodies. It is easy to use, but at the same time SIMBA also has an ope structure and offers high flexibility. In engineering practice and in research, SIMBA provides support for:

- design of WWTPs, considering various treatment schemes including control
- optimisation of treatment processes and of operation of existing WWTPs
- analysis of urban wastewater discharges
- development and test of strategies for real time control of urban drainage systems
- analysis of interactions of run-off, wastewater treatment and receiving water quality

Practice in STOAT

Video tutorials:

https://www.dropbox.com/sh/54avgvr2dht8nii/AABKHbhhln LhEQEtWTcZ8drKa?dl=0

Questions to the developers (WRc):
https://www.linkedin.com/groups/3199352/

Norwegian University
of Life Sciences

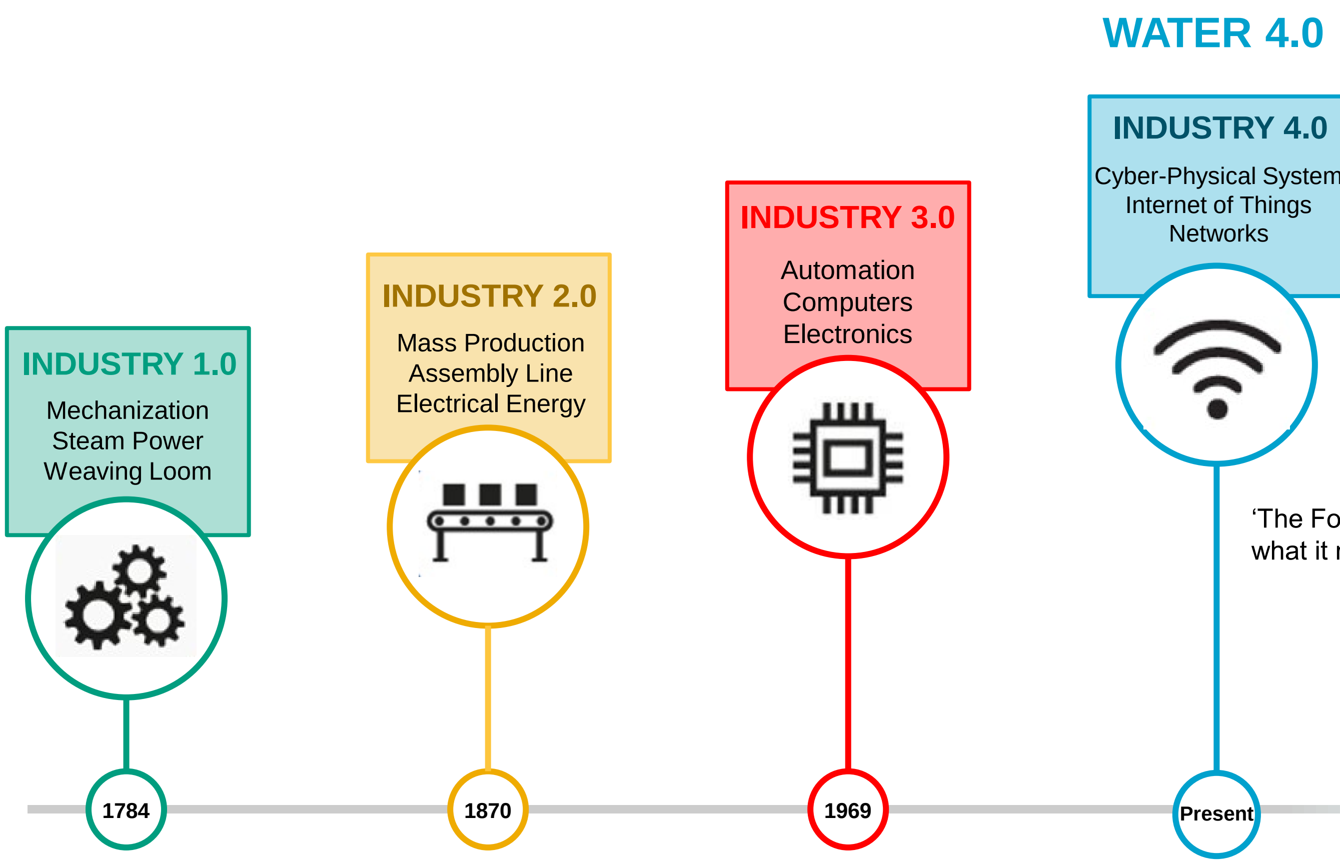
BIM AND DIGITAL TWIN

THT 311

Table of Contents

A SHORT HISTORY

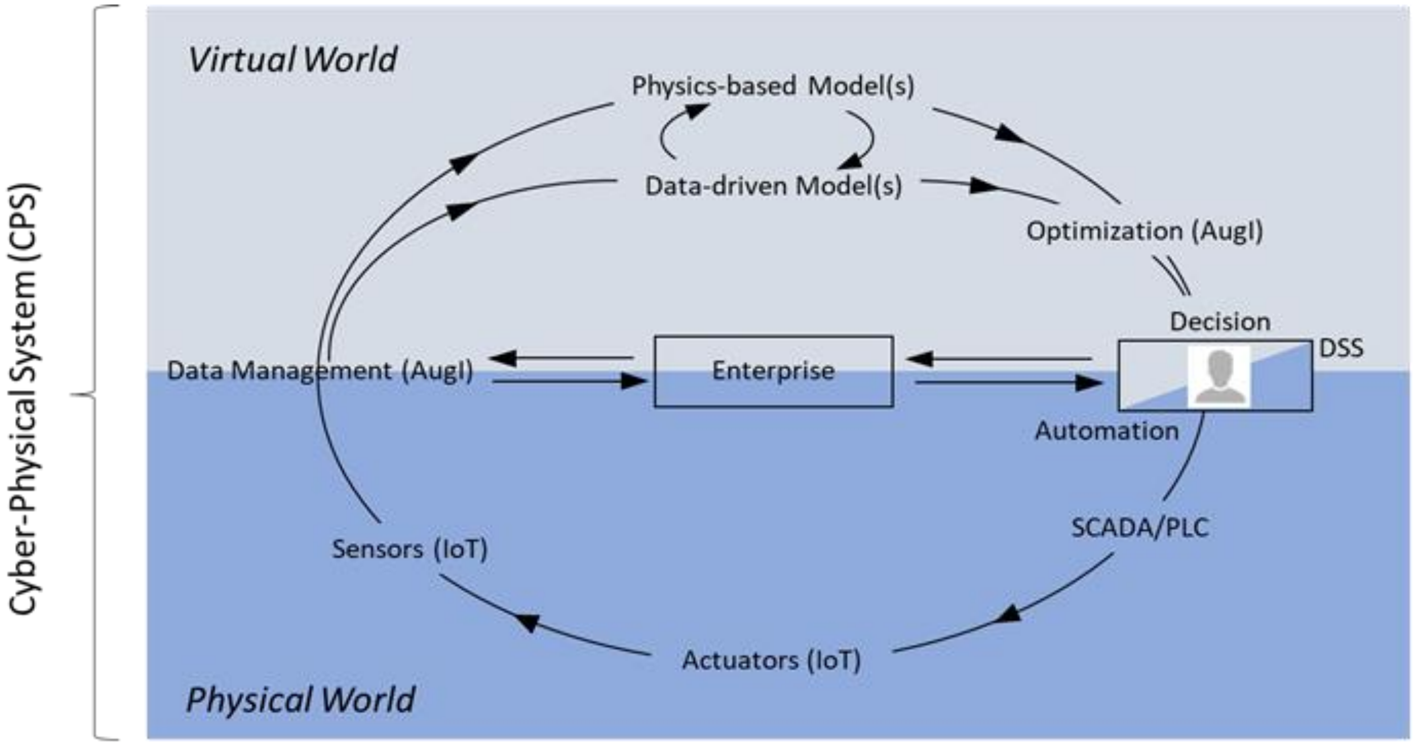
The Fourth Industrial Revolution



'The Fourth Industrial Revolution: what it means, how to respond'.

Klaus Schwab,
World Economic Forum

Cyber-Physical System



www.dhigroup.com/2019/06/06/the-digital-twin-what-is-it-and-how-can-it-benefit-the-water-sector/

Digital Twin was first conceptualized in 1991 by David Gelernter (Mirror Worlds)

Enabler for Digital Twin Technology

NMBU

Sensors

Online Monitoring and Process Surveillance

Online sensors are getting cheaper
Monitoring systems are ubiquitous
Most treatment facilities are automated

IIoT

Industrial Internet of Things

Increasing number of internet enabled devices
Interconnectivity between sensors, actuators, and controller hardware
Cloud computing ensures data and resource sharing

Big Data

Big Data and Artificial Intelligence

Increasing data storage capacity and remote accessibility
Advances in data analytics allowing huge amounts of data to be processed
Machine Learning algorithms for real-time model calibration and update

GUI

Graphical User Interface

Increasing sophistication of 3D visualization and computer-aided design (CAD)
Improved graphics processing for unprecedented realism in computer-operator interactions

WHAT IS A DIGITAL TWIN?

Definition of a Digital Twin

Virtual systems that 'contain all important characteristics and features of the real system', depending on the specific purpose for an application.

- Therrien *et al.* 2020

Digital Twin is a process model fed with real-time data to assist in decision support.

- Quaghebeur *et al.* 2020

***Digital Twin for a water utility is a combination of modeling software that utilizes data from multiple sources and usually across multiple departments and expertise*.**

- SWAN Smart Water Report

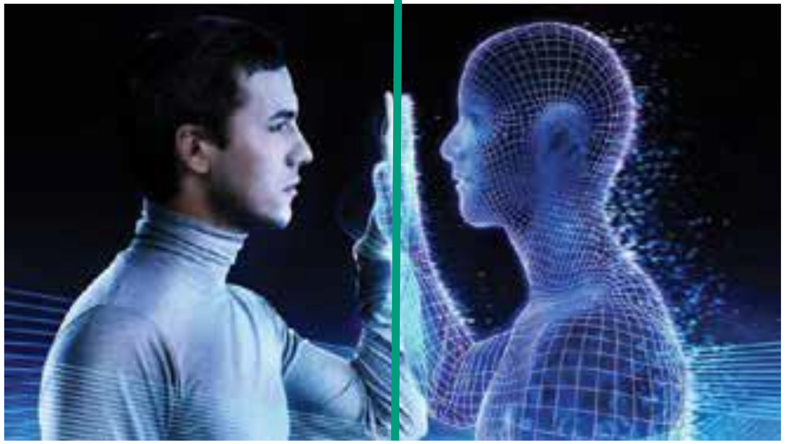
Digital twin is a virtual representation of a physical asset, process, or system.

ORIGINAL | DIGITAL TWIN

Physical Entity

Systems

Process



Model

Algorithms

Analytics

GUI

Photo: CSI Communications

HOW IS IT DIFFERENT FROM PROCESS SIMULATORS?

Process Simulators

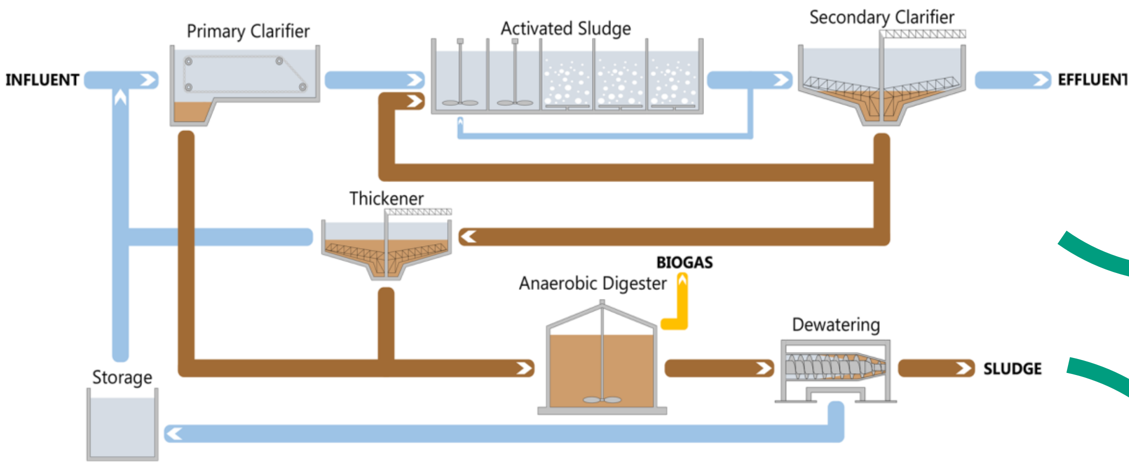


Fig 1. Process flow diagram of a WWTP (Solon *et al.* 2017)

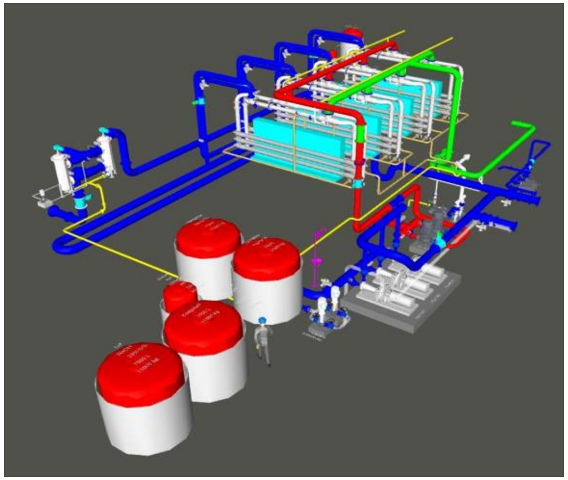


Fig 3. Building Information Model (BIM)

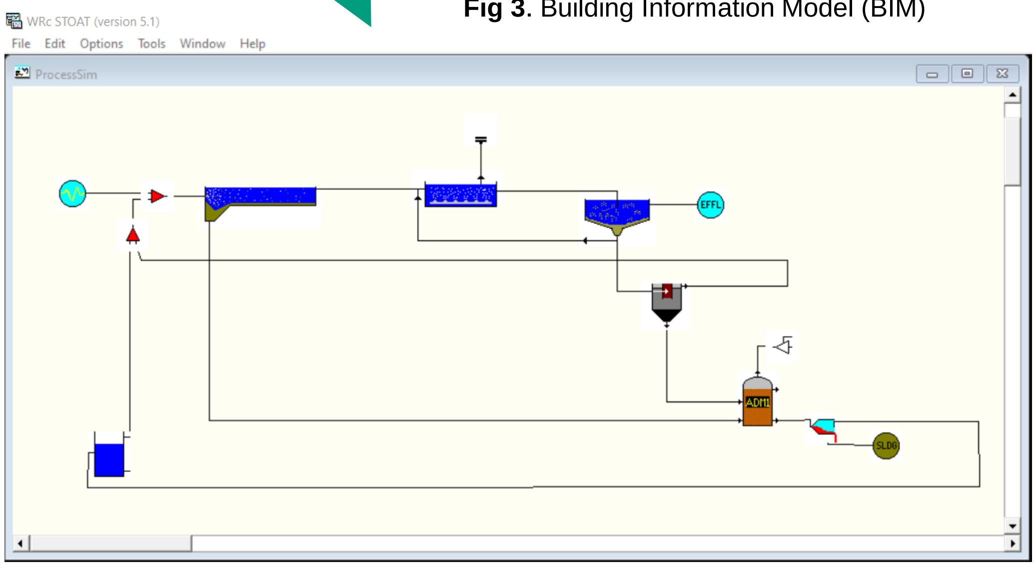
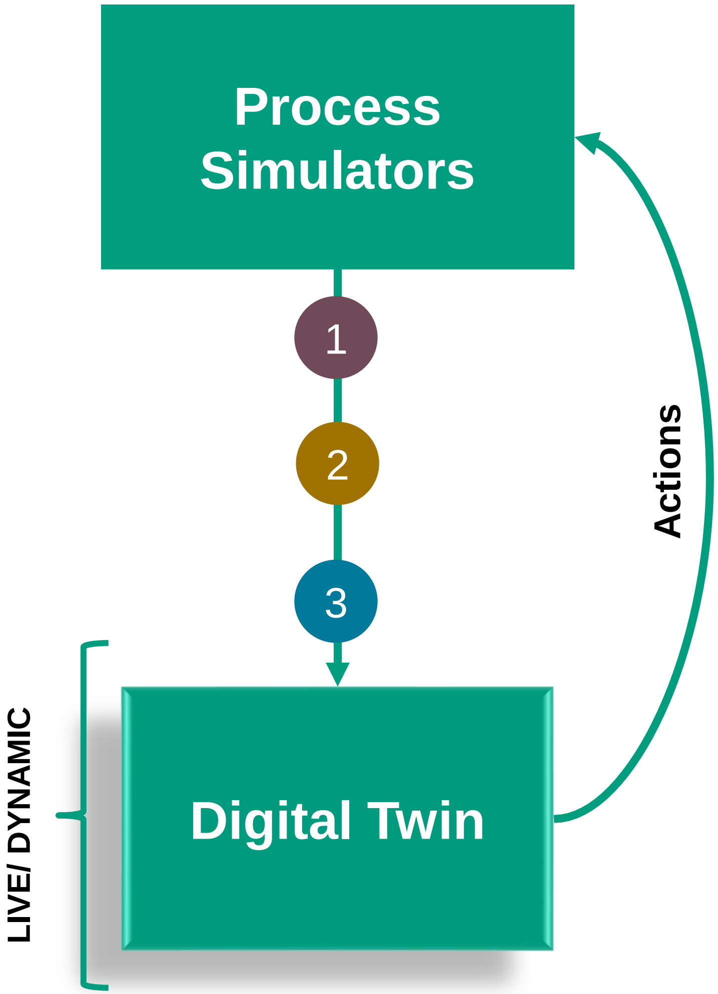


Fig 2. Process simulator of designed in STOAT 5.1

From Process Simulators to Digital Twins



Constructing a Digital Twin

The following stages are to be followed to build a digital twin from a Process Simulator.

1 **Data Acquisition**
Collecting data from online sensors, actuators, frequency drives, valve positioners, and edge devices.

2 **Data Pre-processing**
Cleaning raw data, removing outliers, and normalizing data before model calibration.

3 **Model Calibration**
Fitting plant data to mathematical model.

WHAT CONSTITUES A DIGITAL TWIN?

Components of a Digital Twin

DIGITAL TWIN

1. **Data Integration**

   Processing the incoming data, removing outliers and maintaining a database

2. **Models**

   Mathematical expression that can describe the responses and behavior of the process.

3. **Analytics and Model Update**

   Algorithms to adapt the model to the latest conditions.

4. **Visualization**

   Representing the system or the physical asset in an understandable form.

Components of a Digital Twin

1 **Data Integration**

2 Models

3 Analytics and Model Update

4 Visualization

and Pre-processing

- **Remove Outliers**
- **Normalization /Data scaling**
- **Transformation**

Data Management

- **MSSQL, MySQL, PostgreSQL, ..**
- **Azure, AWS, Alicloud, ..**
- **Data exchange (server ←→ client)**

Components of a Digital Twin

1 Data Integration

2 **Models**

3 Analytics and Model Update

4 Visualization

Process Model

- Mechanistic/ Physical/ White box Models
- Data Driven/ Black box
- Hybrid

Asset Model

- 3-D CAD Models
- Geological Information Systems (GIS) Model
- Building Information Model (BIM)

Performance Model

- Benchmarks and metrics
- Enterprise Resource Planning (ERP)
- Maintenance scheduling

Components of a Digital Twin

1 Data Integration

2 Process Models

3 Analytics and Model Update

4 Visualization

Conventional Techniques

- **Recursive parameter estimators**
- **Kalman Filters**
- **Optimization-based approach (Moving Horizon Estimation)**

Machine Learning

- **Supervised Learning**
- **Unsupervised Learning**
- **Deep Learning**

Components of a Digital Twin

1 Data Integration

2 Process Models

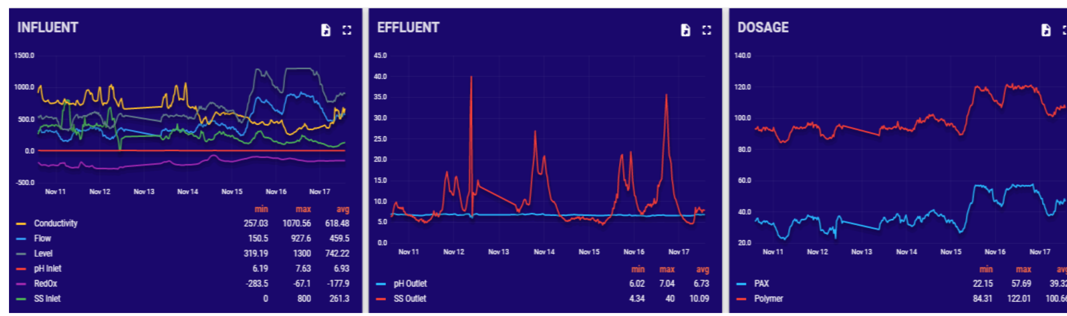
3 Analytics and Model Update

4 Visualization

Dashboard Widgets

www.thingsboard.doscon.no

Trend Curves



www.thingsboard.doscon.no

Virtual Reality

www.stambol.com

www.esri.com

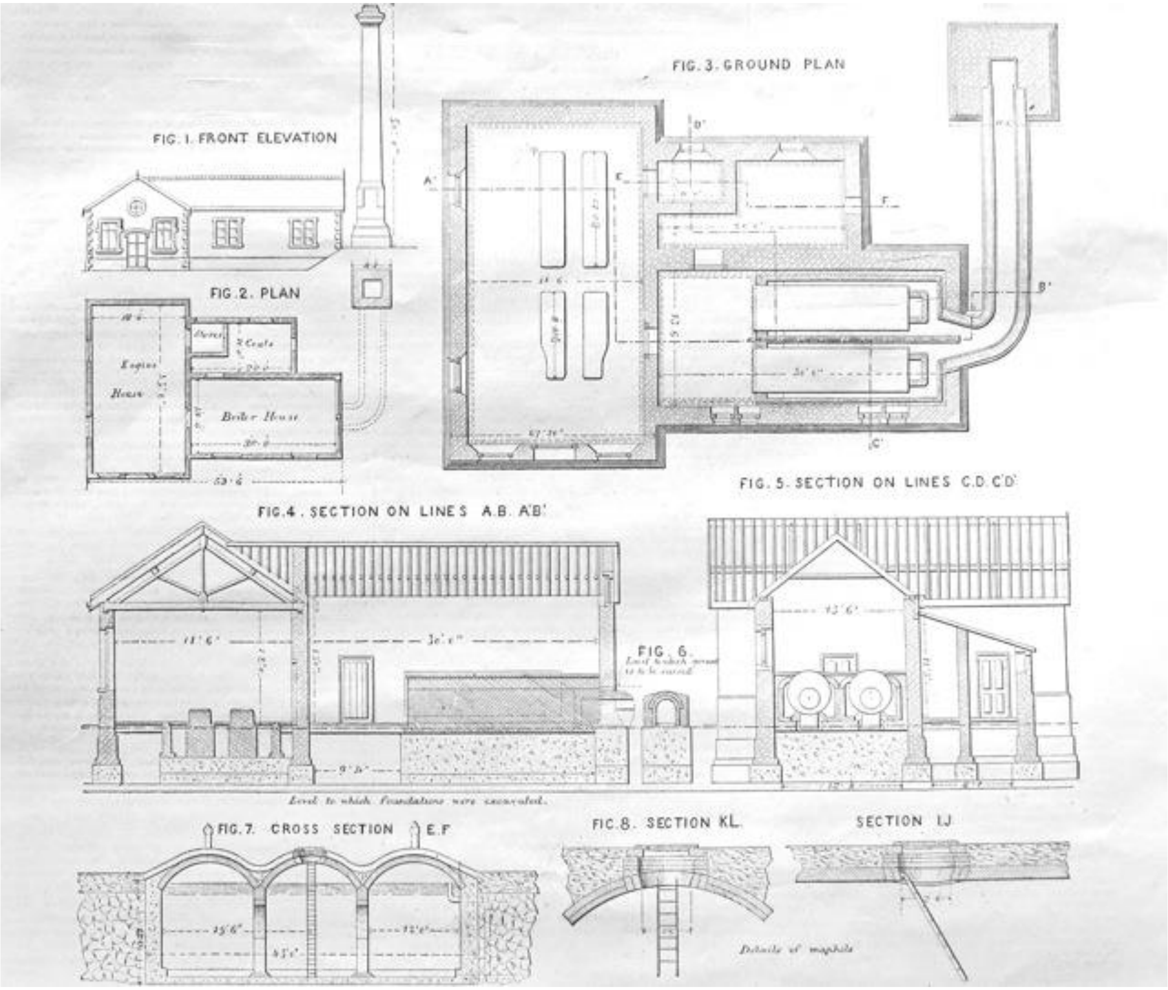
FEATURES AND UTILITY OF DIGITAL TWINS IN WATER OPERATIONS

Utility of Digital Twin in Water Sector

- Design and construction of Treatment Plants
- Operator Training Simulators
- Predictive analysis and maintenance
- Virtual/ Software sensors.
- What-if scenarios and analysis.
- Early warning systems

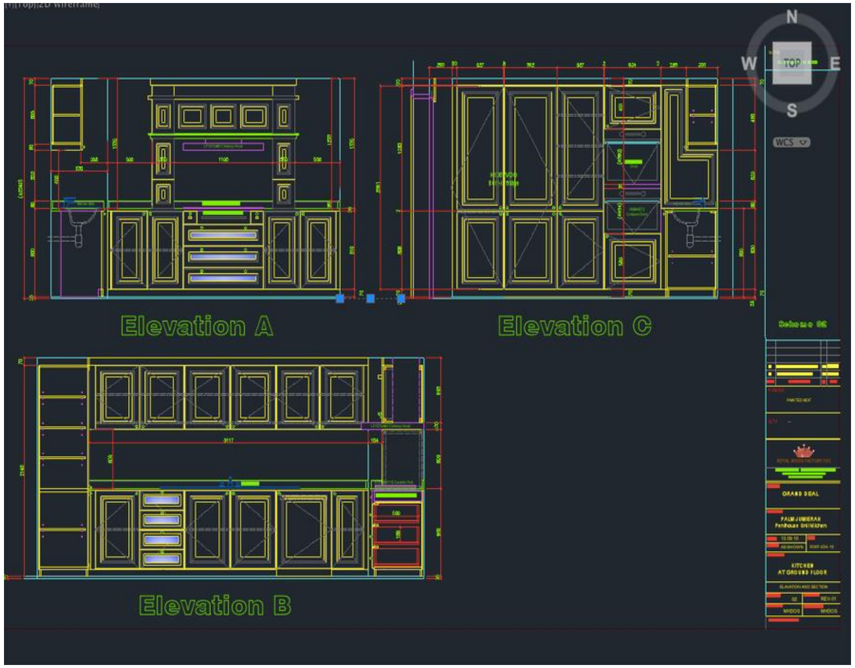
BUILDING INFORMATION MODEL

Evolution of BIM – (Before 1960)

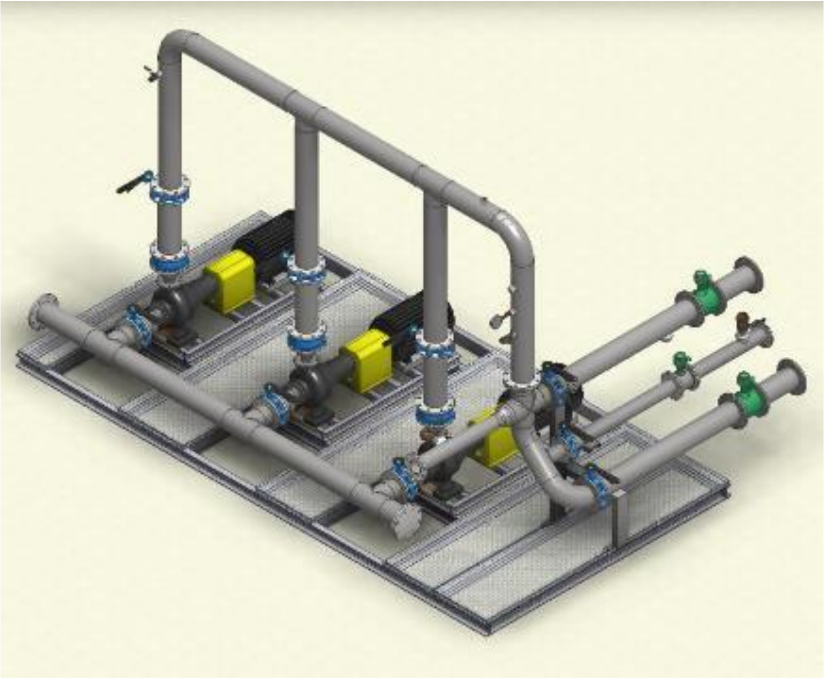


- Floor plans
- Graphical Projections
- 2-Dimensional
- Hand drawn
- Draftswoman/draftsmen

Evolution of BIM - (C.A.D)

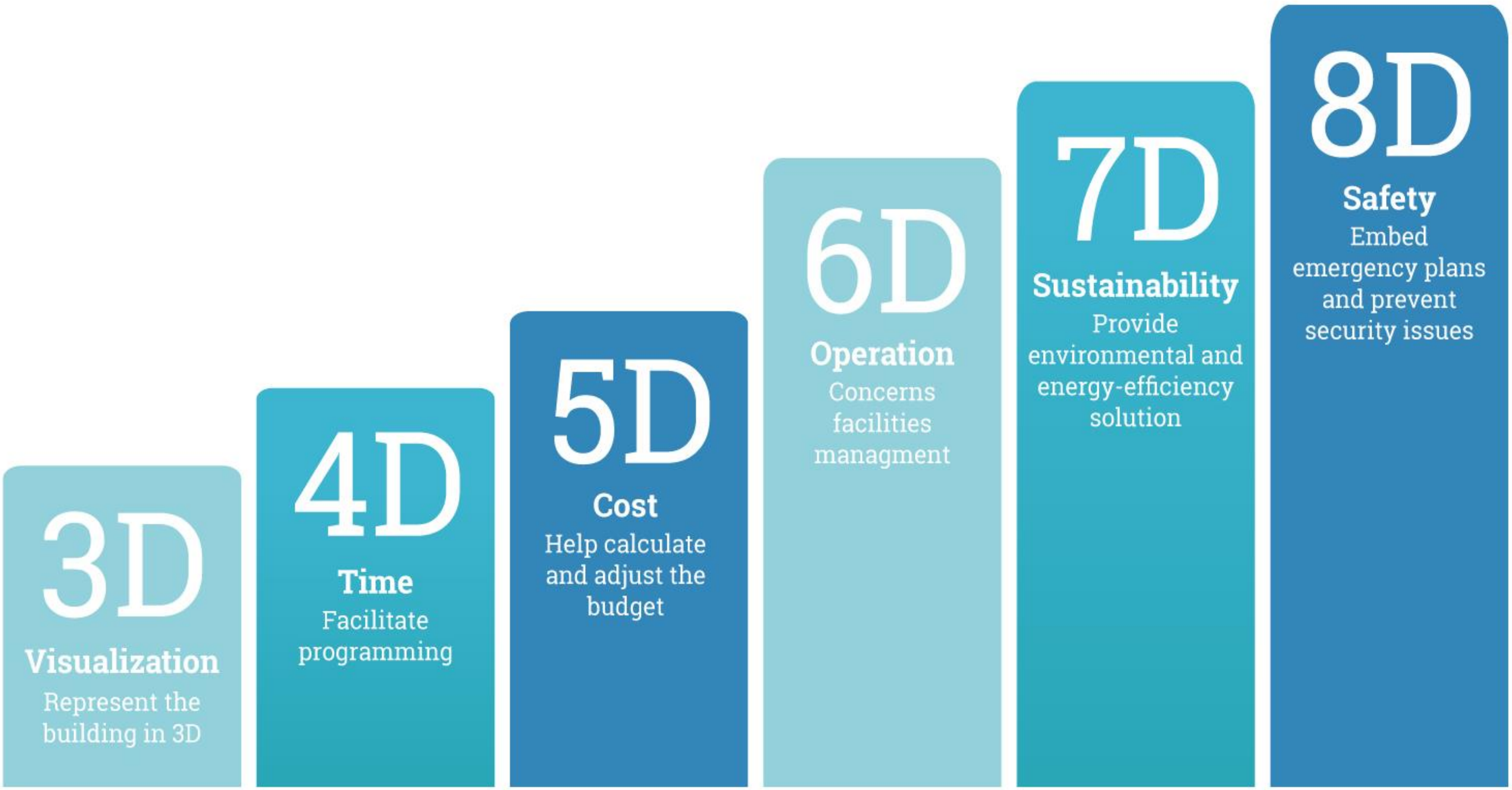


2-Dimensional Layout generated by Computed Aided Design (CAD) software.



3-Dimensional CAD models.

Evolution of BIM – The age of DT



Source: https://github.com/255ribeiro/simulacao

BIM Software

CASE STUDIES

Case Study I

OPERATOR TRAINING SIMULATOR (OTS)

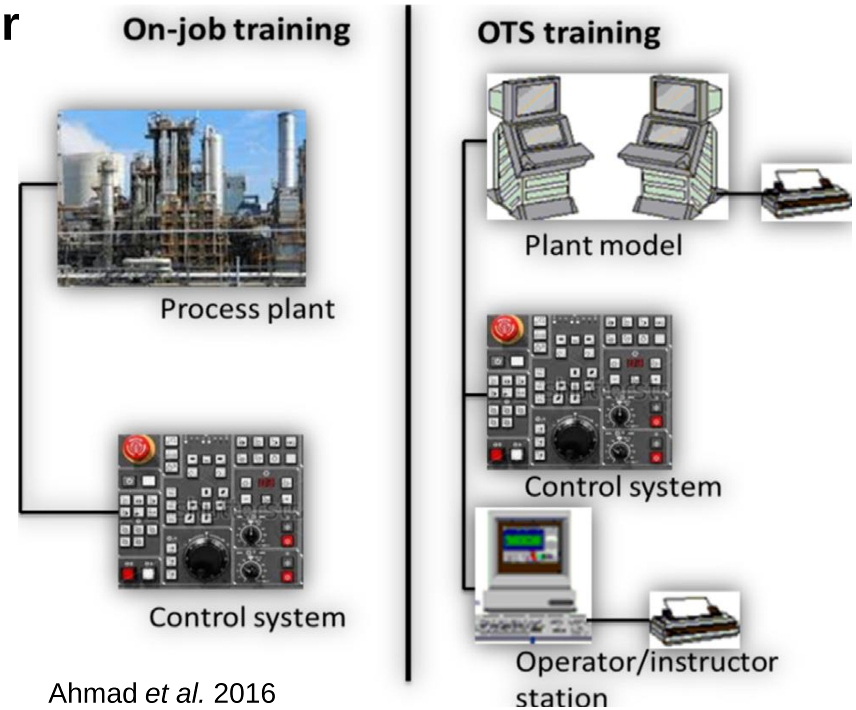
What is an OTS?

“Operator Training System (OTS) provides a virtual plant on your computer, allowing plant operators to train in plant operations ahead of plant start-up and throughout plant lifecycle.”

- Yokogawa OTS

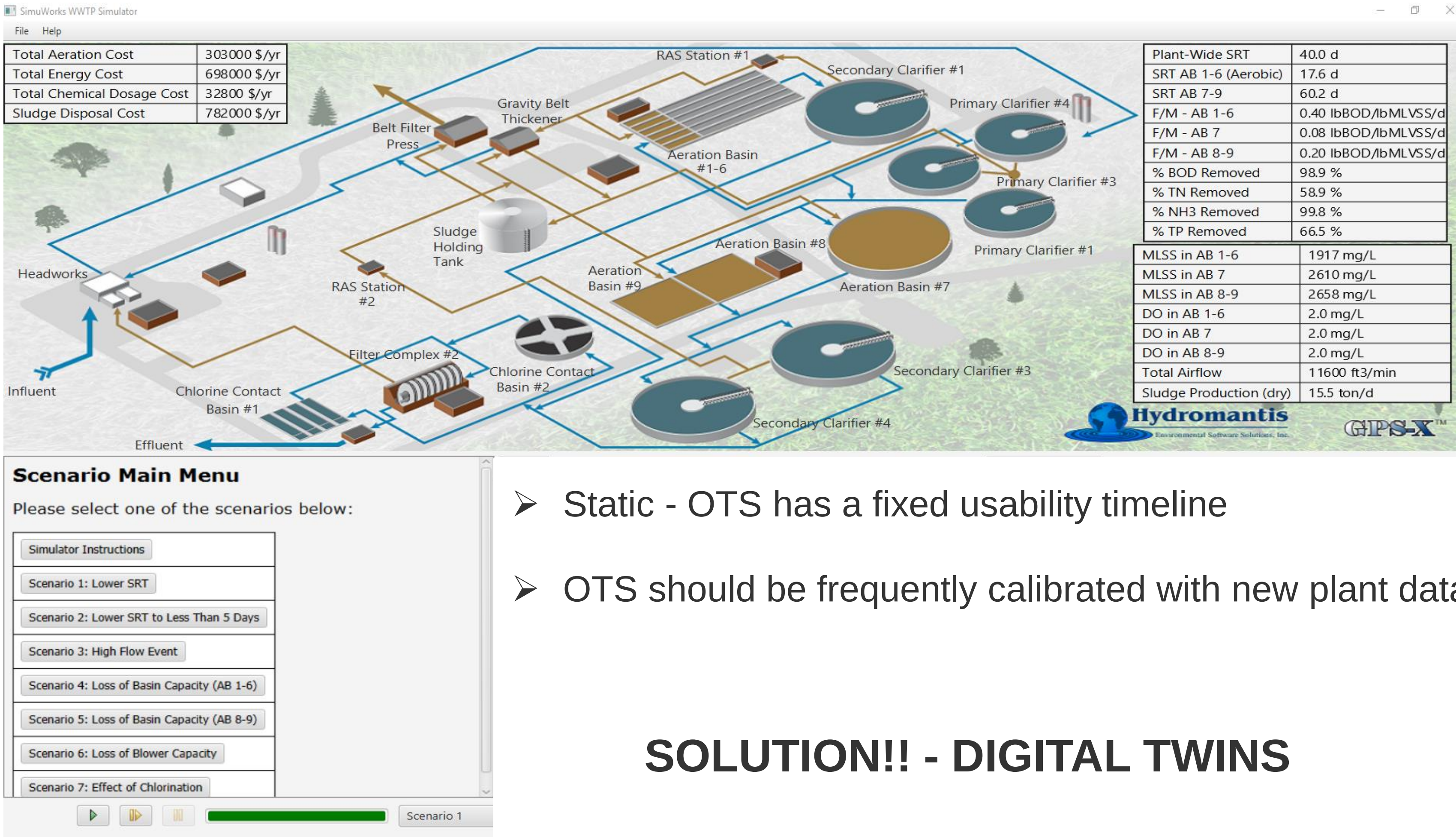
Process Simulator + Scenario Manager

- Simulating startup and shutdown
- Simulating equipment malfunctions
- Simulating external disturbances
- Simulating responses to control actions
- Provide performance scores



Ahmad *et al.* 2016

SimuWorks OTS Scenario Manager



- Static - OTS has a fixed usability timeline
- OTS should be frequently calibrated with new plant data

SOLUTION!! - DIGITAL TWINS

www.hydromantis.com/SimuWorks-customize.html#lookandfeel

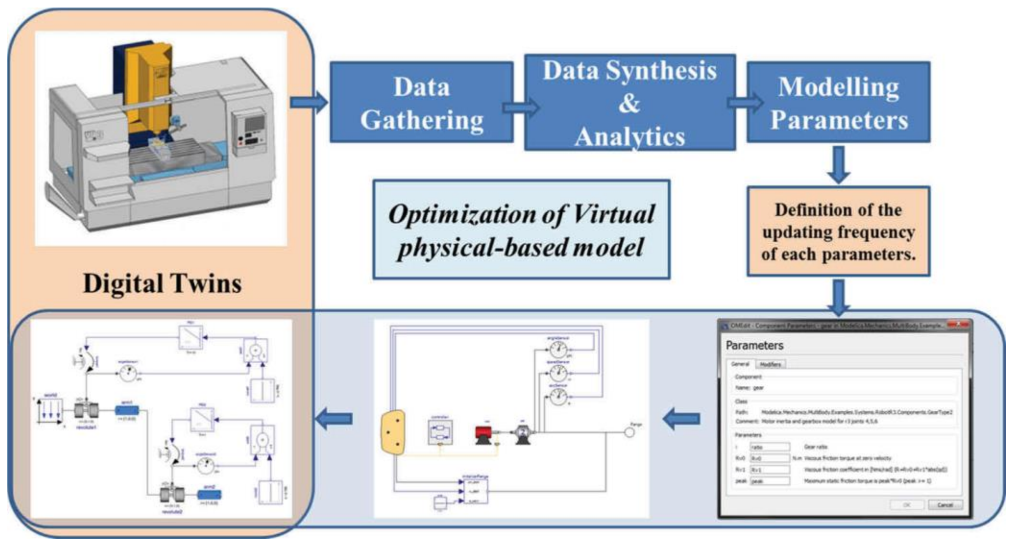
Case Study II

PREDICTIVE MAINTENANCE OF EQUIPEMNTS

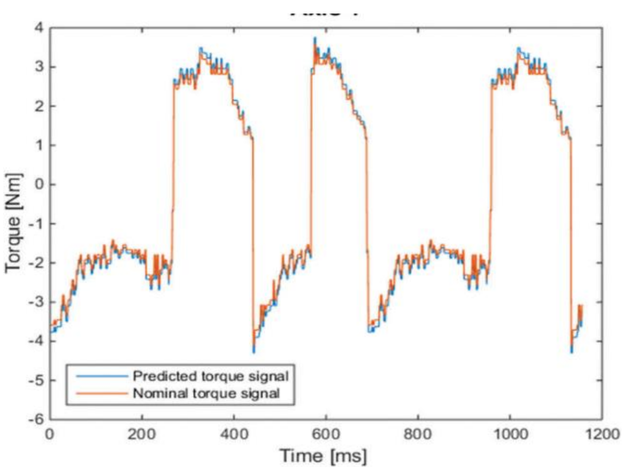
Pump Features and Digital Twin

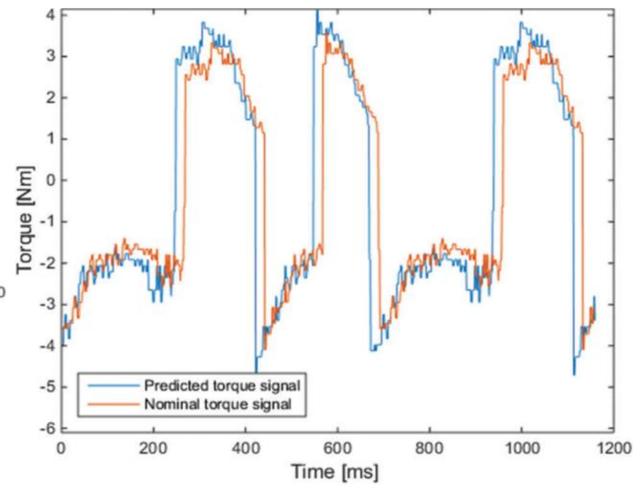
Aivaliotis *et al.* 2019

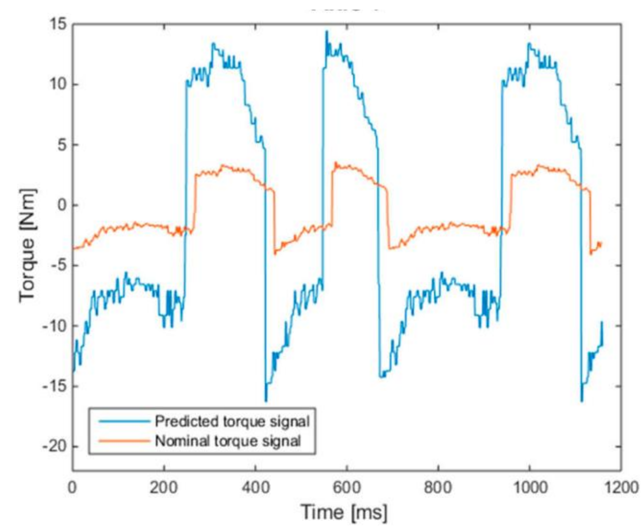
- Pumps and compressors are widely used in WWTP.
- Equipment with moving parts have an operating life.



Remaining Useful Life (RUL)

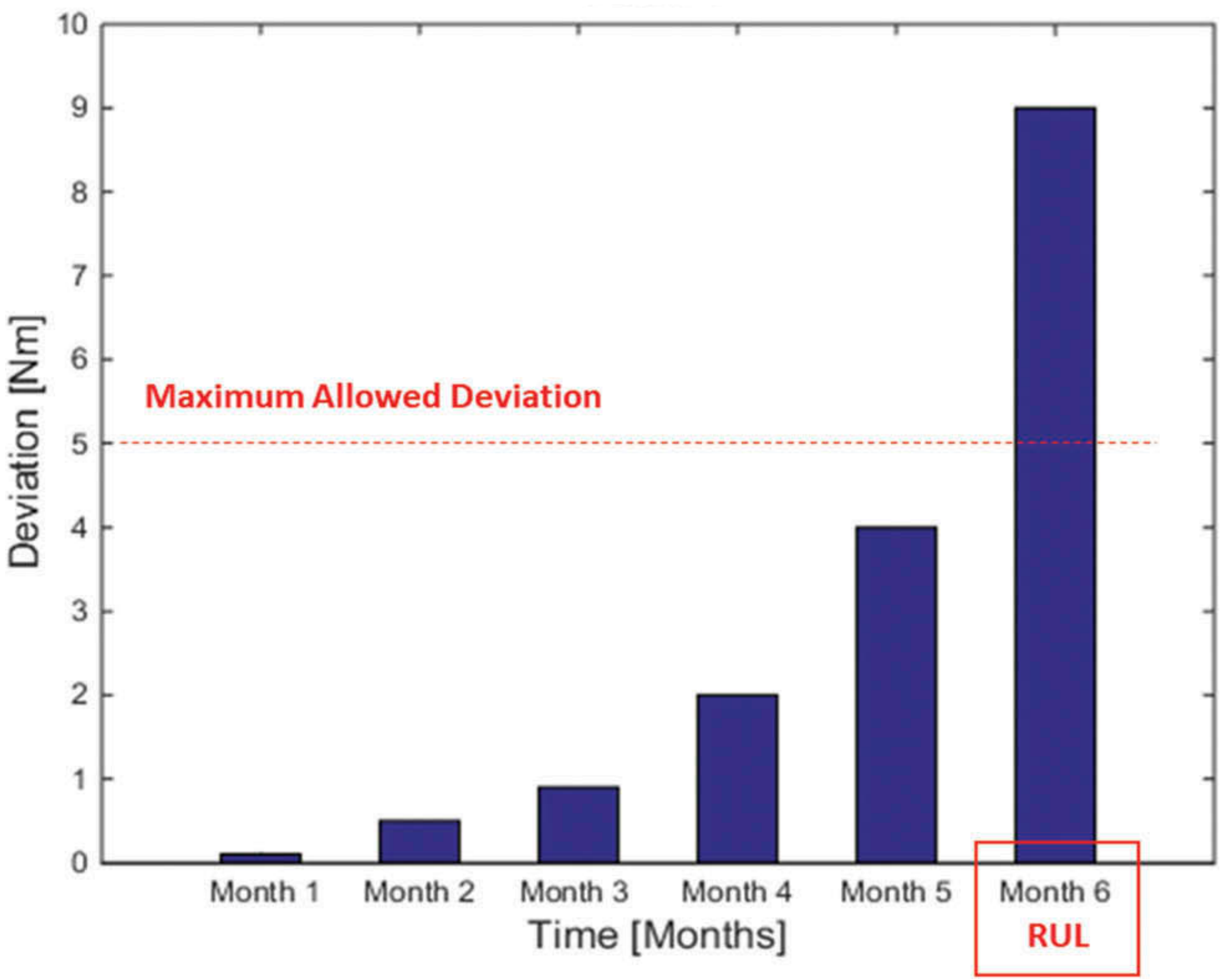






1 month **4 months** **6 months**

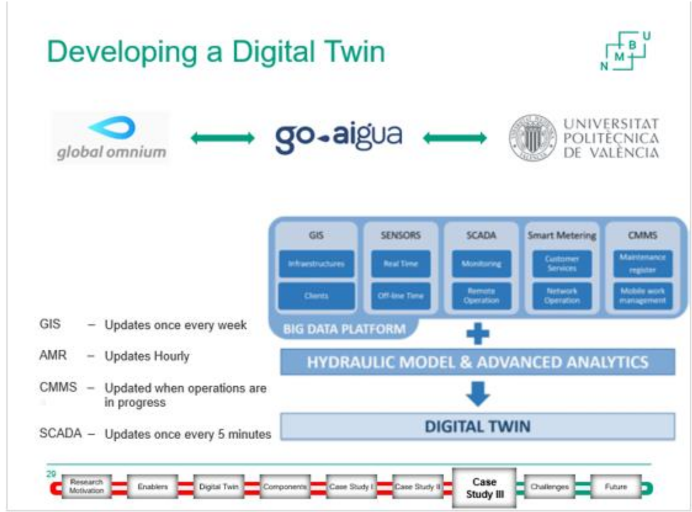
Remaining Useful Life (RUL)

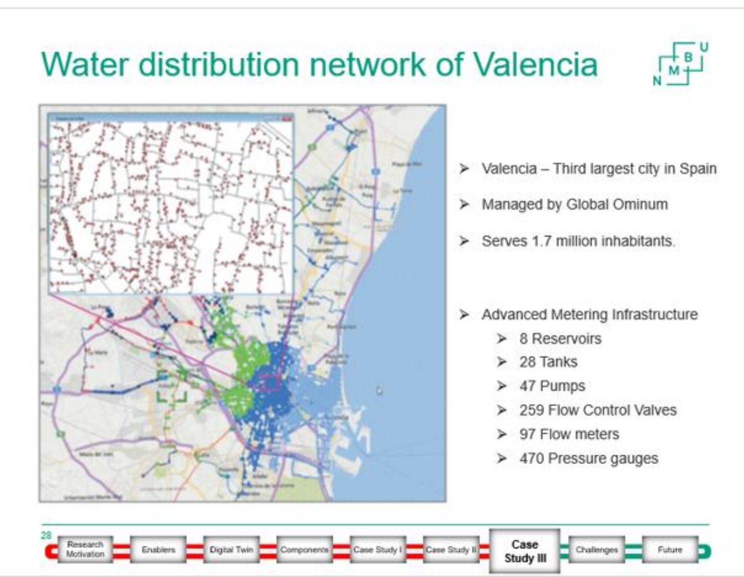


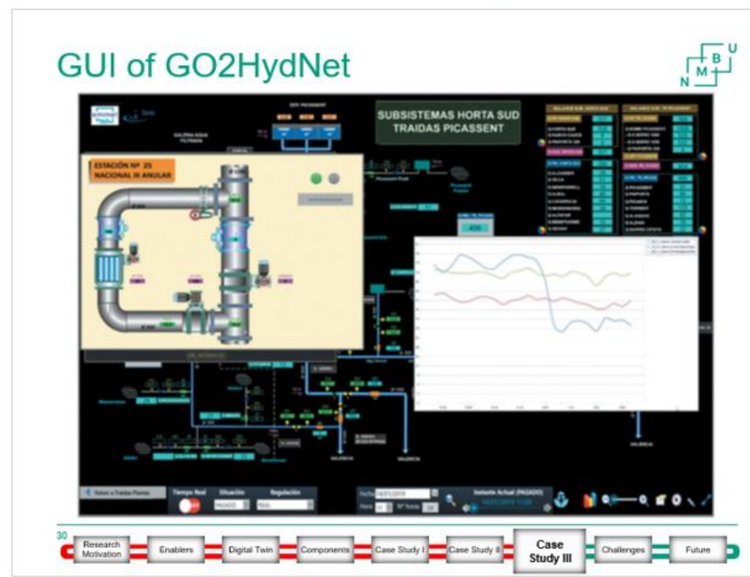
Case Study III

WATER DISTRIBUTION NEWTORK

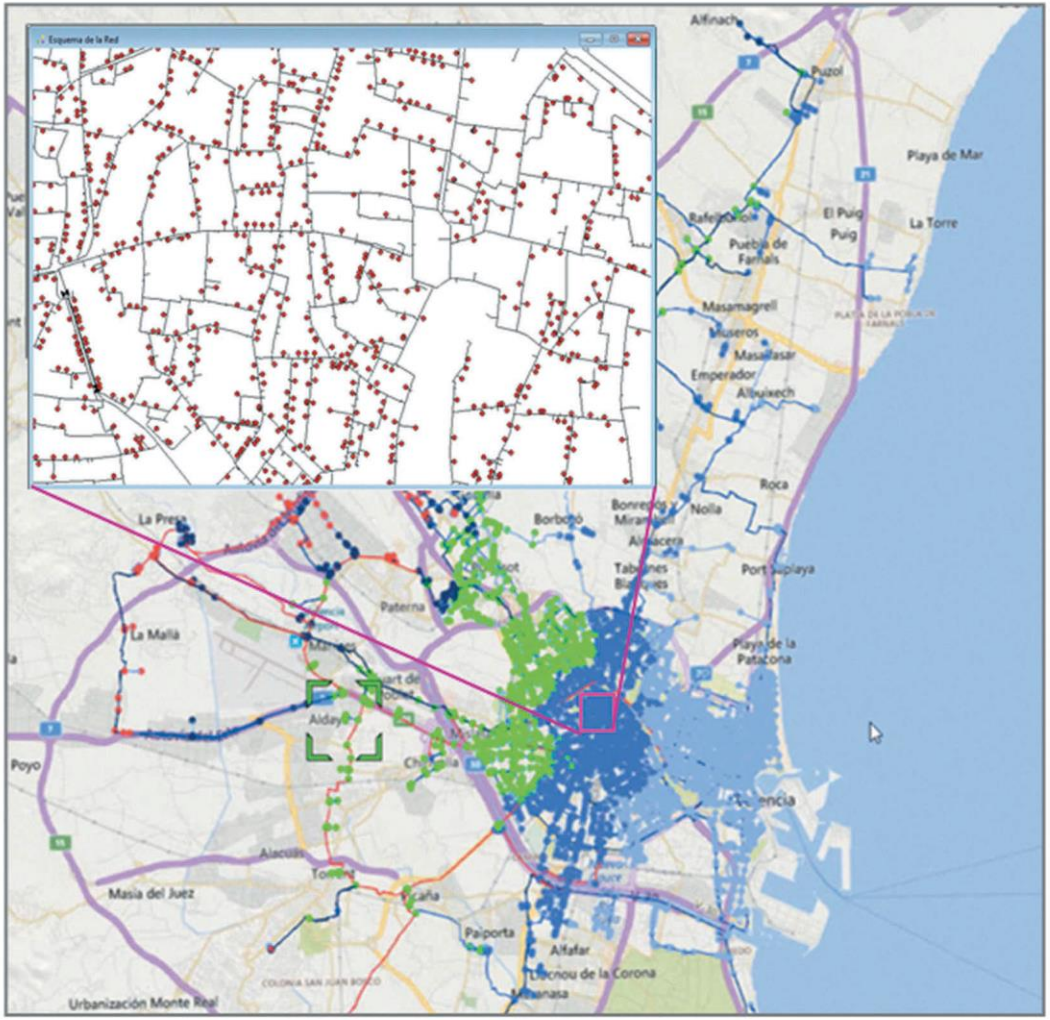
Water Distribution Network







Water distribution network of Valencia

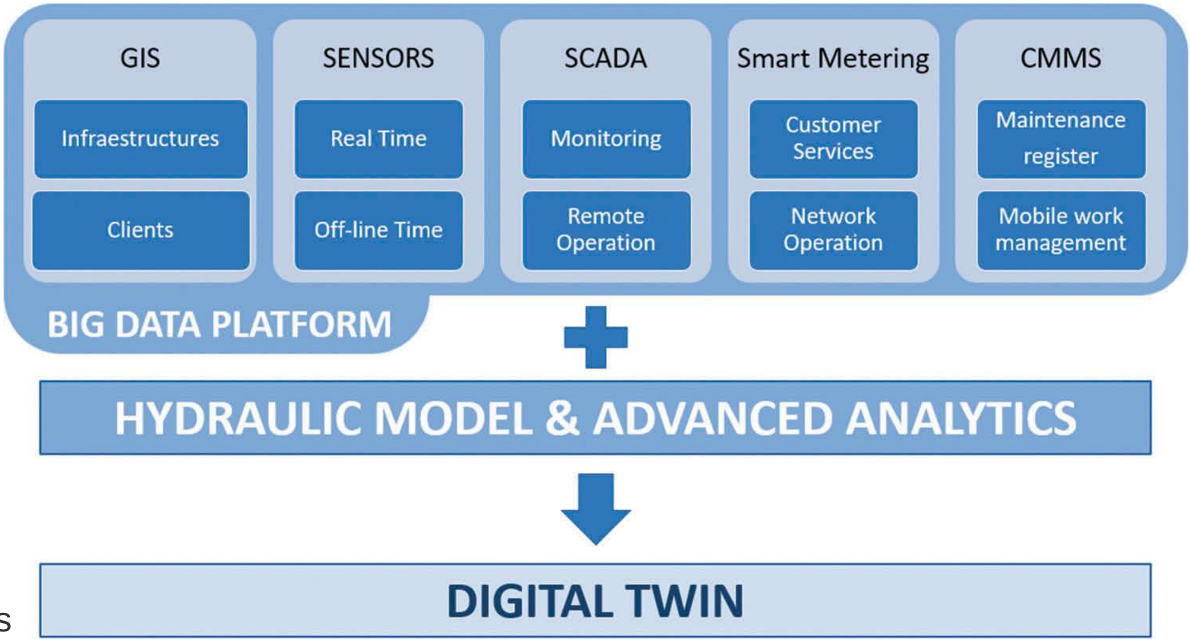


- Valencia – Third largest city in Spain
- Managed by Global Ominum
- Serves 1.7 million inhabitants.

- Advanced Metering Infrastructure
  - 8 Reservoirs
  - 28 Tanks
  - 47 Pumps
  - 259 Flow Control Valves
  - 97 Flow meters
  - 470 Pressure gauges

Developing a Digital Twin

global omnium ⟷ go-aigua ⟷ UNIVERSITAT POLITÈCNICA DE VALÈNCIA



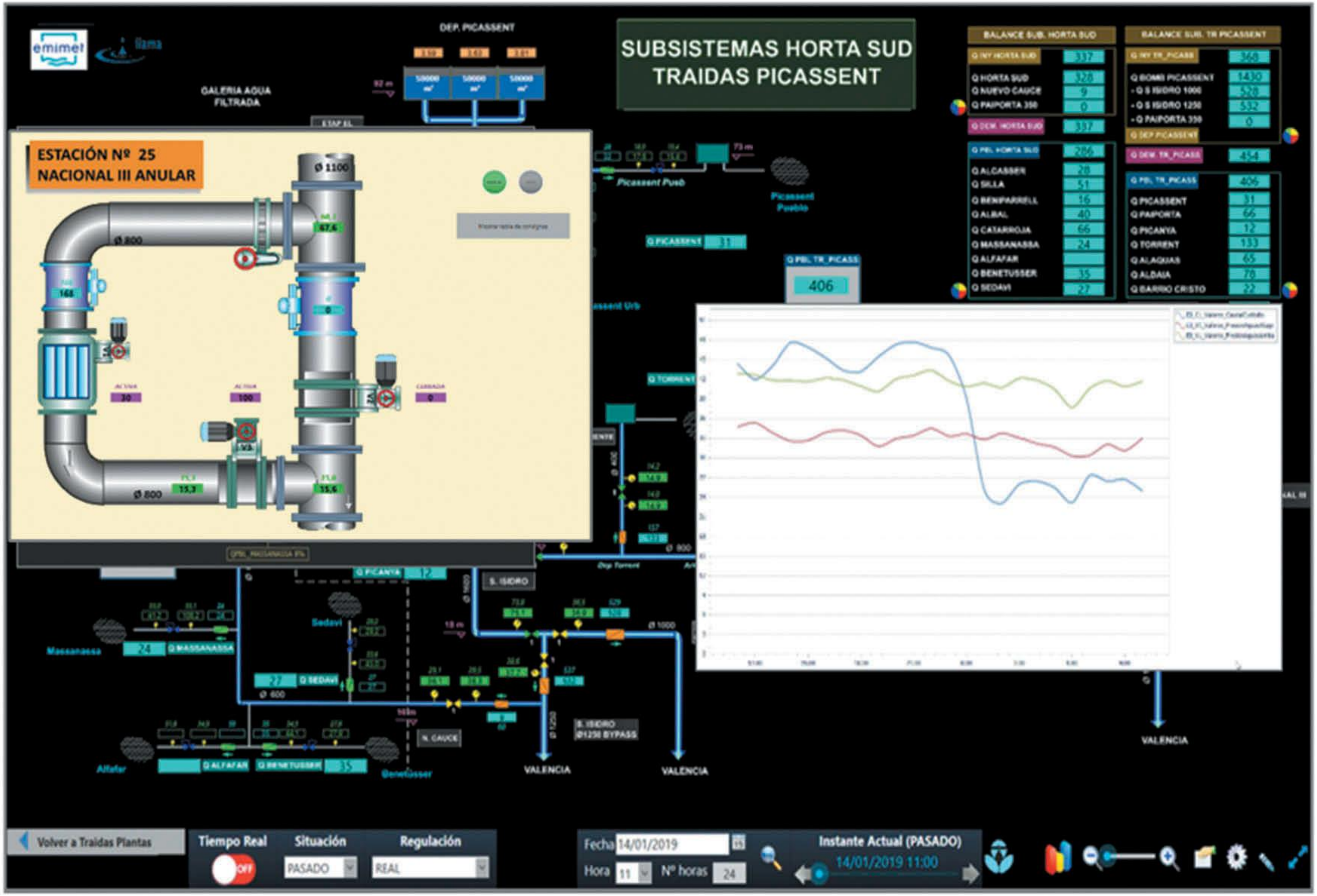
GIS – Updates once every week

AMR – Updates Hourly

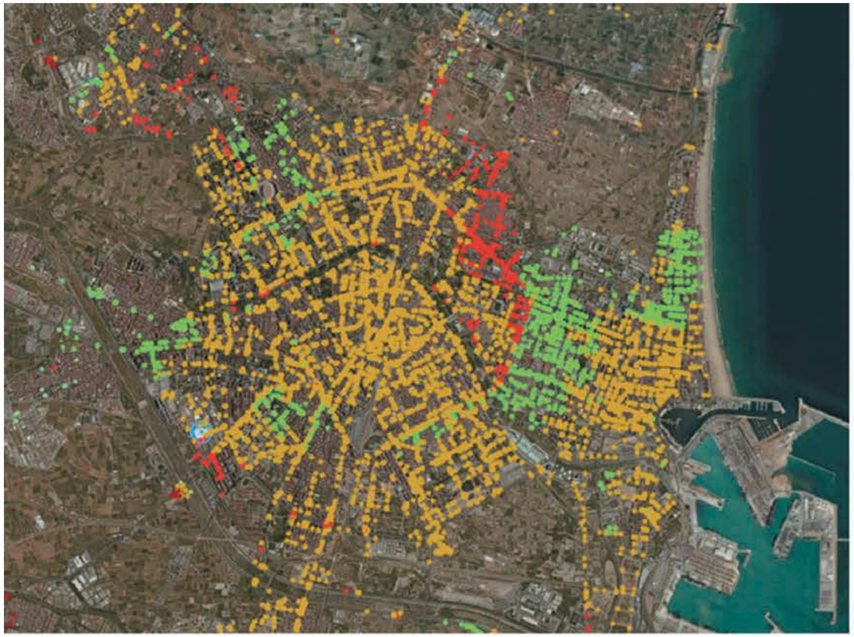
CMMS – Updated when operations are in progress

SCADA – Updates once every 5 minutes

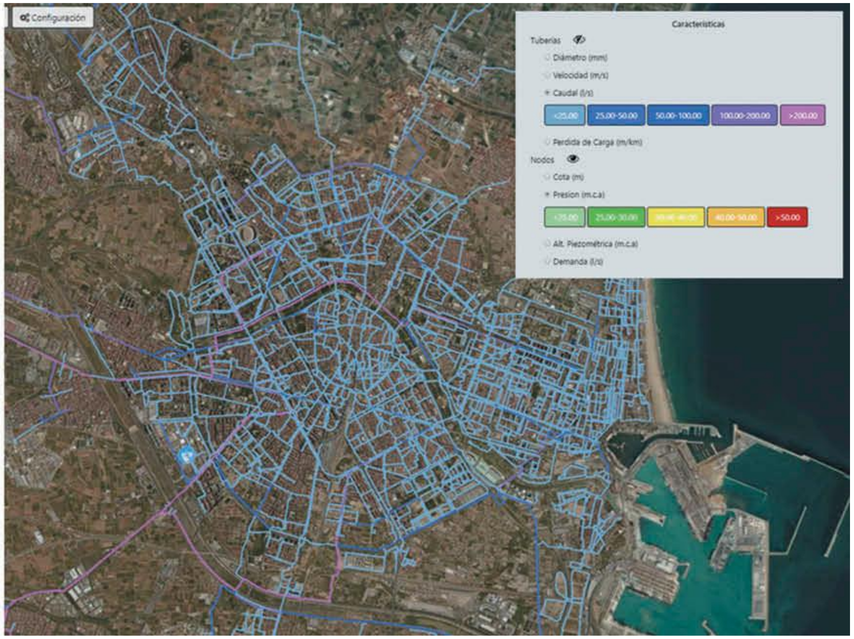
GUI of GO2HydNet



Virtual Sensors



500 pressure and flow sensors installed in the water distribution network.



Pressure and flow measurement for 10000 nodes

pressure sensors
flow sensors

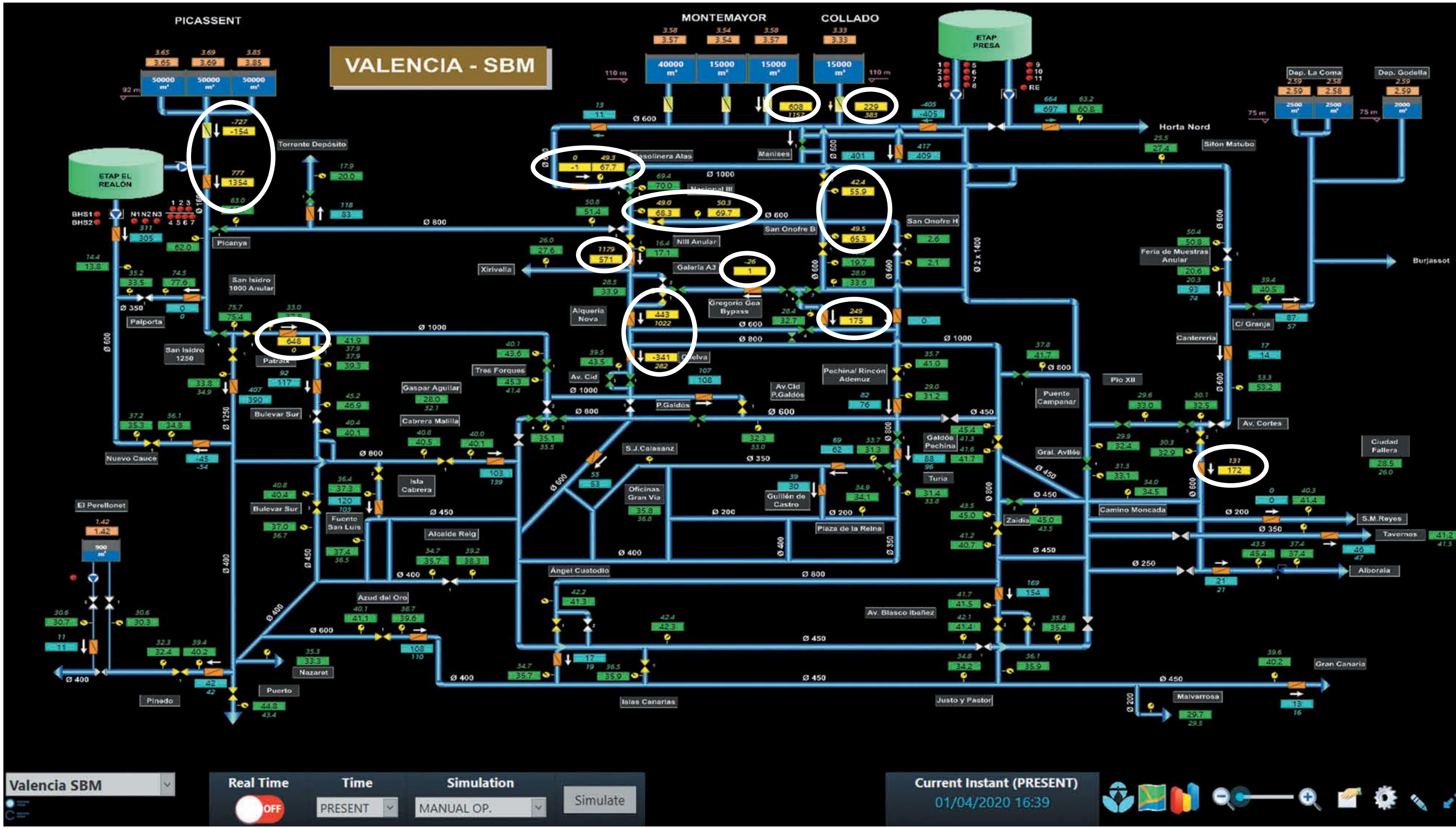
→

Hydraulic Model
+
Analytics

→

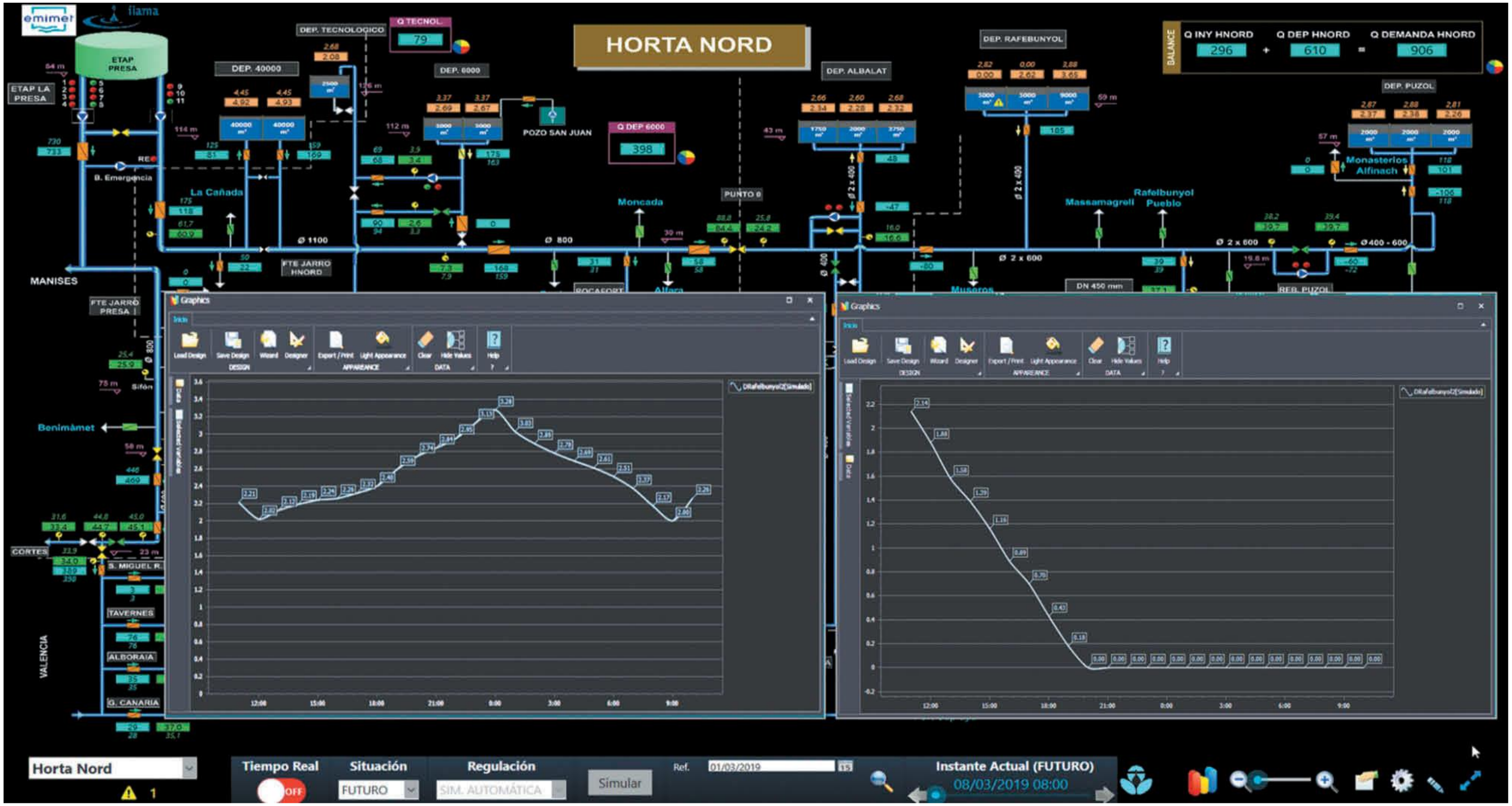
Pressure and flow in the entire network (10000 nodes)

Predicting Pipe Failure



Predicting pipe failure in real time. The yellow boxes represent the area of the network with higher probably of failure.

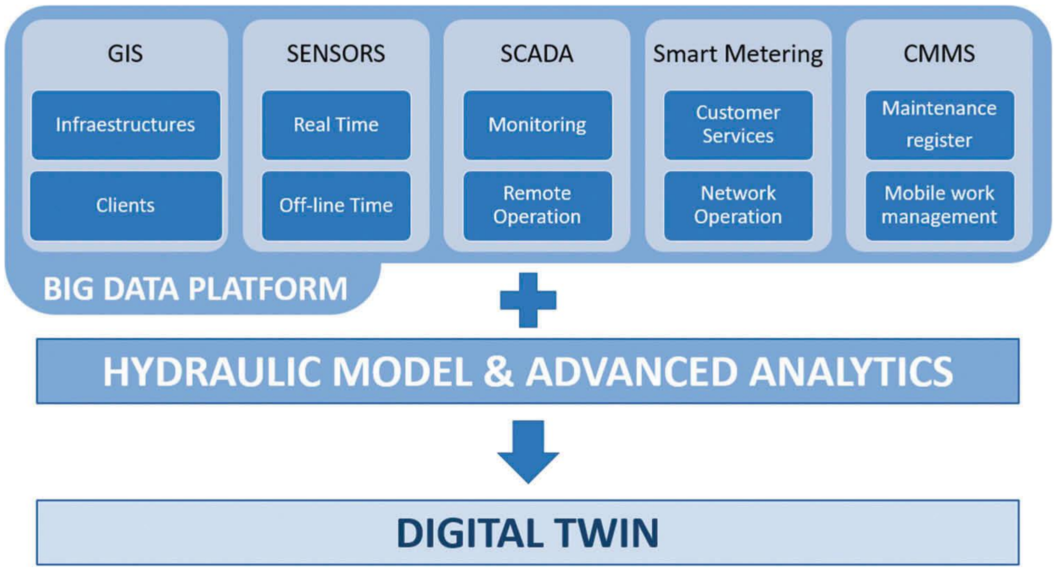
Maintenance Scheduling



Forecasted tank level evolution for a near future in normal conditions (right).

Programmed maintenance stoppage at a treatment plant (e.g. tank emptying during tank cleaning)

Digital Twin – Achievements



40 %

network efficiency

1 billion gal/ year

water saved

2,500/ month

leaks detected

15%

energy savings

20%

OpEx reduction

CHALLENGES

Challenges

System Integrability

Multiple stakeholders and service providers

Lack of standardization

Human Factor

Expectations from Digital Twins

Inadequate training in the use of Digital Twins

Usefulness of Data

Data rich does not imply information rich

Sophisticated data pre-processing approach is needed

Cyber security

Vulnerability of internet-enabled devices

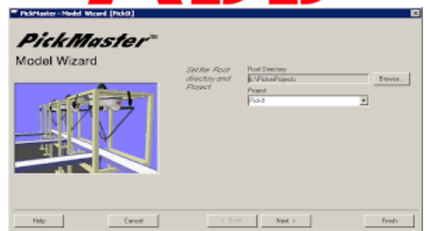
Firewalls and data-encryption is necessary

FUTURE OF DIGITAL TWINS

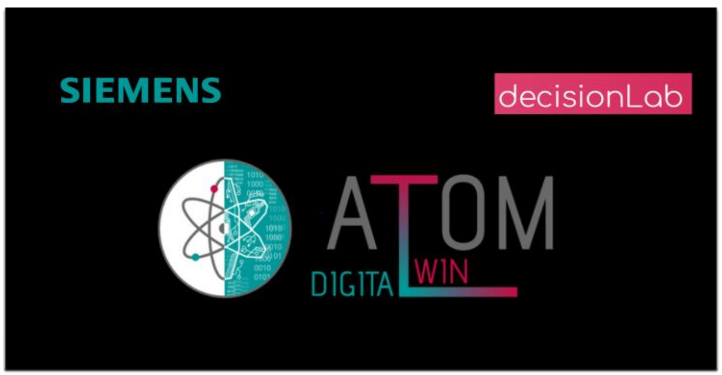
Examples of Commercial Digital Twins

EMERSON

ABB



KONGSBERG



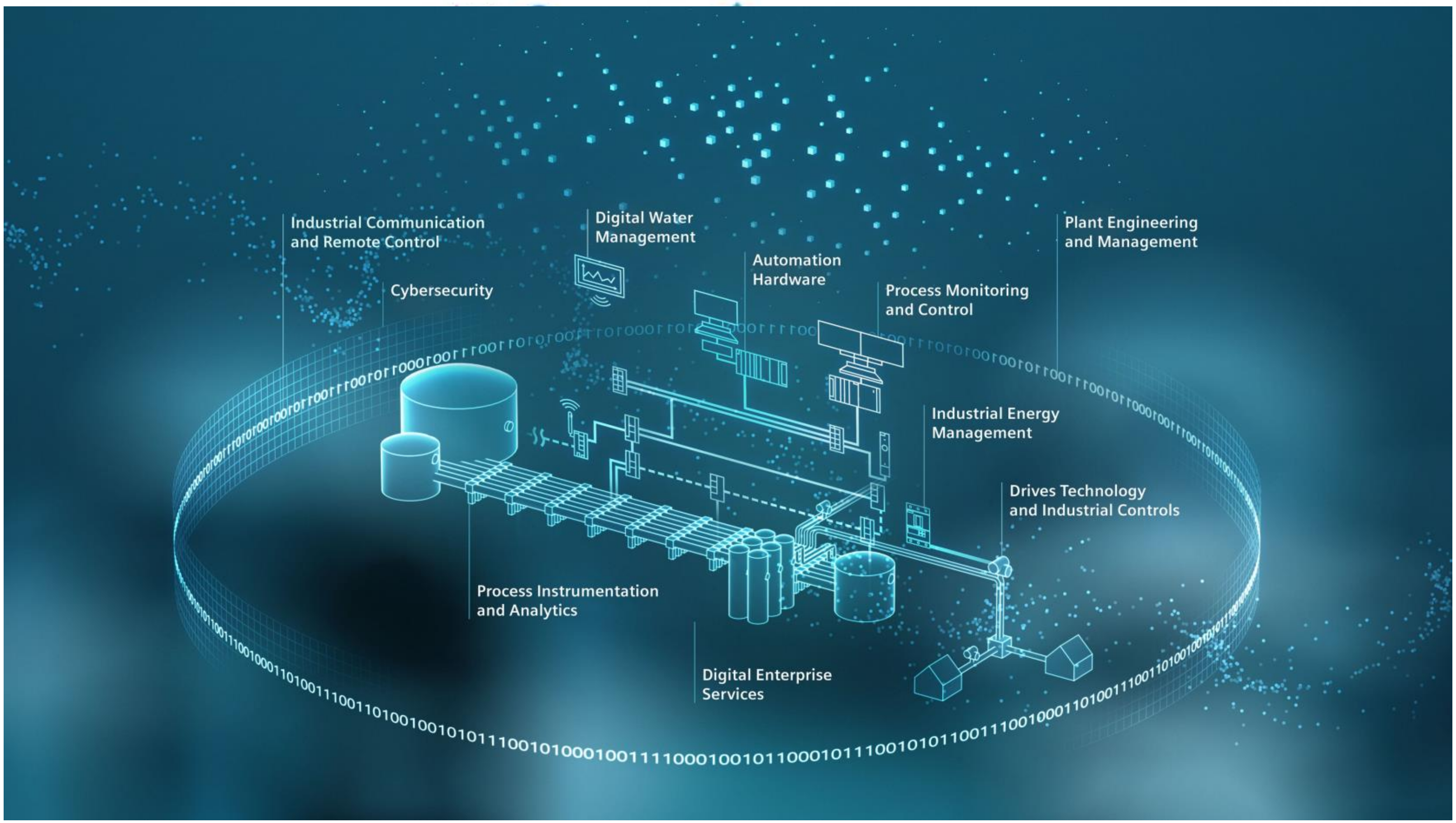
GE Digital

ditto
BOSCH

Digital Twins Forum

Smart Water Networks Forum (SWAN)

A list of companies working towards the development of Digital Twins in water sector



The Future of Digital Twins

"Savings from monitoring, automation and control are in the region of <u>USD 320 billon</u> from 2016-2020."

- GWI Water's Digital Future

"By 2021 <u>half</u> of the industrial, public companies will start using data from Digital Twins of IoT connected products."

- IDC, 2017

"<u>13%</u> of organizations implementing Internet of Things (IoT) projects already use digital twins, while <u>62%</u> are either in the process of establishing digital twin use or plan to do so."

- Grand View Research Inc.

"The global digital twin market size is expected to reach <u>USD 26.07 billion</u> by 2025. The market is estimated to register a strong CAGR of 38.2% over the forecast years."

- Markets and Markets

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Dr. Nataliia Sivchenko

19.06.20

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- Literature databases
- Scientific social networks
- Mendeley desktop

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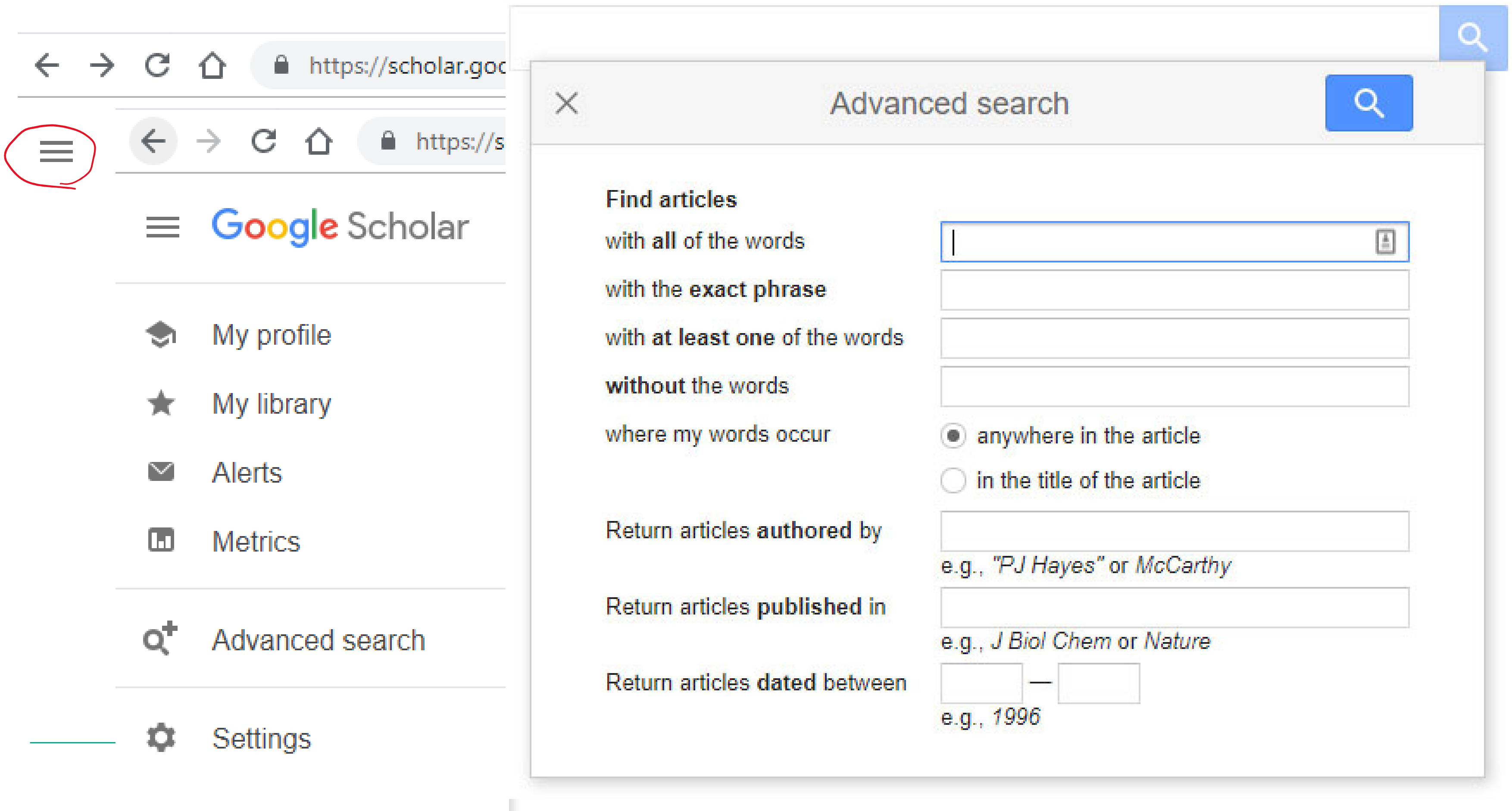

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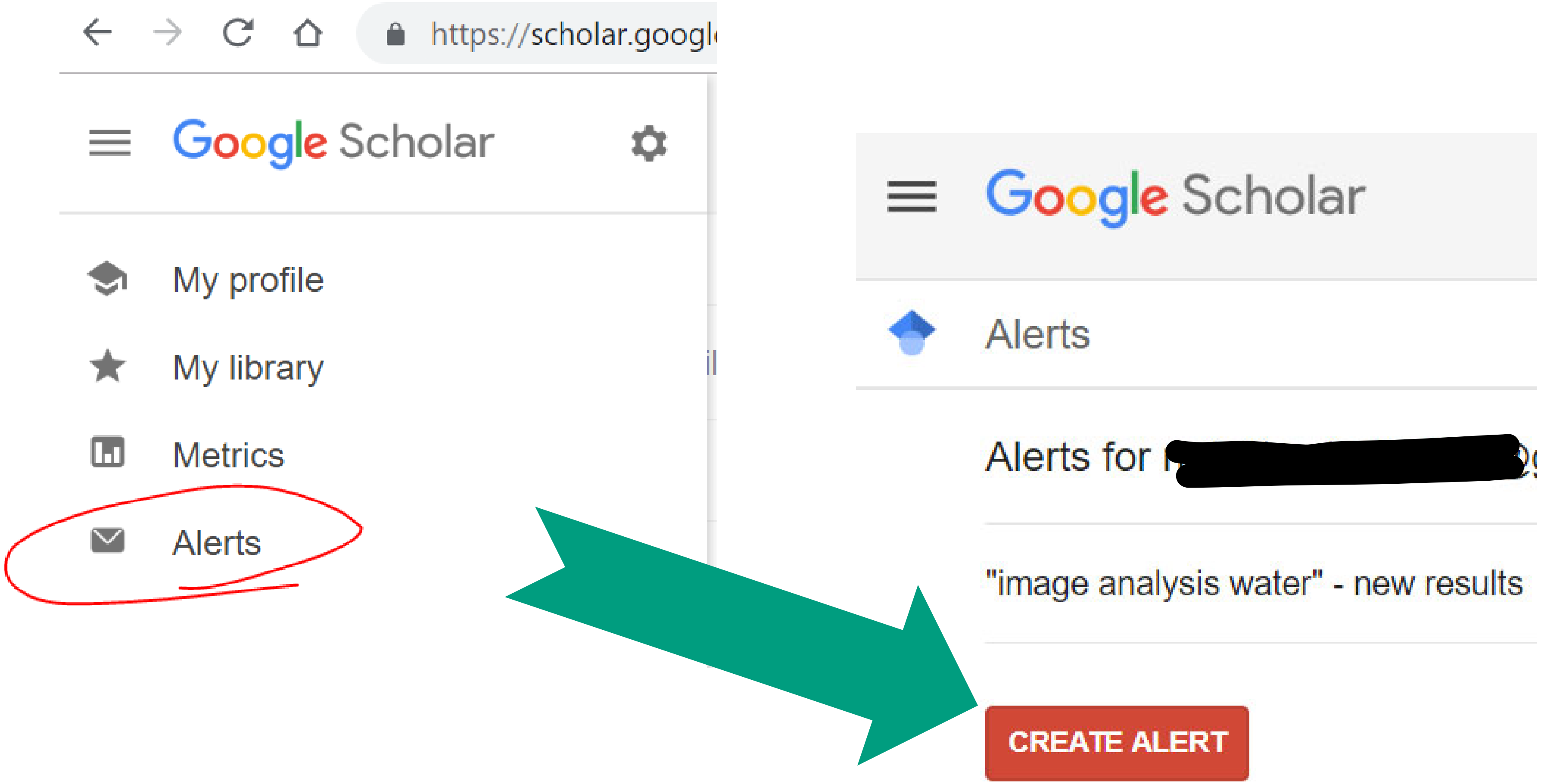

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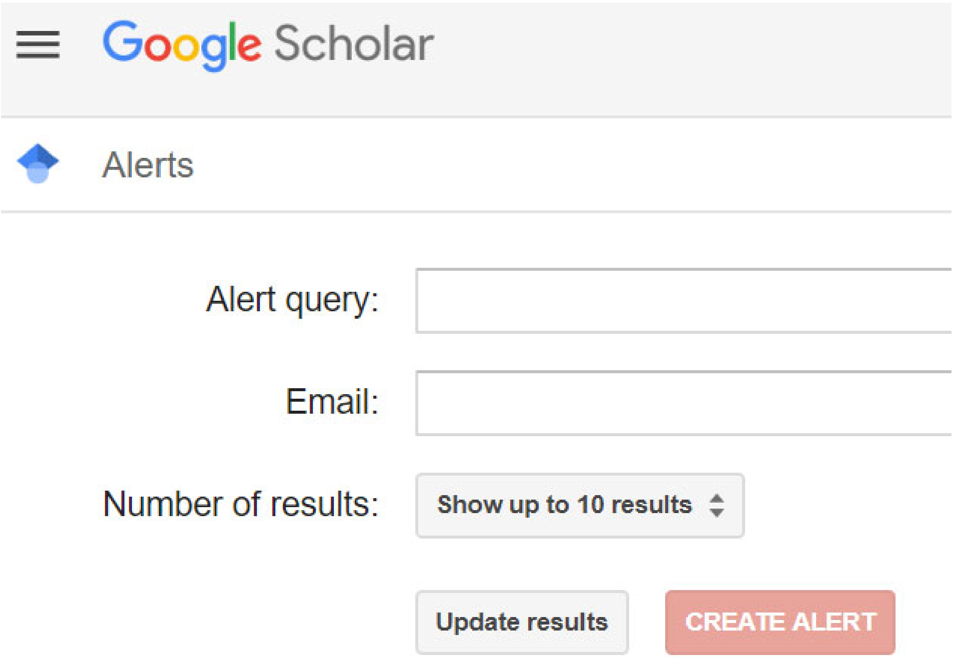

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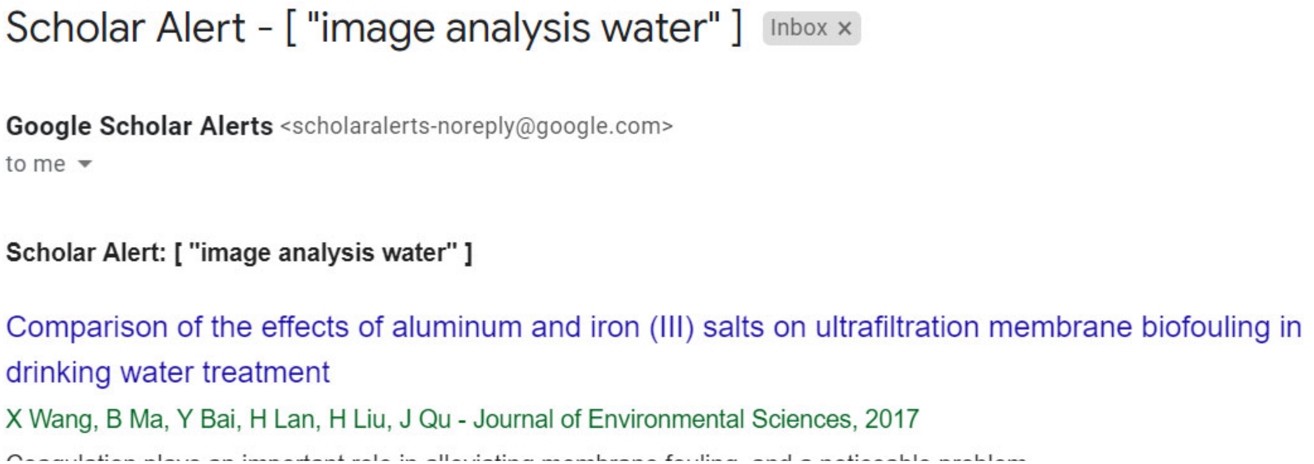

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coagulation water -blood

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The effect of turbidity levels and Moringa oleifera concentration on the effectiveness of coagulation in water treatment — [PDF] researchgate.net

T Nkurunziza, JB Nduwayezu... - Water Science and ..., 2009 - iwaponline.com

Laboratory experiments were carried out to assess the **water** purification and antimicrobial properties of Moringa oleifera (MO). Hence different concentrations (25 to 300 mg/L) were prepared from a salt (1 M NaCl) extract of MO fine powder and applied to natural surface ...

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Coagulation in drinking water treatment: particles, organics and coagulants

JK Edzwald - Water Science and Technology, 1993 - iwaponline.com

A review of **coagulation** in drinking **water** treatment is presented. The paper emphasizes the importance of raw **water** chemistry, natural organic matter (NOM) concentration and type, and the chemistry of coagulants. Mineral and organic particles may be stable in **water** due to ...

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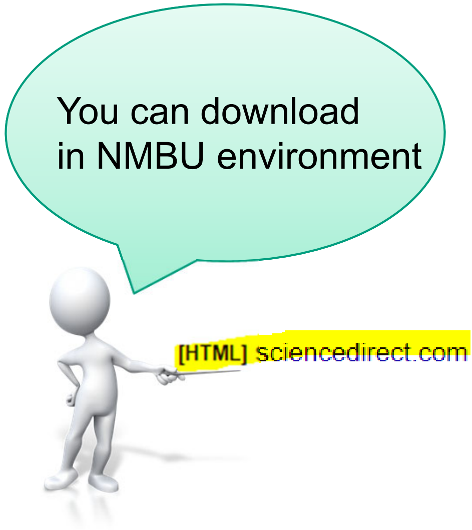

[HTML] Natural organic matter removal by coagulation during drinking water treatment: a review — [HTML] sciencedirect.com

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Natural organic matter (NOM) is found in all surface, ground and soil waters. An increase in the amount of NOM has been observed over the past 10–20 years in raw **water** supplies in several areas, which has a significant effect on drinking **water** treatment. The presence of ...

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[HTML] Quality of water treated by coagulation using Moringa oleifera seeds — [HTML] sciencedirect.com

A Ndabigengesere, KS Narasiah - Water research, 1998 - Elsevier

A model turbid **water** was treated by **coagulation**-flocculation and sedimentation, with Moringa oleifera seeds as a coagulant, using jar tests. The quality of the treated **water** was analyzed and compared with that of the **water** treated with alum. Experiments were ...

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JG Hering, PY Chen, JA Wilkie... - Journal of Environmental ..., 1997 - ascelibrary.org

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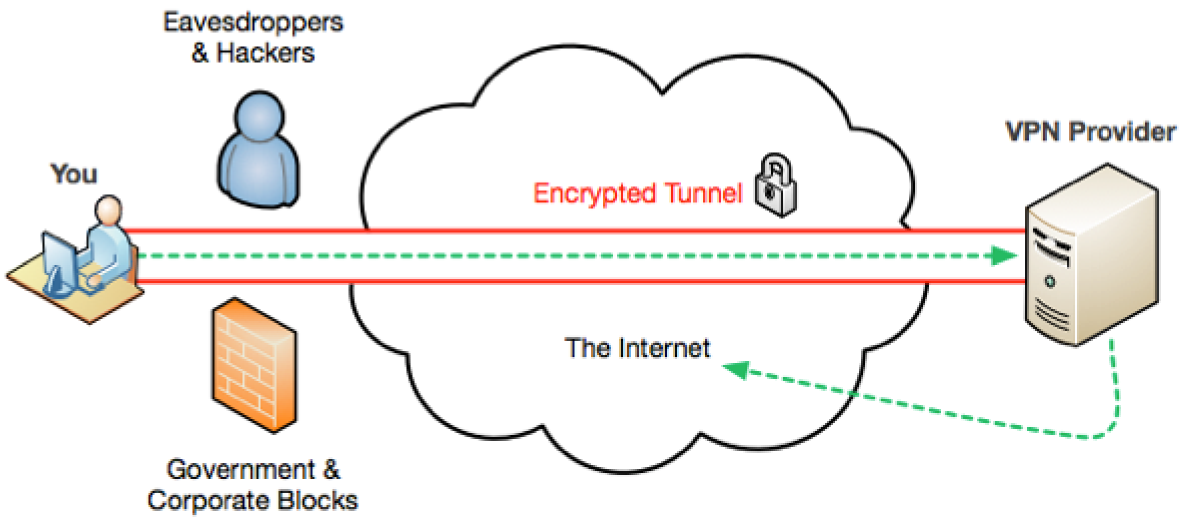

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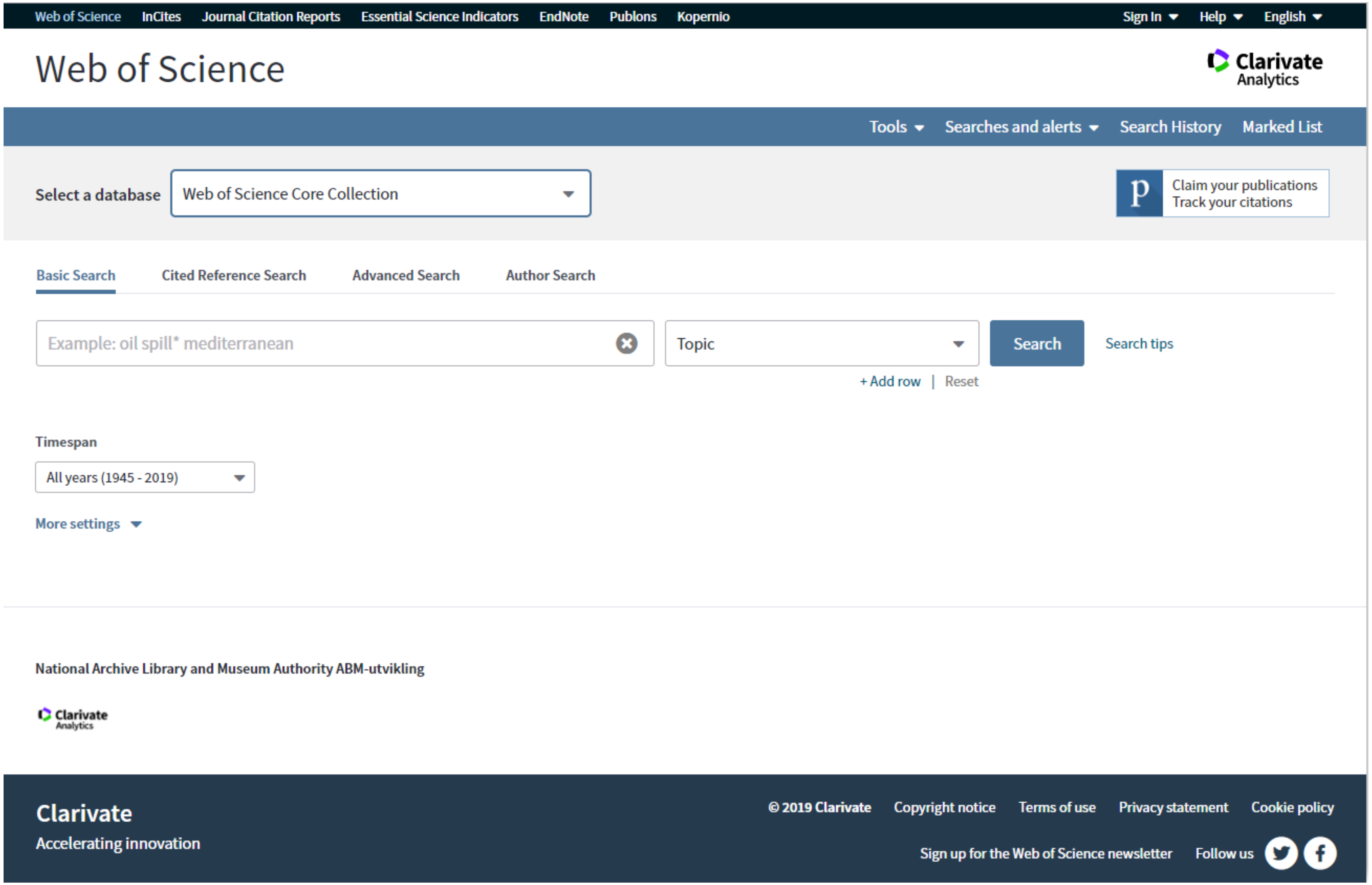

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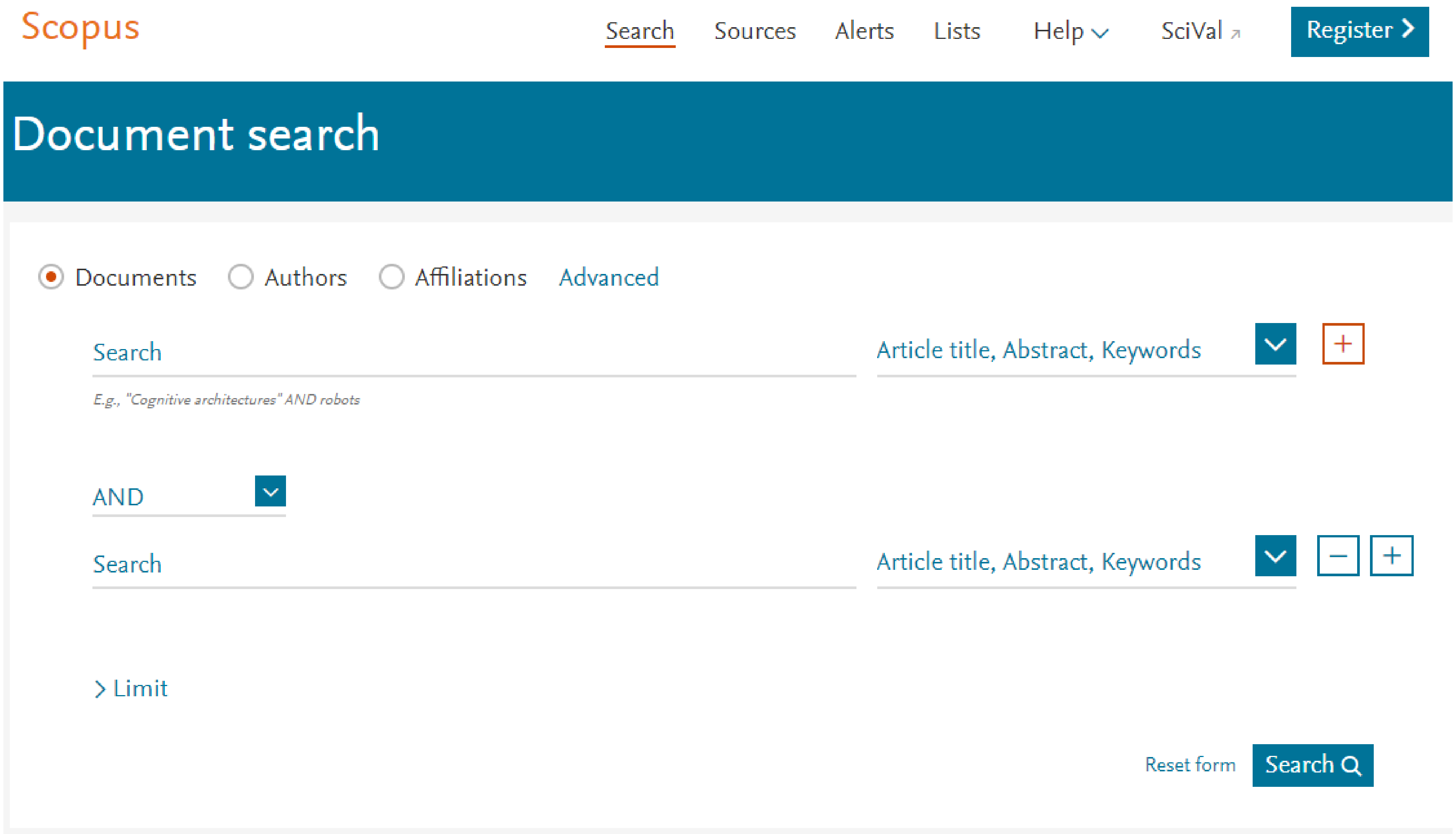

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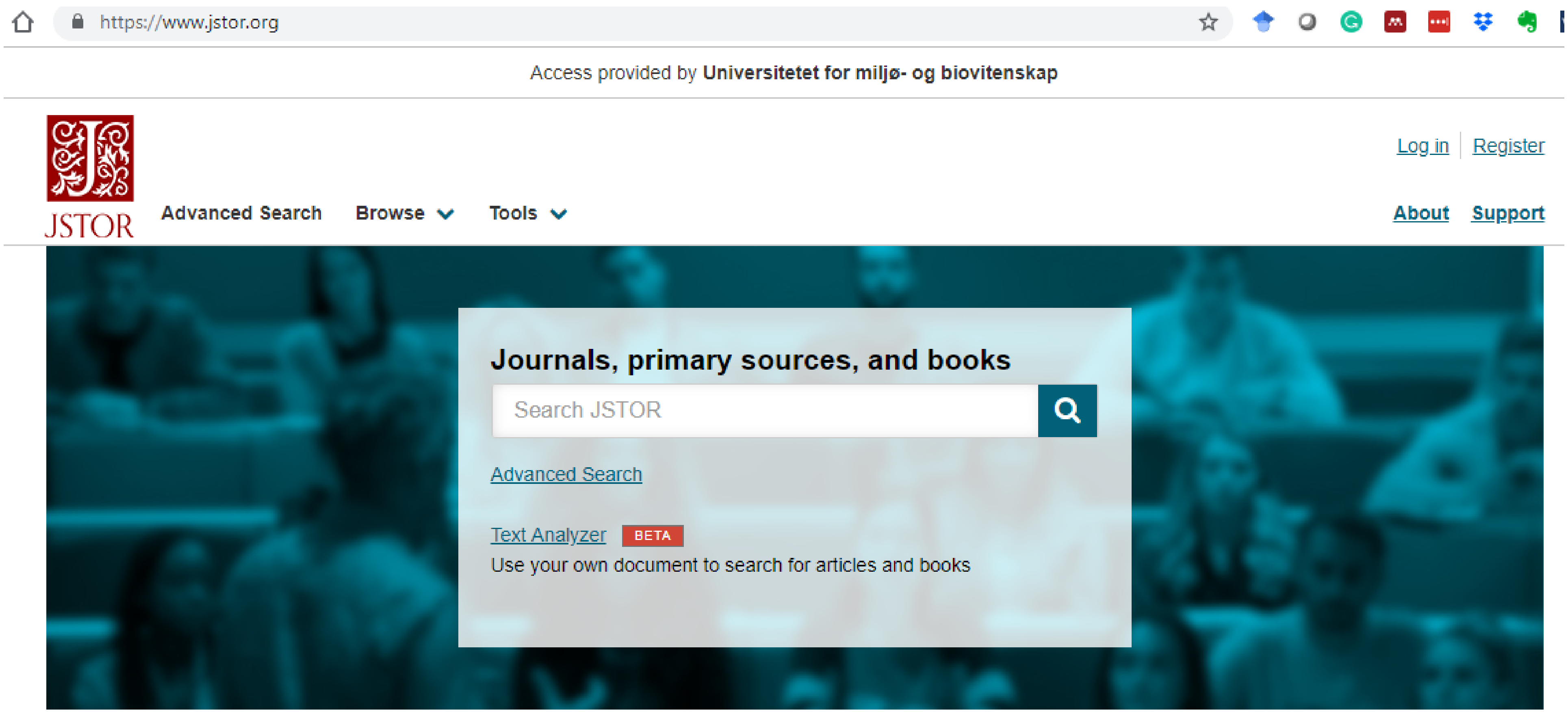

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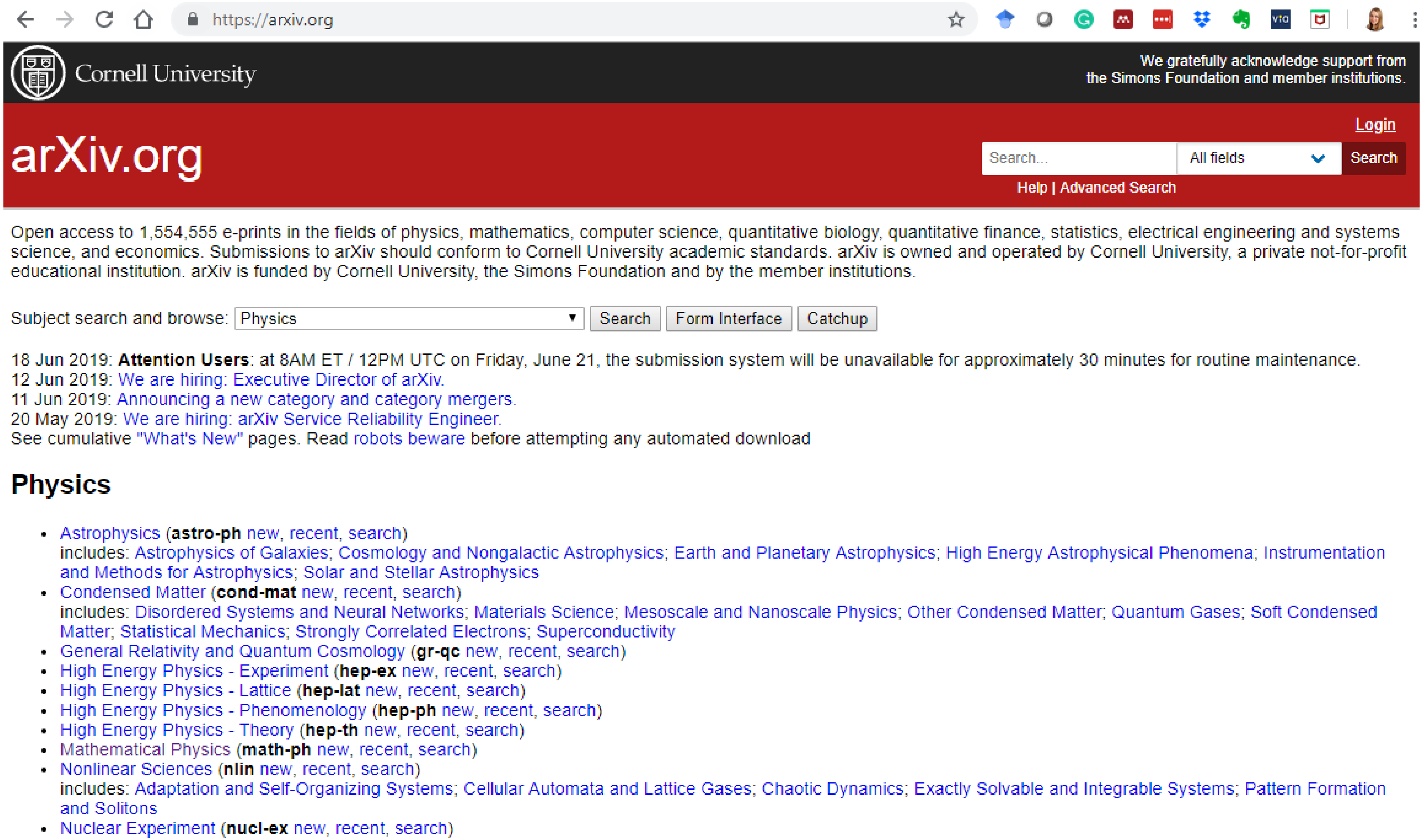

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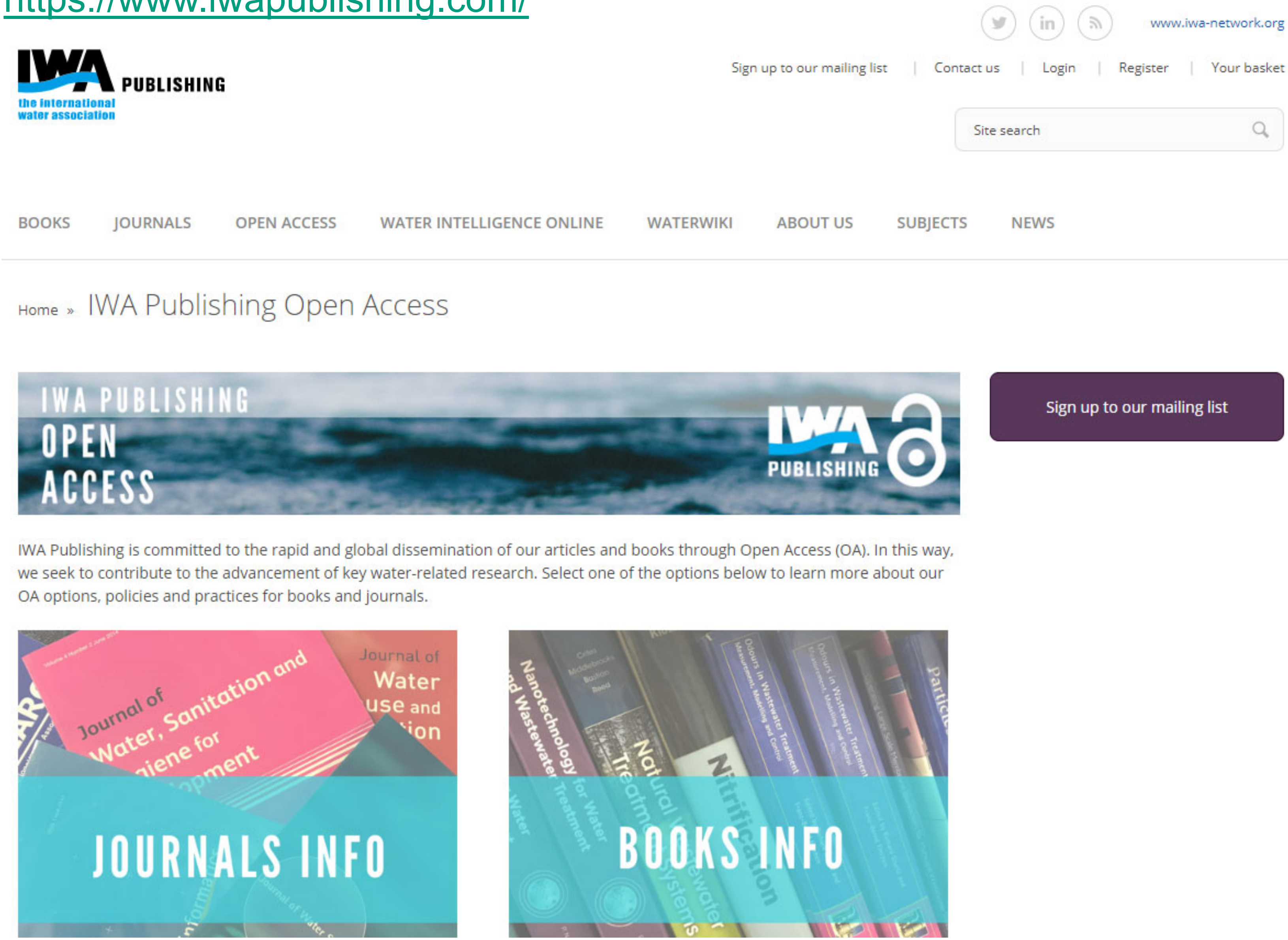

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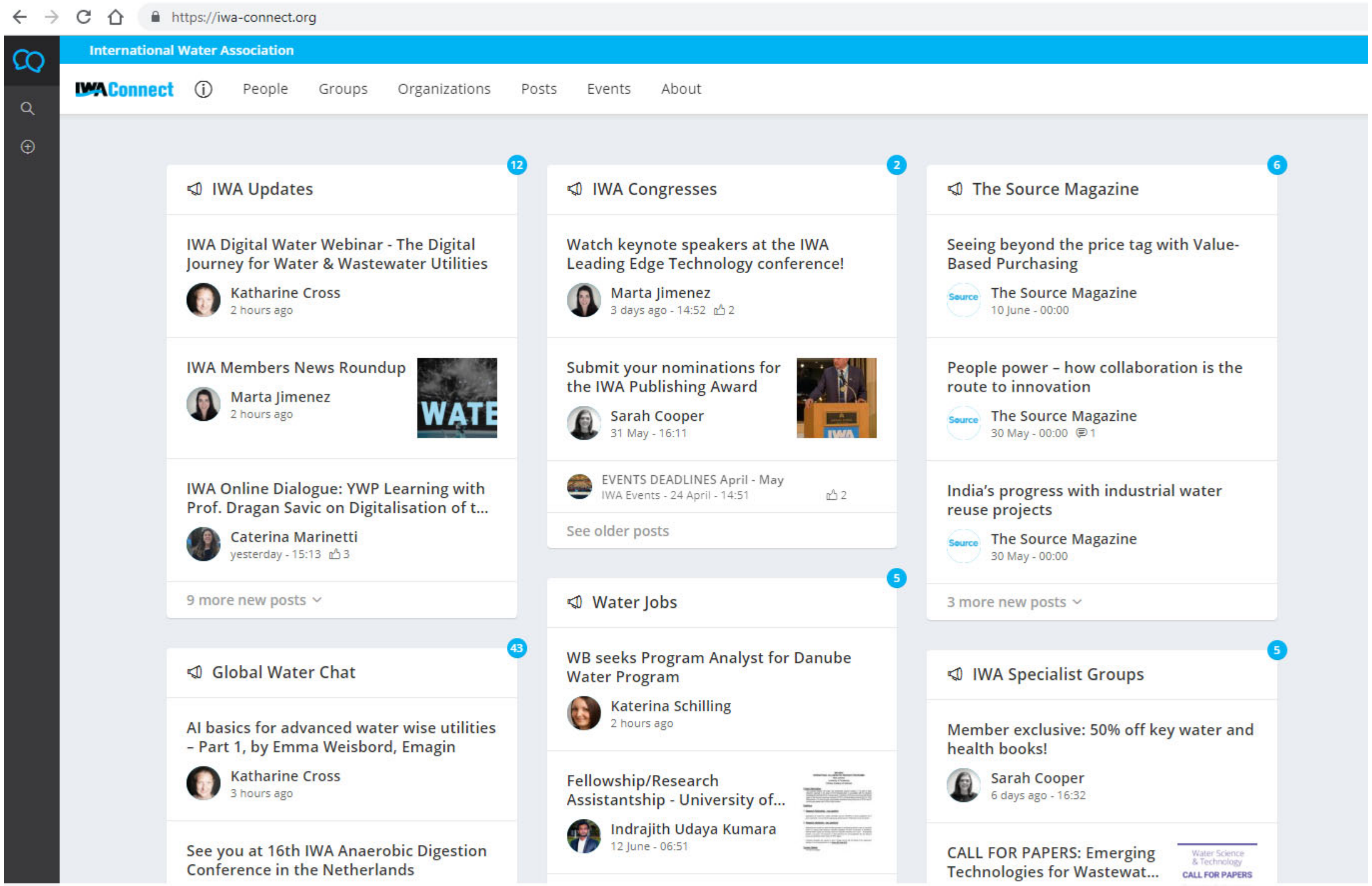

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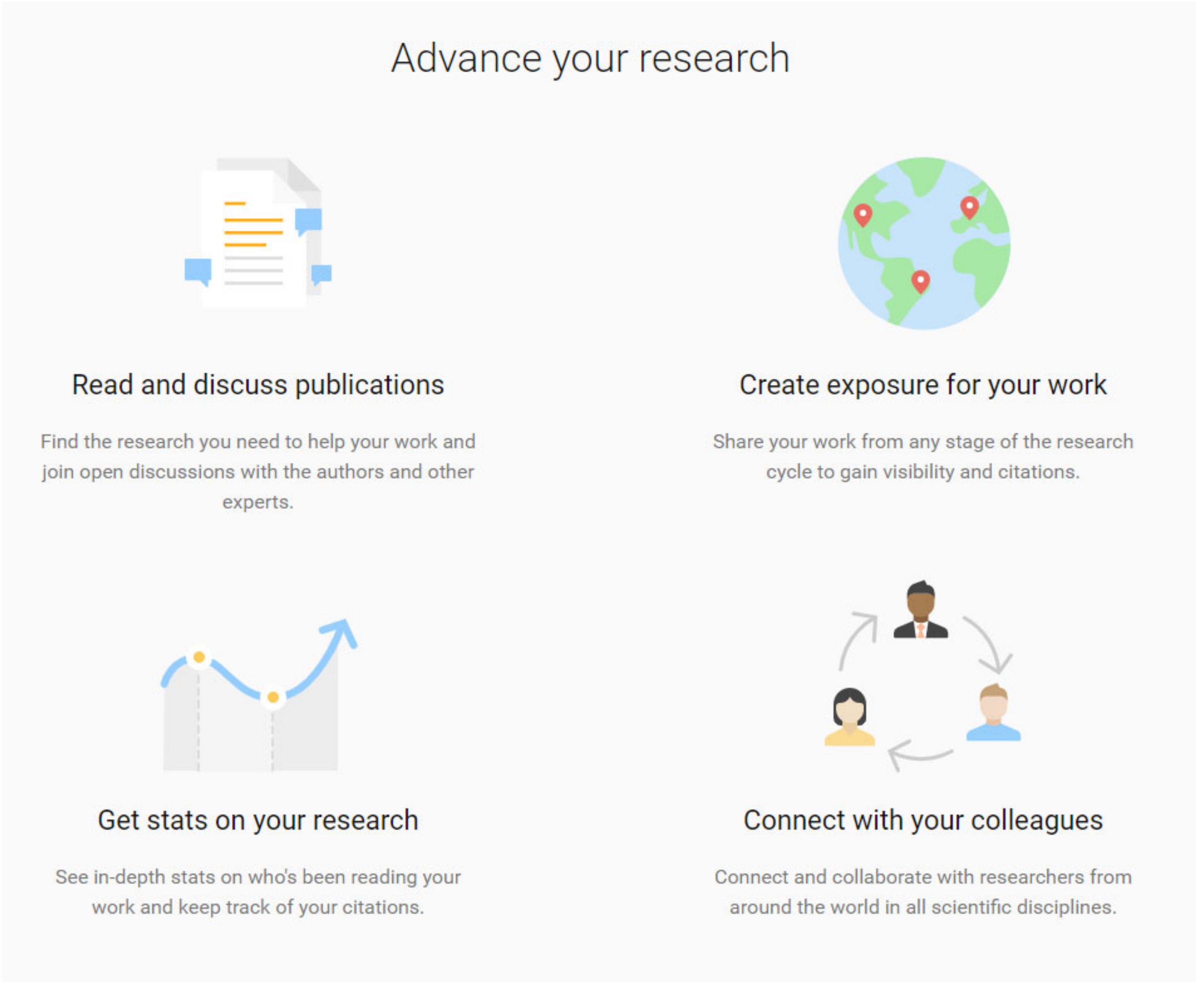

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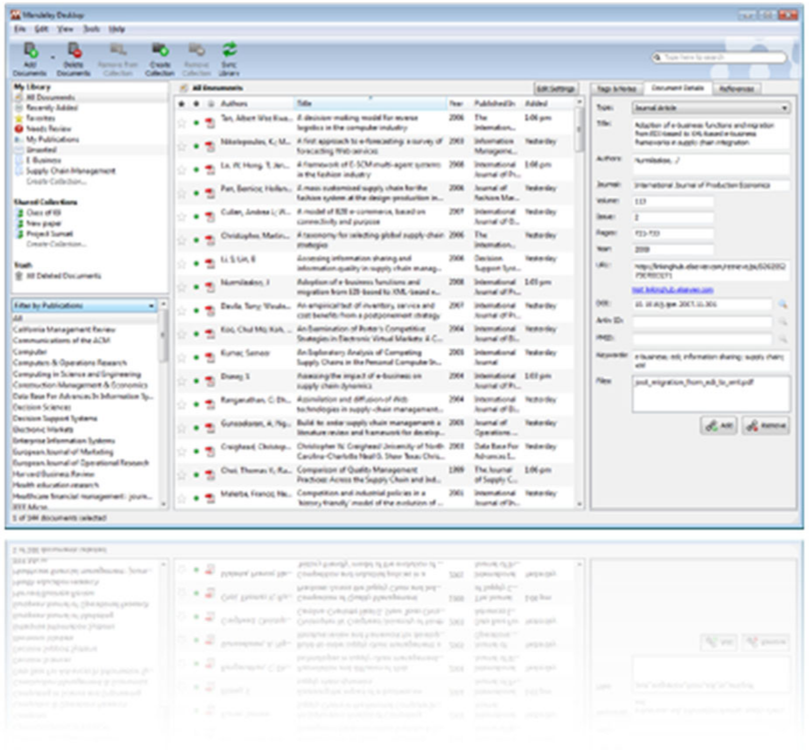

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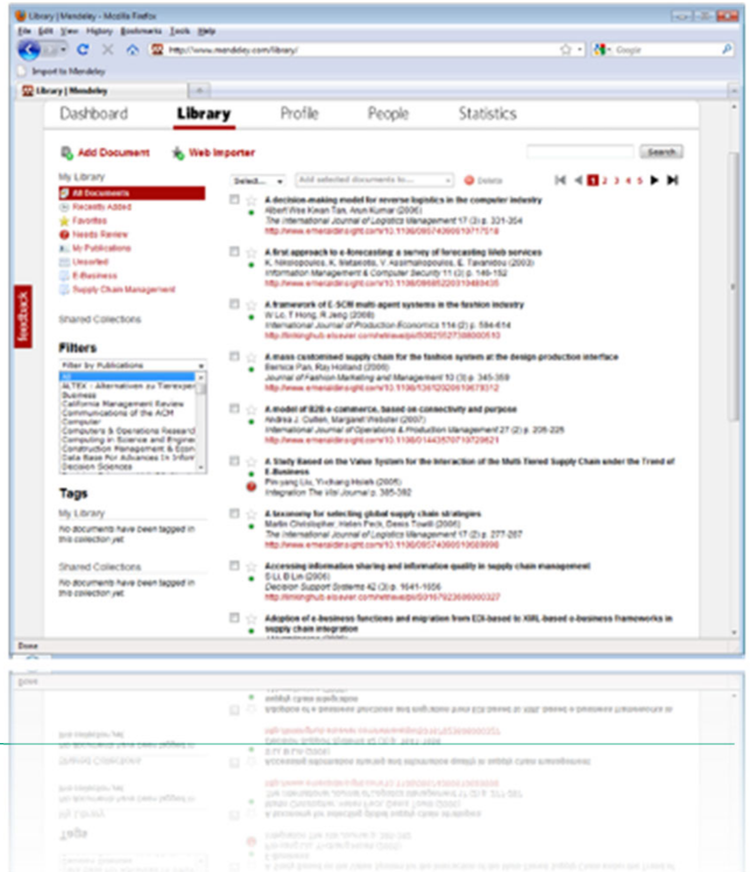

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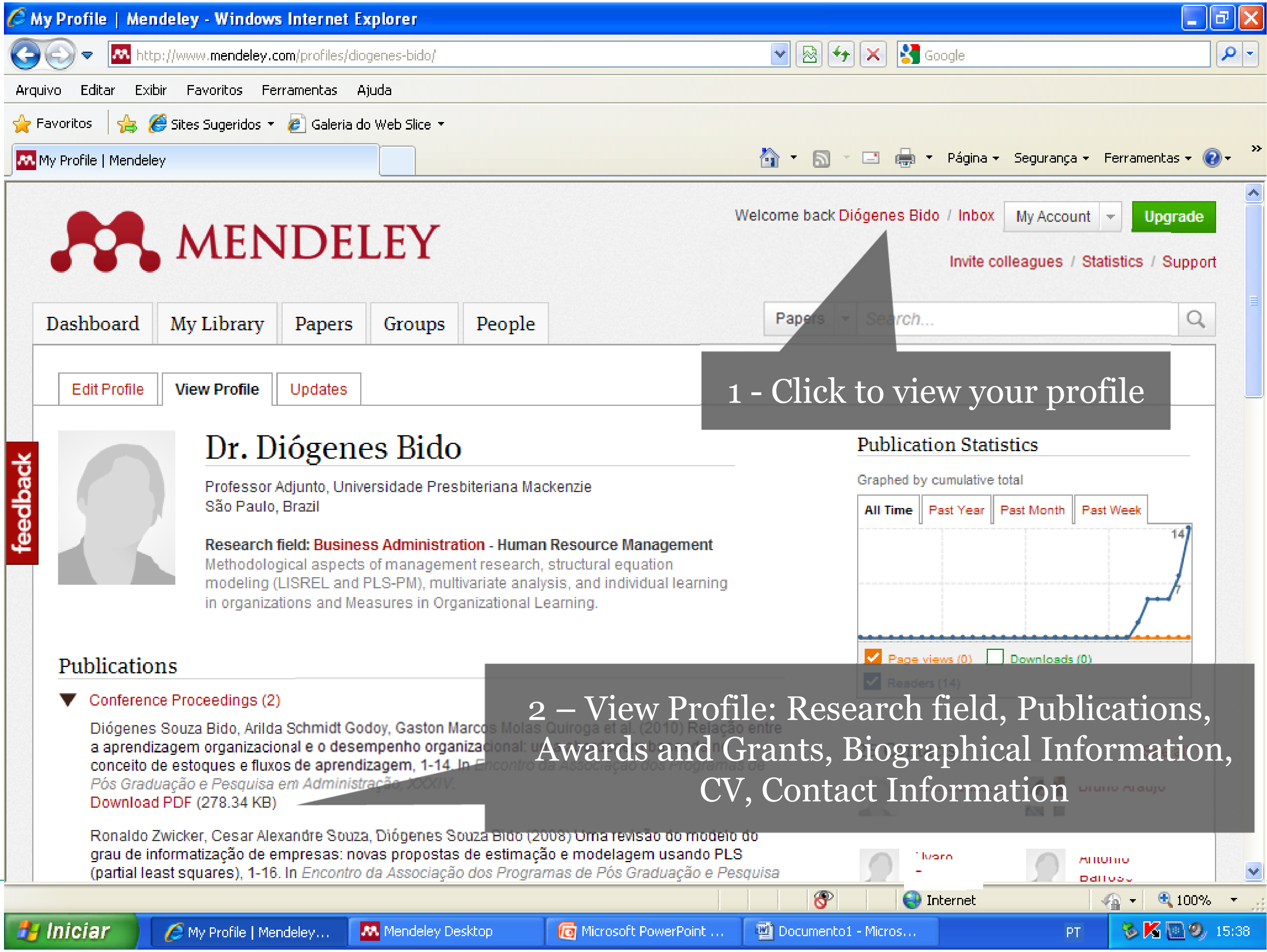
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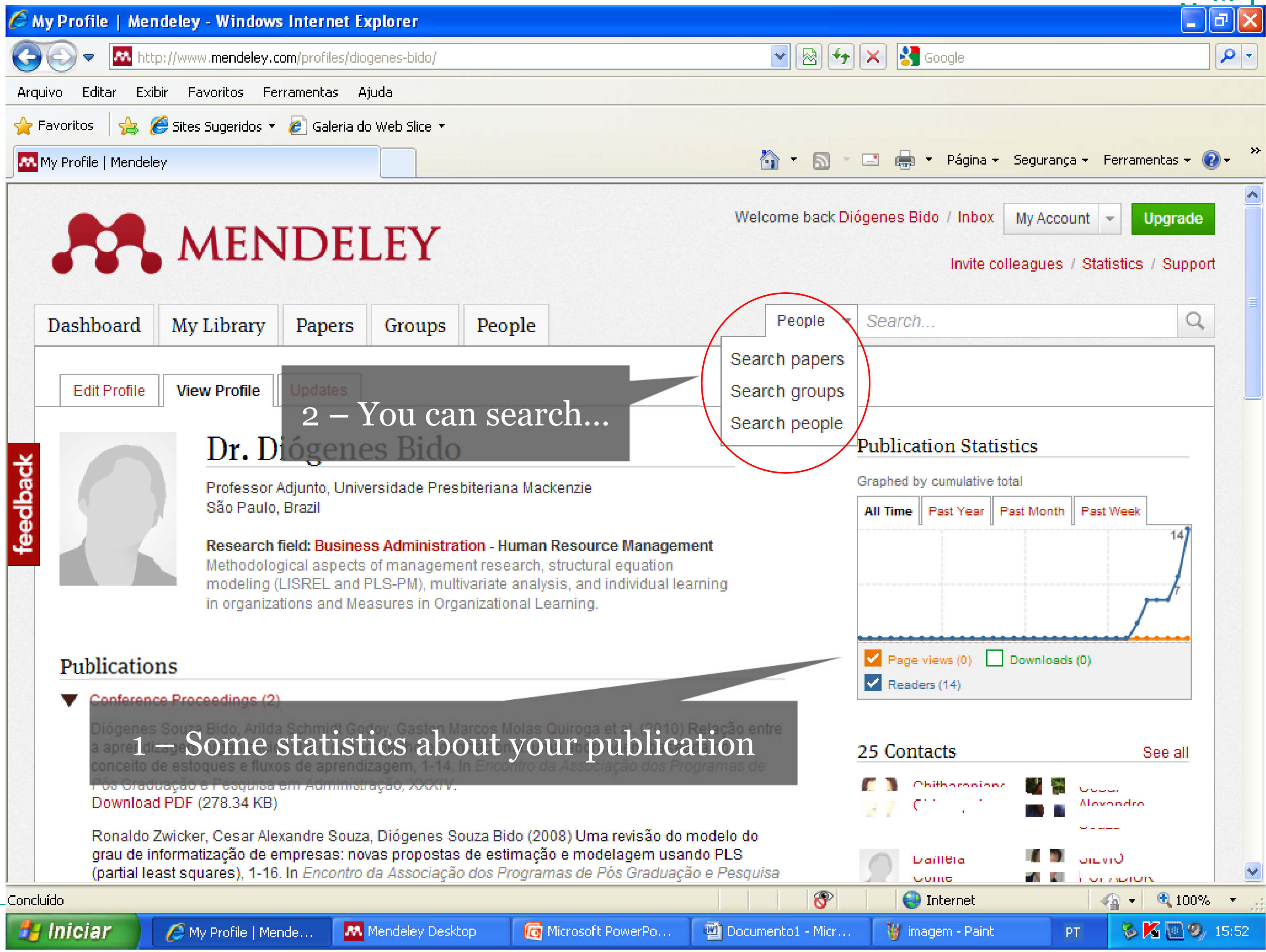

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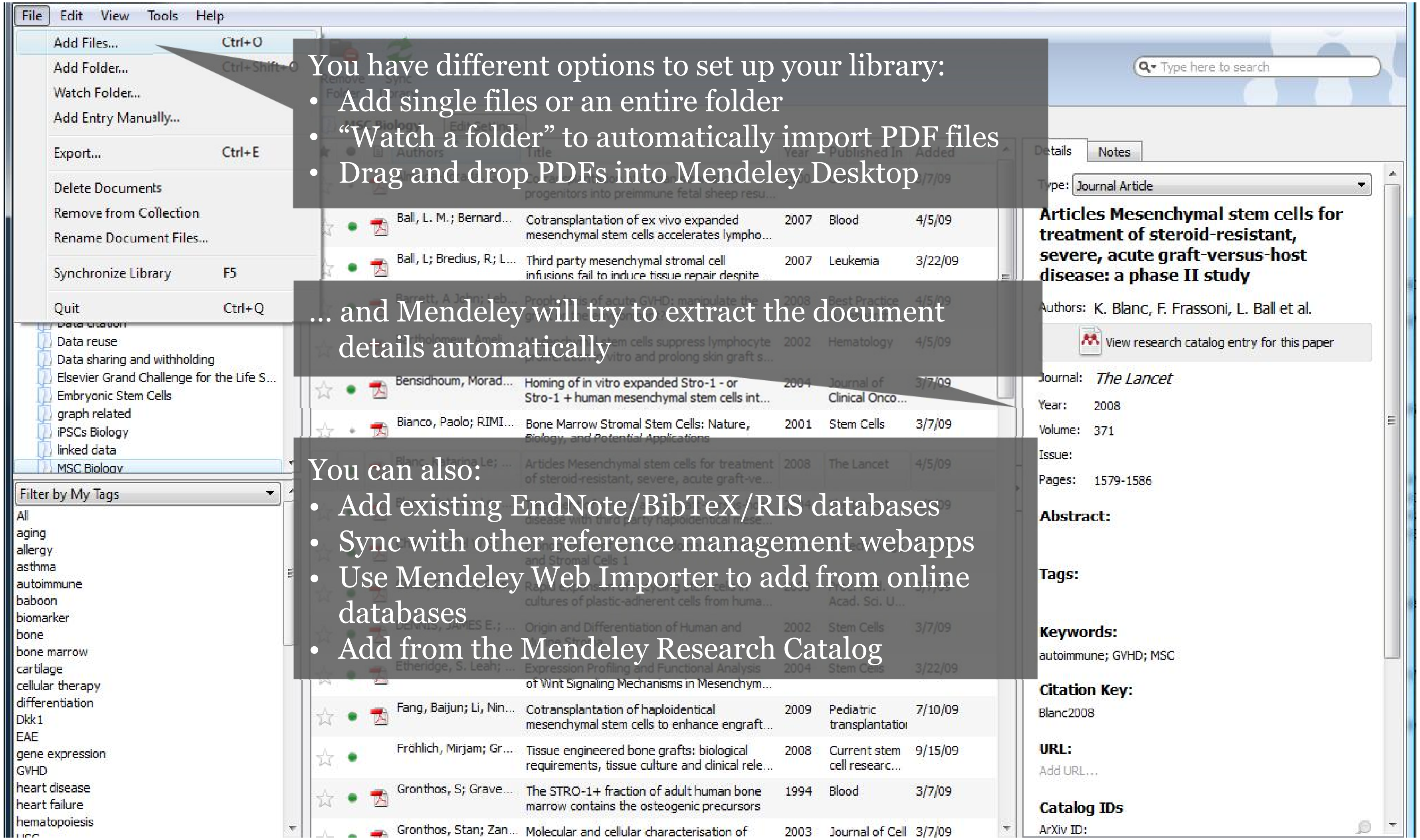
Ronaldo Zwicker, Cesar Alexandre Souza, Diógenes Souza Bido (2008) Uma revisão do modelo do grau de informatização de empresas: novas propostas de estimação e modelagem usando PLS (partial least squares), 1-16. In Encontro da Associação dos Programas de Pós Graduação e Pesquisa
25 Contacts
See all
feedback

Adding your papers



You have different options to set up your library:

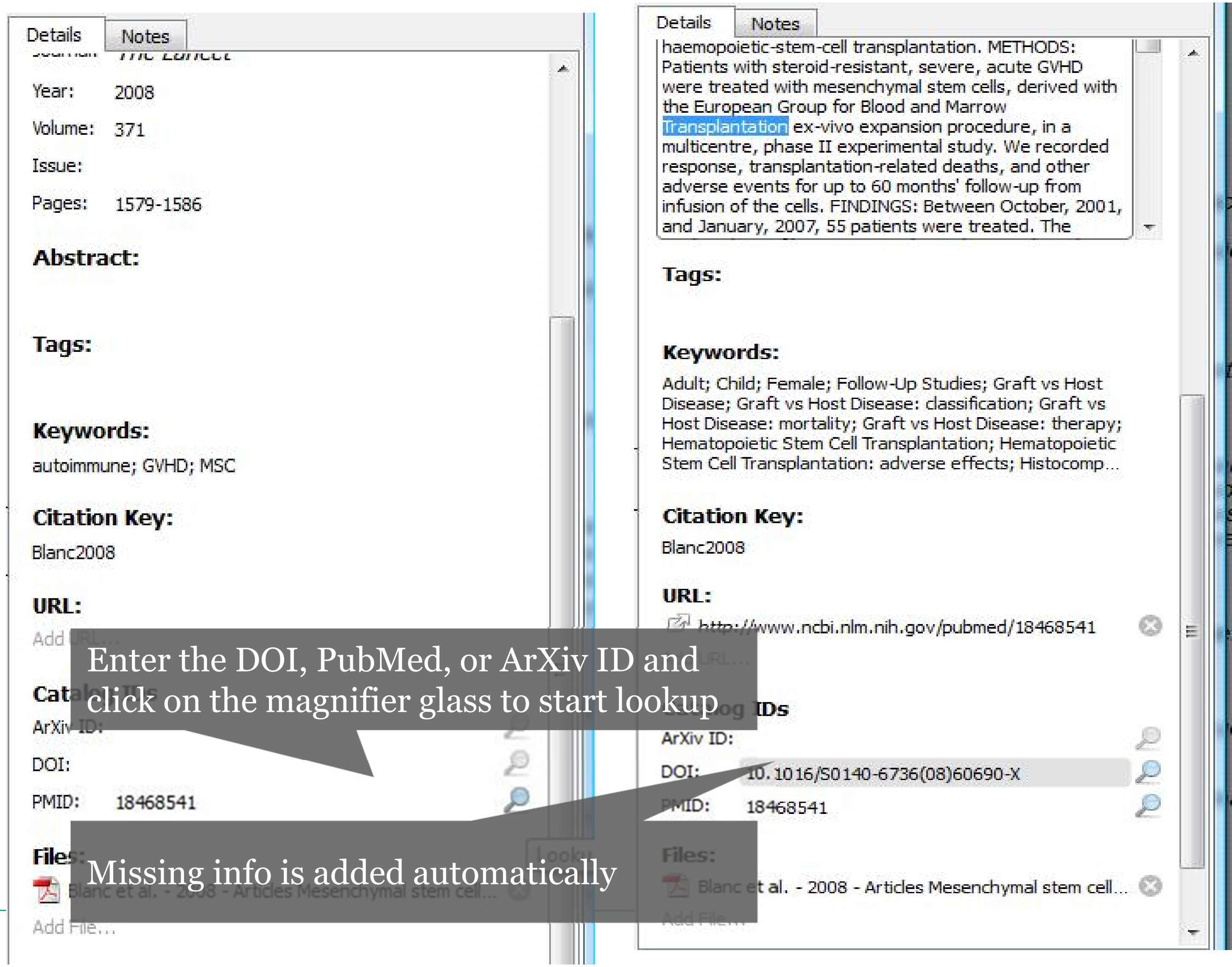
- Add single files or an entire folder
- "Watch a folder" to automatically import PDF files
- Drag and drop PDFs into Mendeley Desktop

... and Mendeley will try to extract the document details automatically

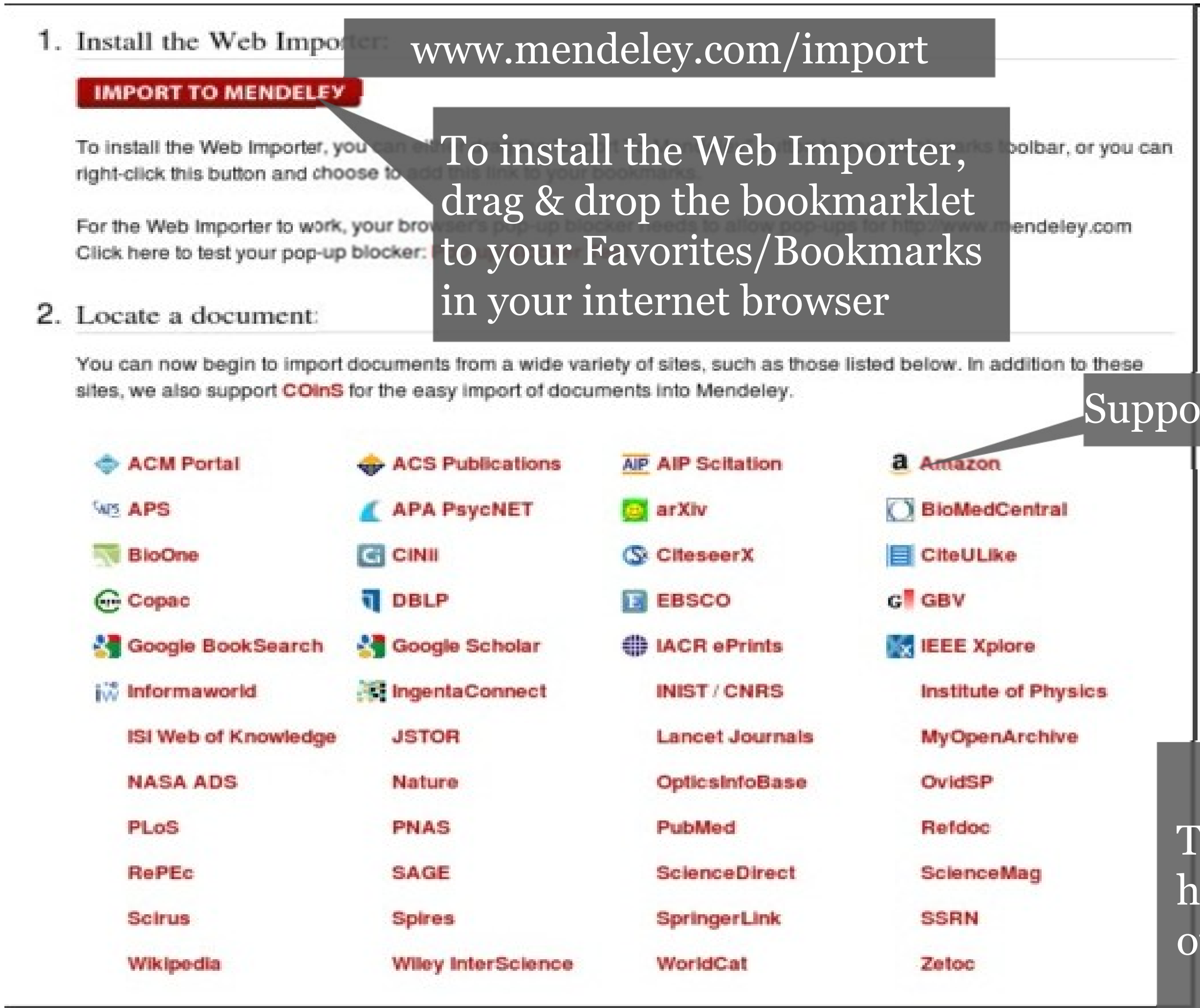
You can also:

- Add existing EndNote/BibTeX/RIS databases
- Sync with other reference management webapps
- Use Mendeley Web Importer to add from online databases
- Add from the Mendeley Research Catalog

Document details lookup



Web Importer



1. Install the Web Importer:

IMPORT TO MENDELEY

To install the Web Importer, you can ... toolbar, or you can right-click this button and choose to add this link to your bookmarks.

For the Web Importer to work, your browser's pop-up blocker needs to allow pop-ups for http://www.mendeley.com
Click here to test your pop-up blocker:

2. Locate a document:

You can now begin to import documents from a wide variety of sites, such as those listed below. In addition to these sites, we also support COinS for the easy import of documents into Mendeley.

ACM Portal	ACS Publications	AIP Scitation	Amazon
APS	APA PsycNET	arXiv	BioMedCentral
BioOne	CiNii	CiteseerX	CiteULike
Copac	DBLP	EBSCO	GBV
Google BookSearch	Google Scholar	IACR ePrints	IEEE Xplore
Informaworld	IngentaConnect	INIST / CNRS	Institute of Physics
ISI Web of Knowledge	JSTOR	Lancet Journals	MyOpenArchive
NASA ADS	Nature	OpticsInfoBase	OvidSP
PLoS	PNAS	PubMed	Refdoc
RePEc	SAGE	ScienceDirect	ScienceMag
Scirus	Spires	SpringerLink	SSRN
Wikipedia	Wiley InterScience	WorldCat	Zetoc

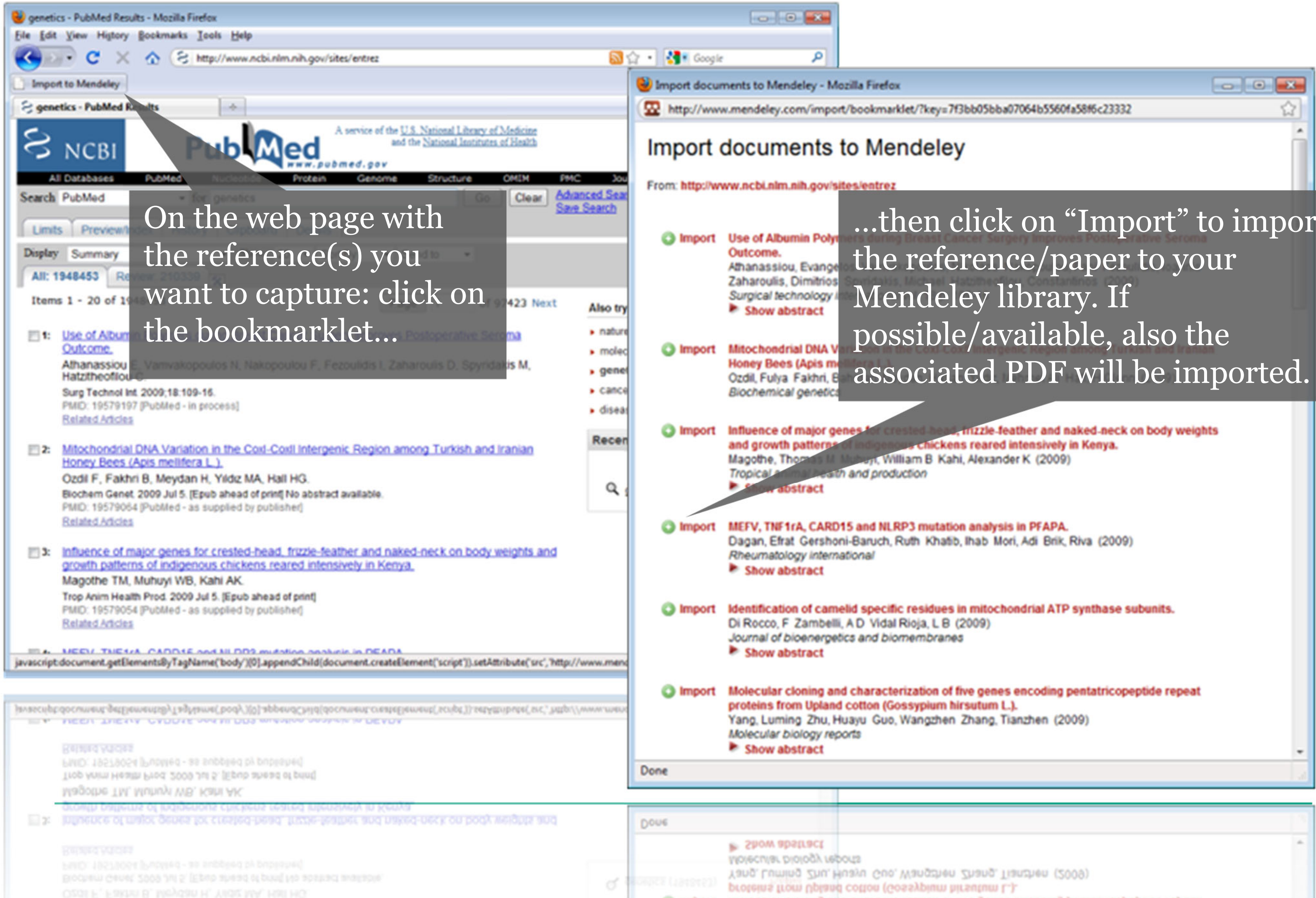
www.mendeley.com/import

To install the Web Importer, drag & drop the bookmarklet to your Favorites/Bookmarks in your internet browser

Supported sites

The Web Importer helps you grab citations off the web

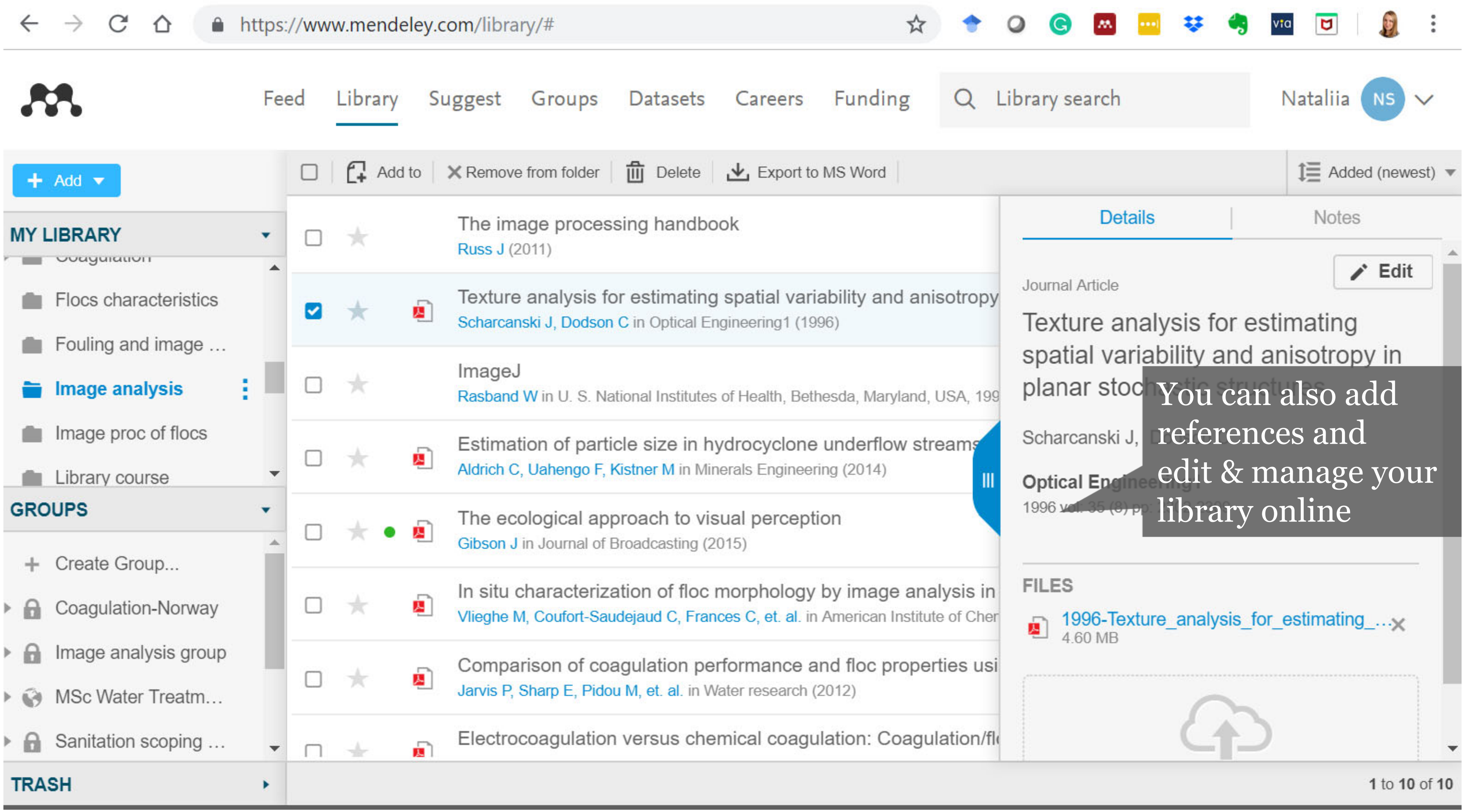
Using the Web Importer



On the web page with the reference(s) you want to capture: click on the bookmarklet...

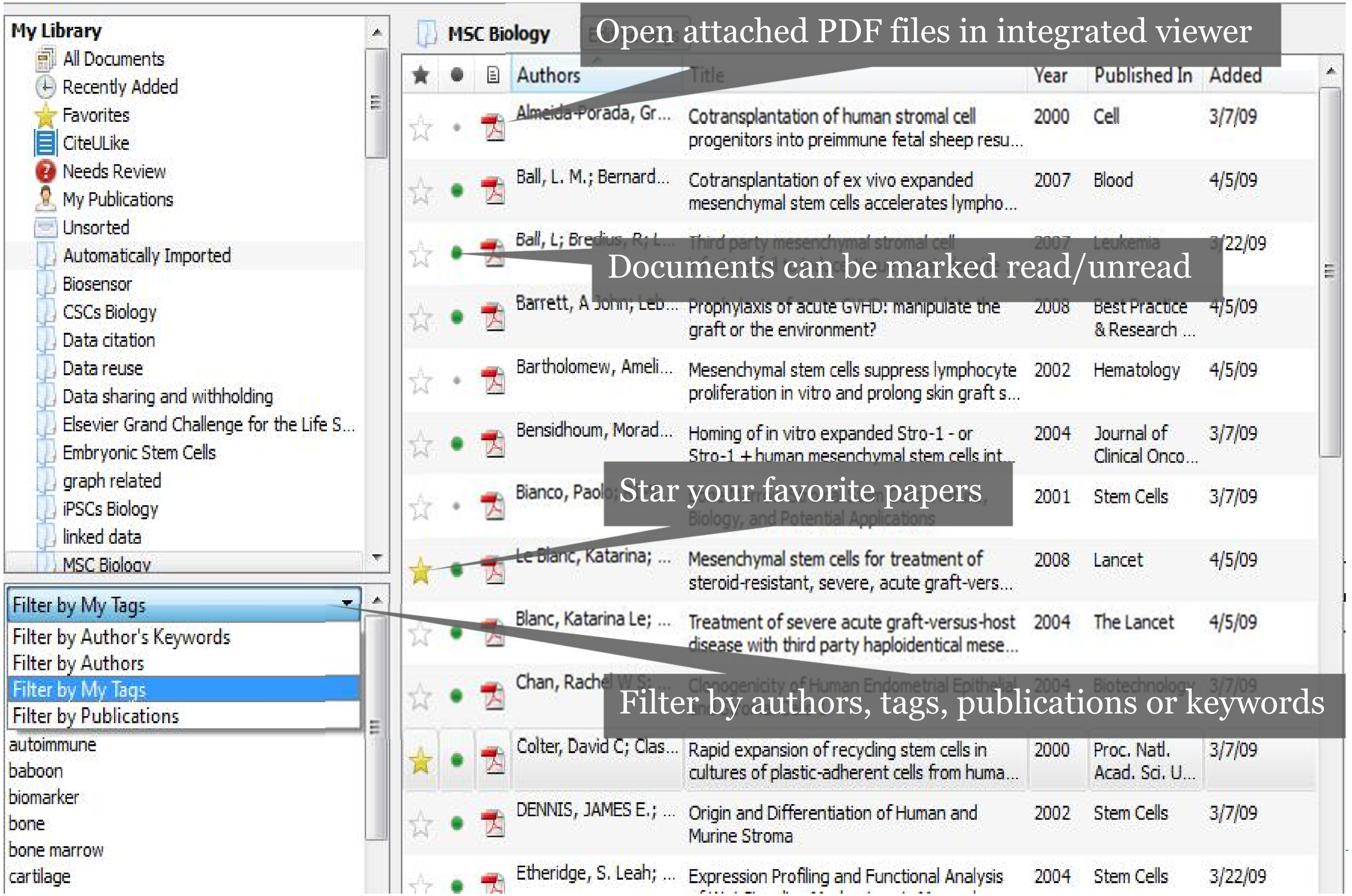
...then click on “Import” to import the reference/paper to your Mendeley library. If possible/available, also the associated PDF will be imported.

Synchronize and manage your library online

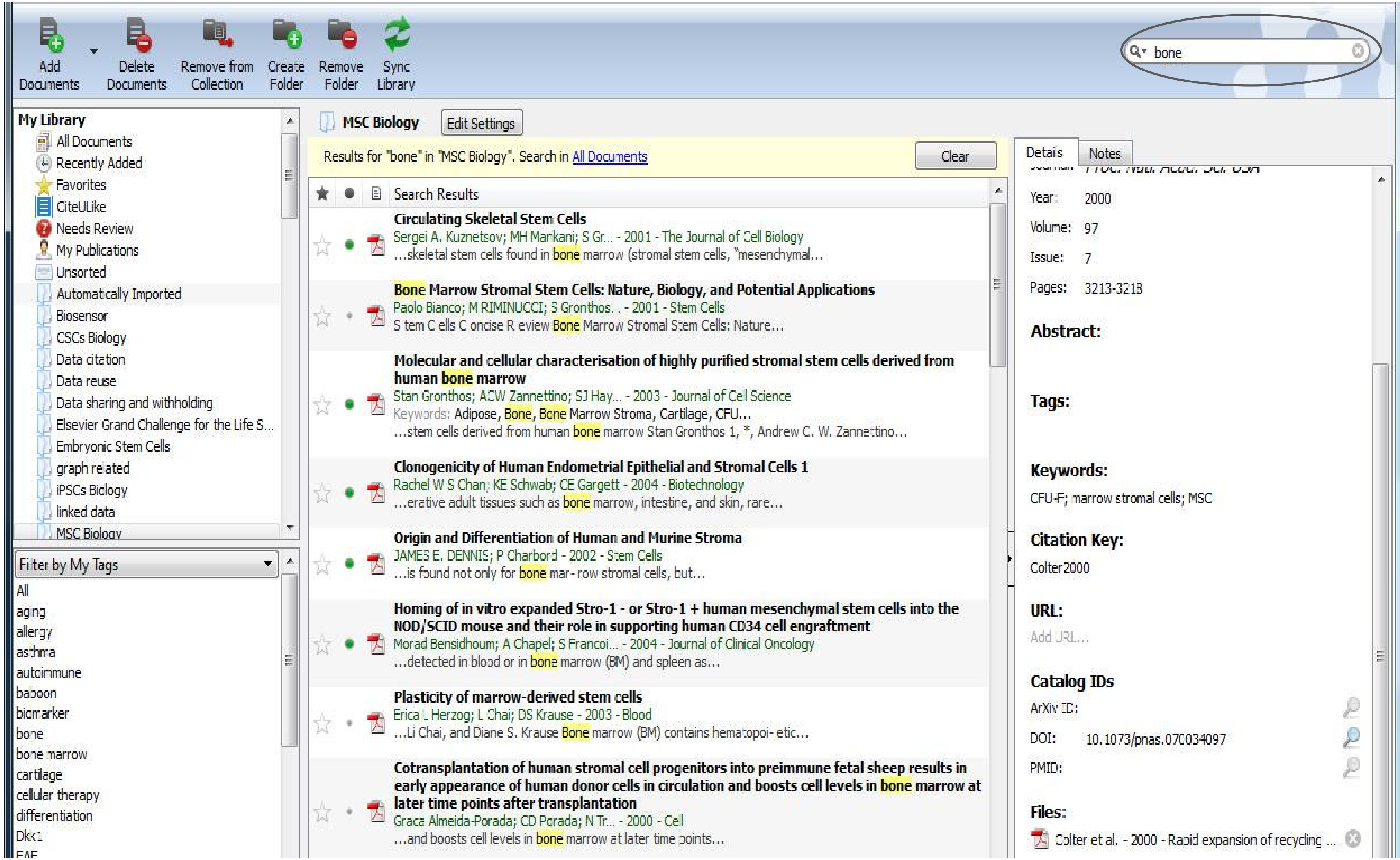


You can also add references and edit & manage your library online

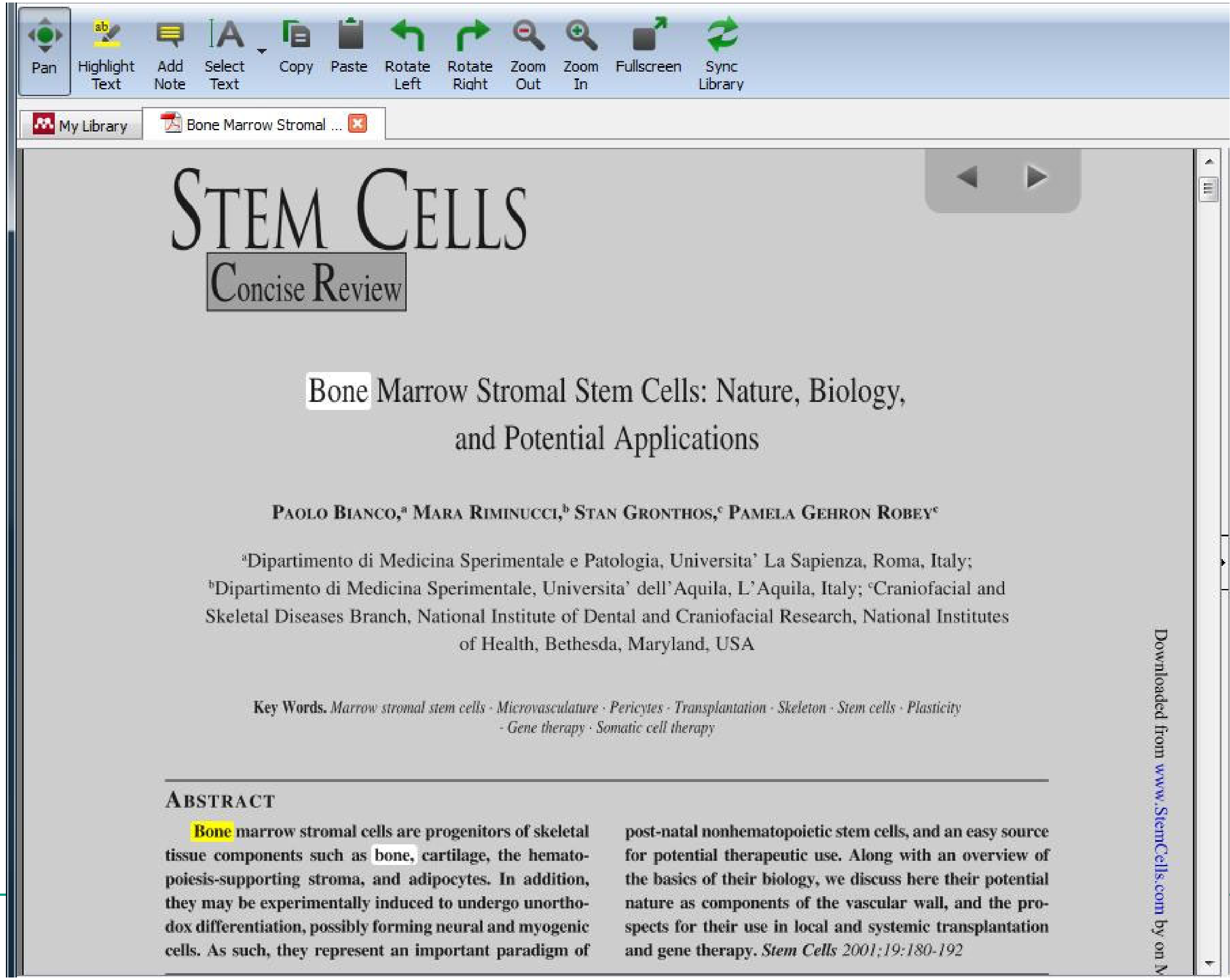
Manage your library



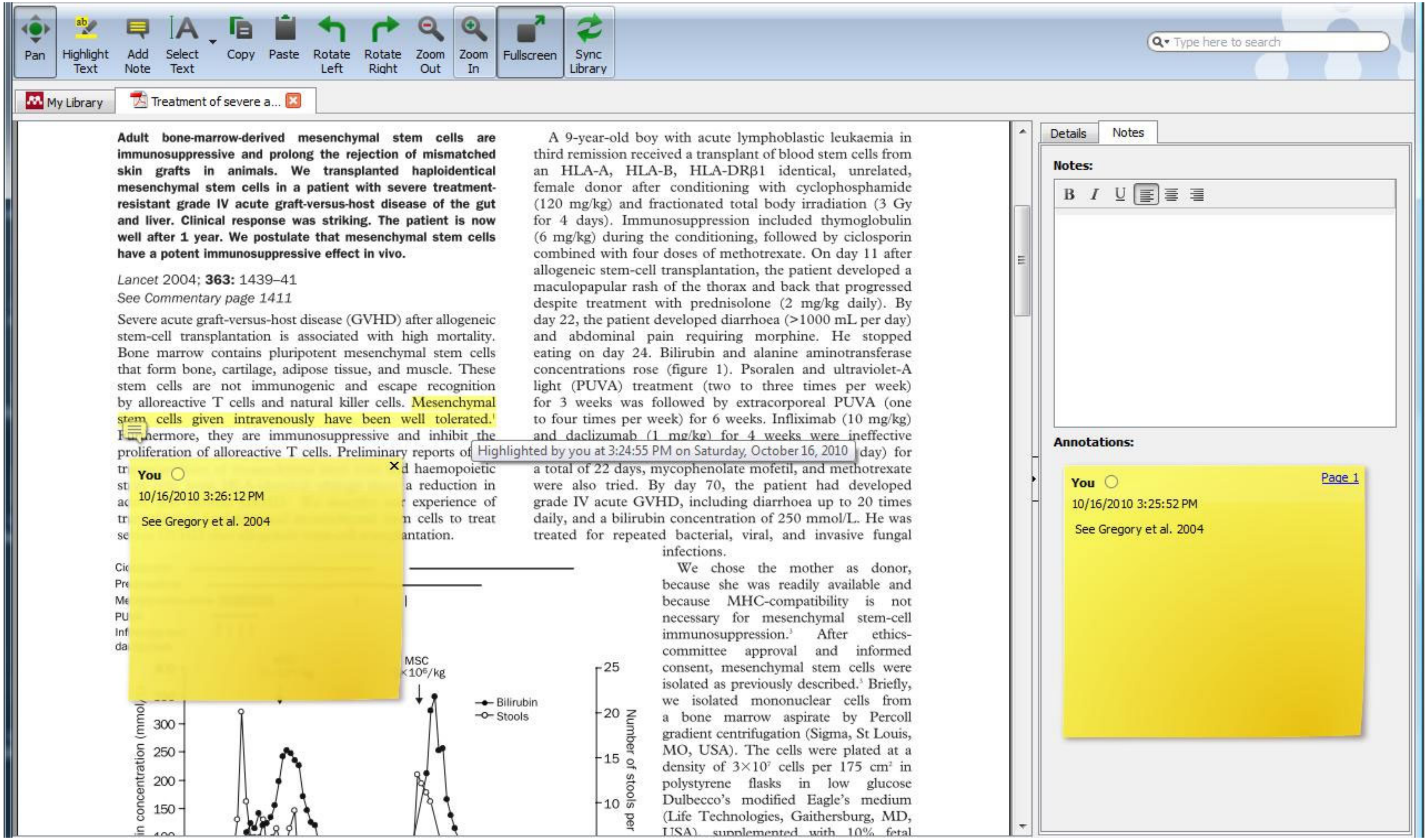
Search as you type



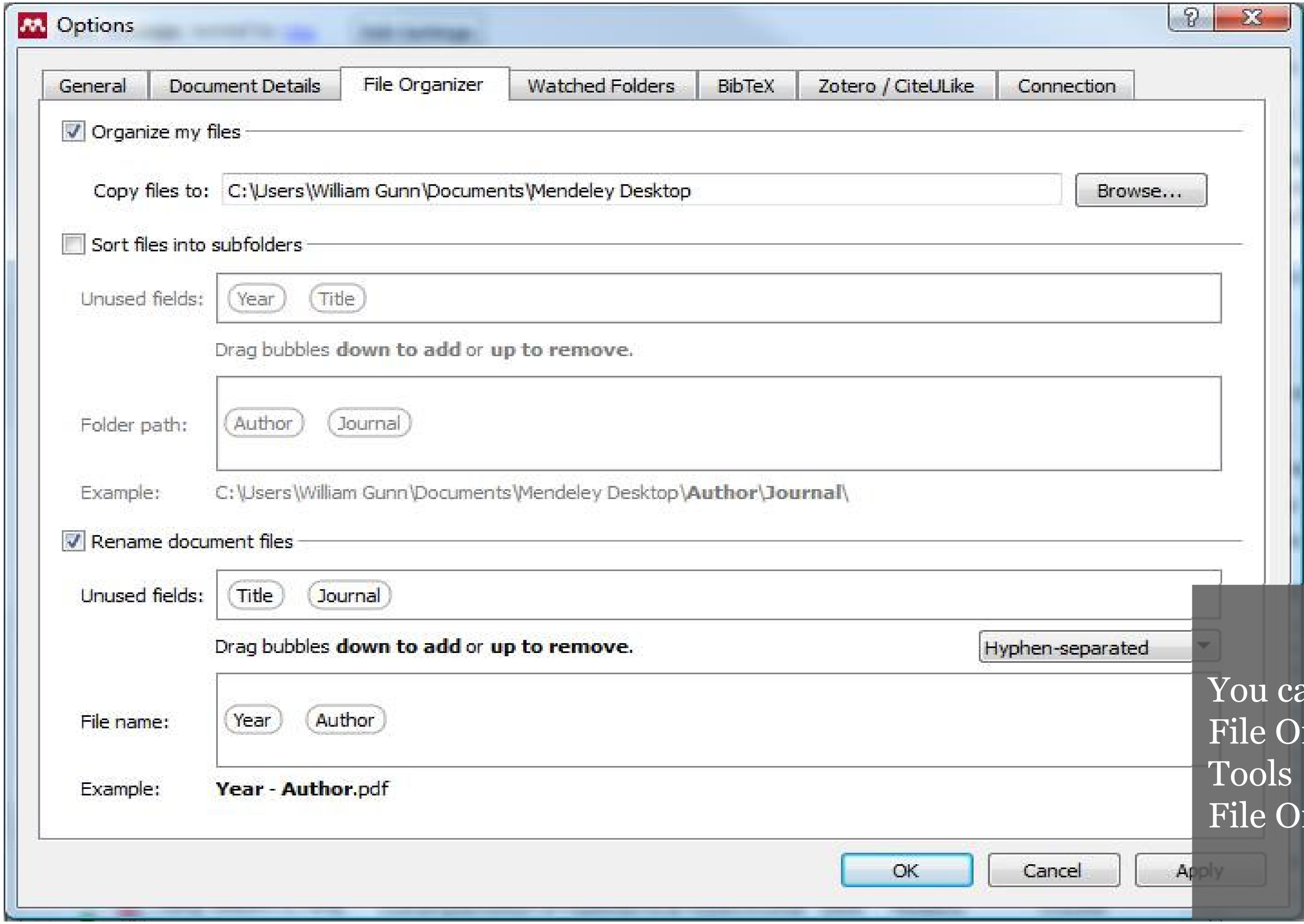
Full text search in Mendeley's PDF viewer



Annotate and highlight

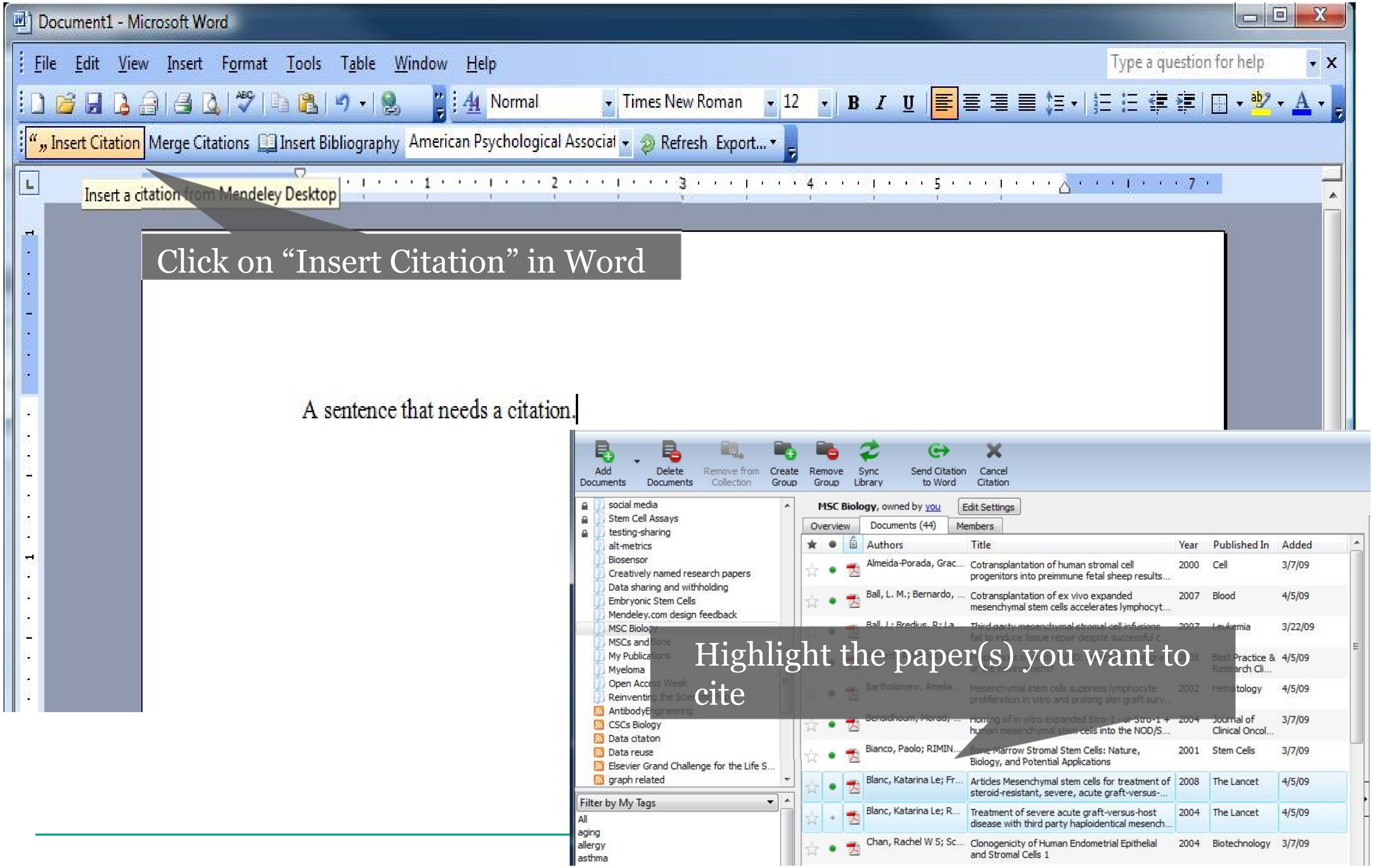


Mendeley‘s File Organizer

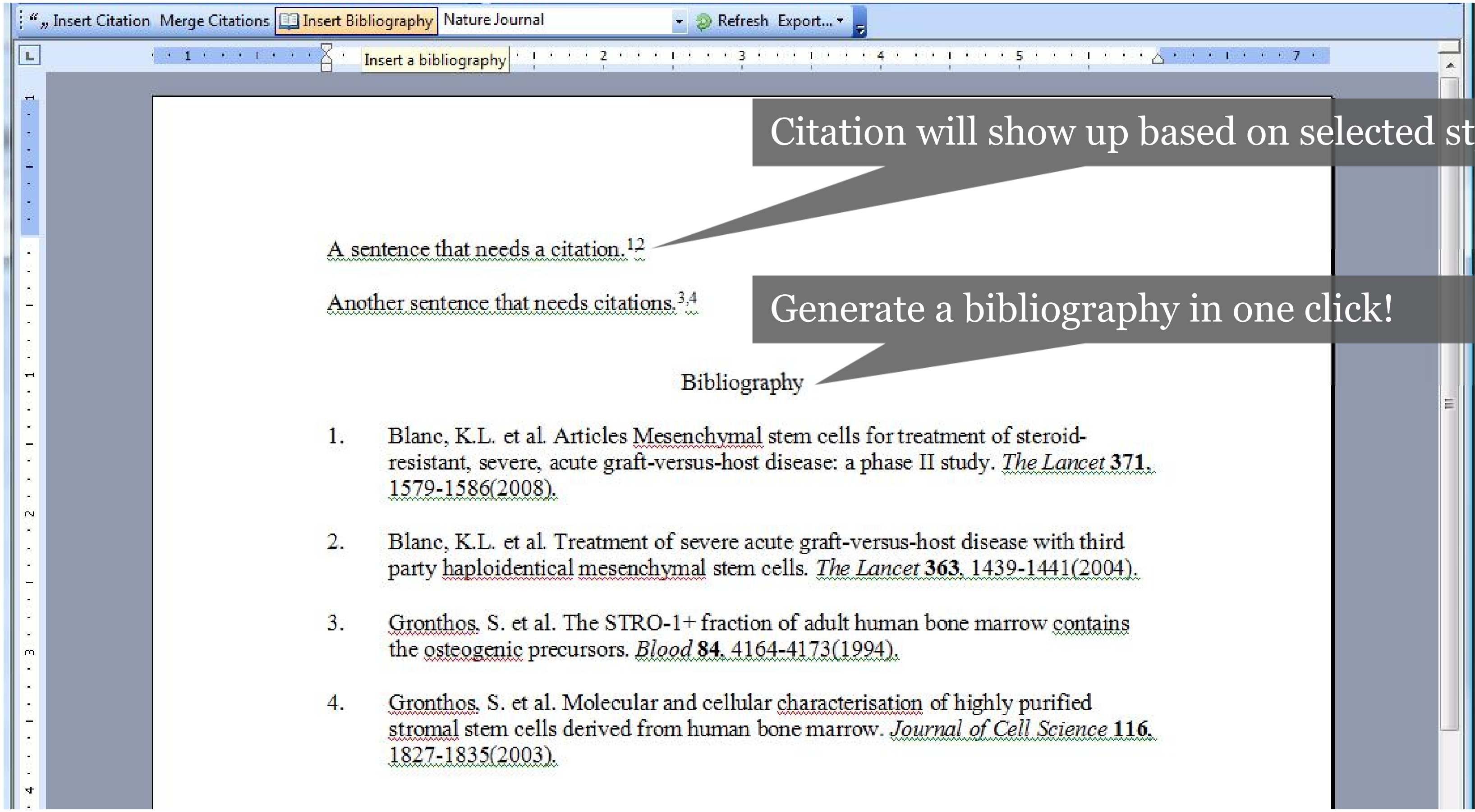


You can find the File Organizer in Tools > Options > File Organizer

Citing in Word & Open Office



Citing in Word & Open Office



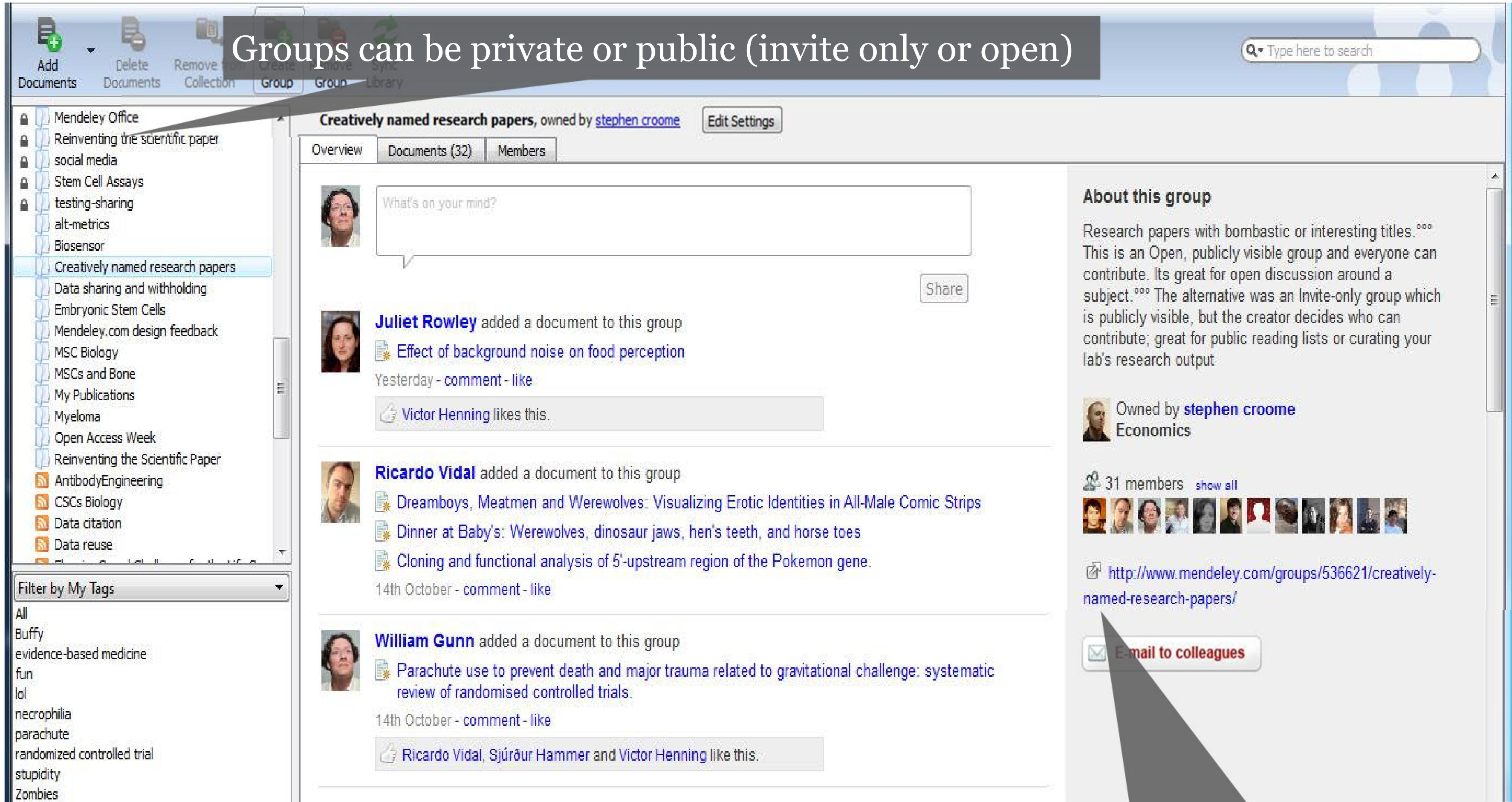
Citation will show up based on selected style

Generate a bibliography in one click!

Cite into Google documents
or other editors by
copy & paste

Share references with Mendeley Groups

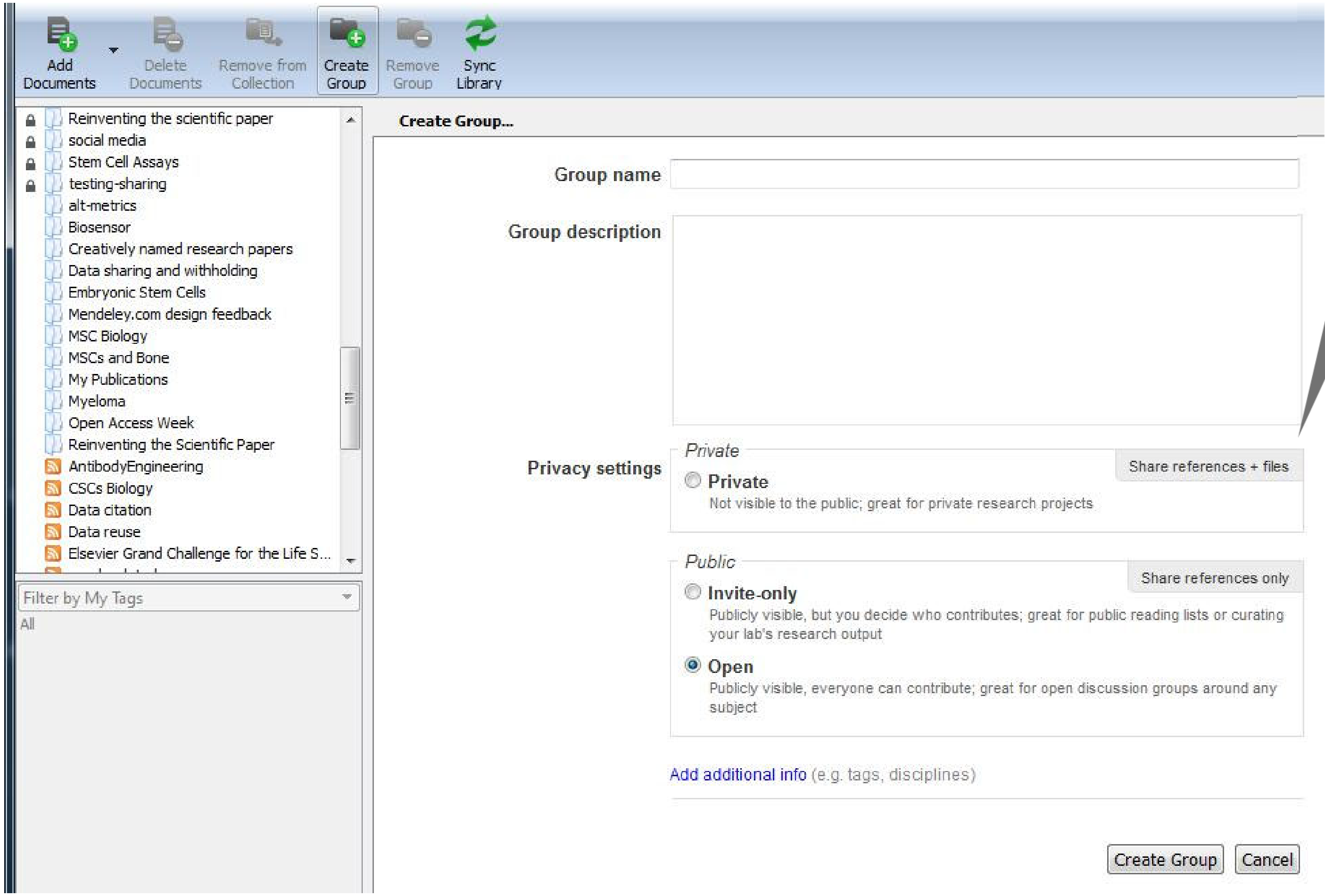
Groups can be private or public (invite only or open)



Public groups only have the reference details – no full text. Private groups contain the full text including notes & annotations.

View the group online – other users can request to join or simply follow the activity of the group

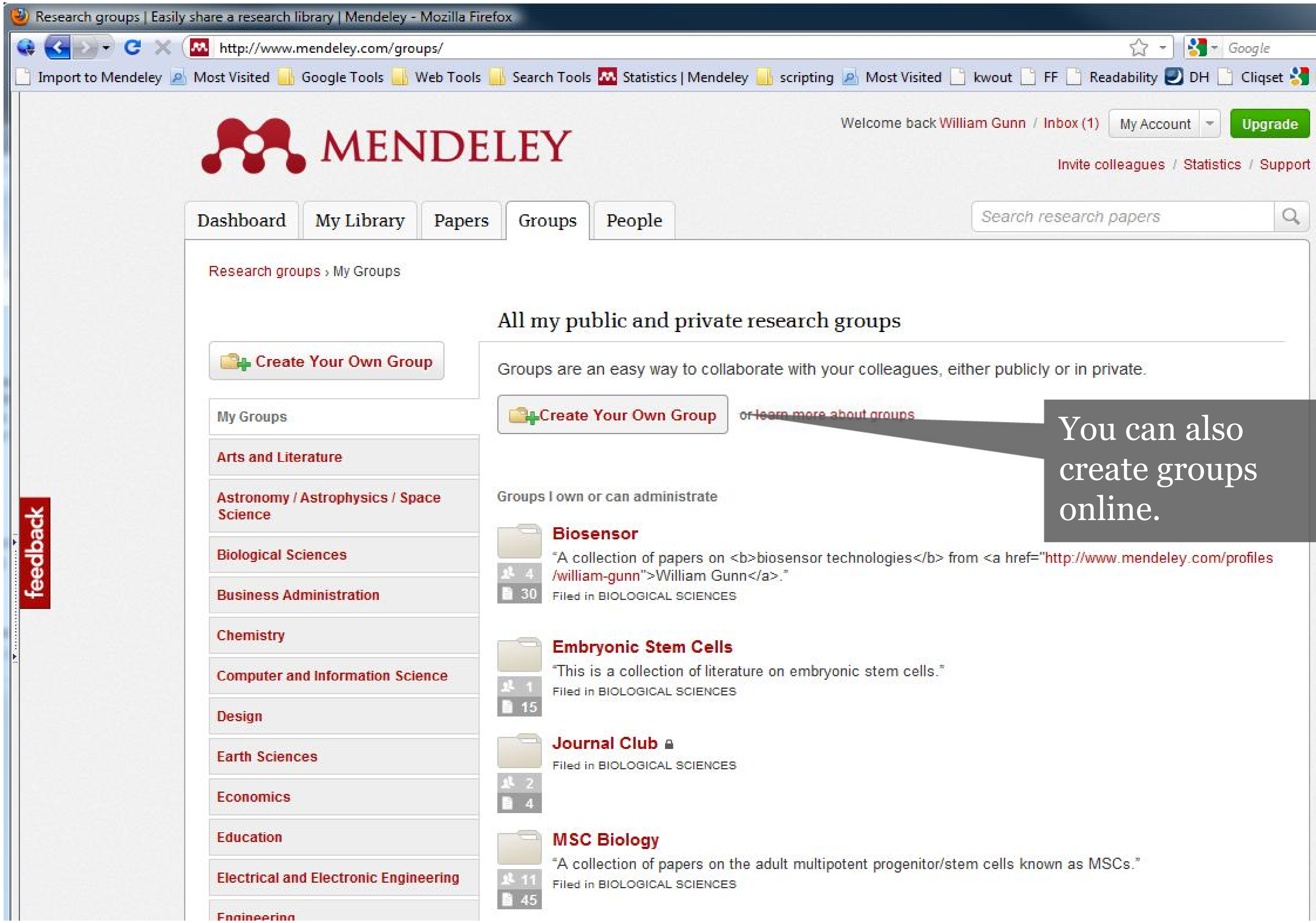
Create Groups in Mendeley Desktop



Private groups contain the full text.

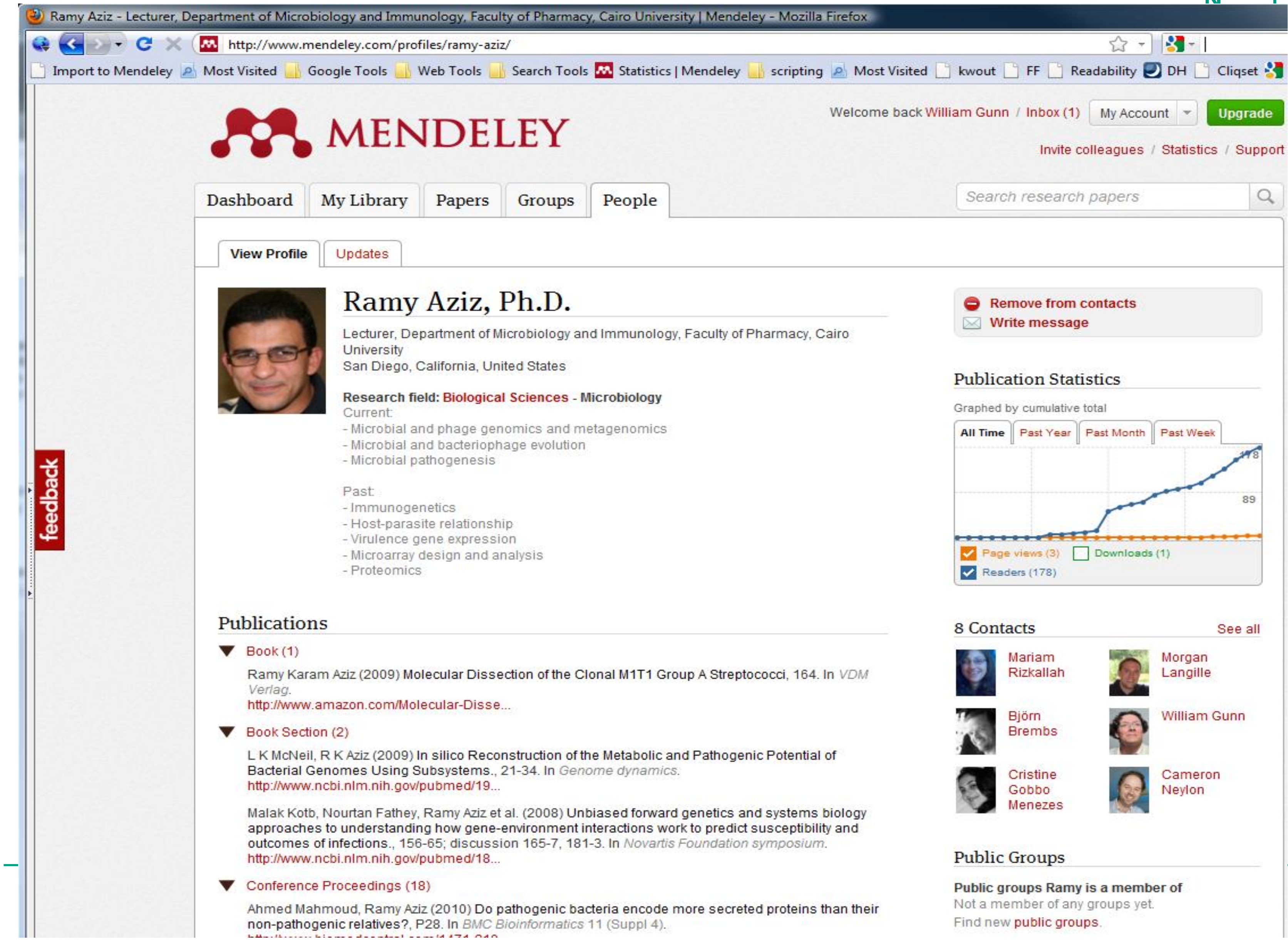
Public groups share references only.

Create Groups in Mendeley Desktop

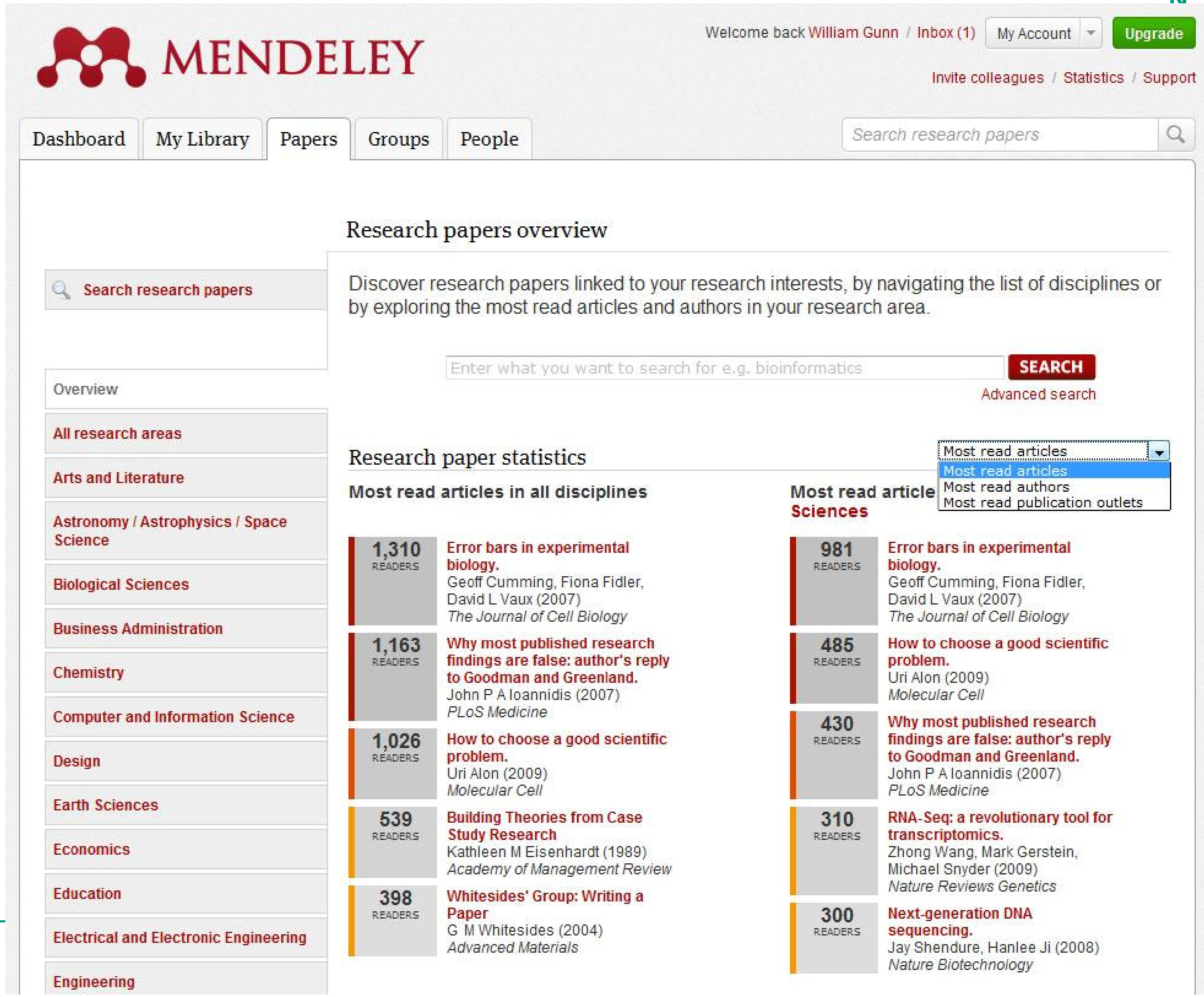


You can also create groups online.

Create your professional research profile



Search the Mendeley Research Catalog



Get readership information on papers

MENDELEY

Welcome back William Gunn / Inbox (1) My Account Upgrade

Invite colleagues / Statistics / Support

Dashboard | My Library | Papers | Groups | People

Search research papers

Find research papers › Biological Sciences › Bioinformatics Papers › R › RNA-Seq: a revolutionary tool for transcriptomics.

RNA-Seq: a revolutionary tool for transcriptomics.

Zhong Wang, Mark Gerstein, Michael Snyder

Add to My Library

Nature Reviews Genetics (2009)
Volume: 10, Issue: 1, Publisher: Nature Publishing Group, Pages: 57-63
PubMed ID: 19015660

Available from www.ncbi.nlm.nih.gov

Tags

ngs review rnaseq rna-seq transcriptome

Abstract

RNA-Seq is a recently developed approach to transcriptome profiling that uses deep-sequencing technologies. Studies using this method have already altered our view of the extent and complexity of eukaryotic transcriptomes. RNA-Seq also provides a far more precise measurement of levels of transcripts and their isoforms than other methods. This article describes the RNA-Seq approach, the challenges associated with its application, and the advances made so far in characterizing several eukaryote transcriptomes.

Cite this document (BETA)

APA | BibTeX | Cell | Chicago | Harvard | MLA | **Nature** | Science

1. Wang, Z., Gerstein, M. & Snyder, M. RNA-Seq: a revolutionary tool for transcriptomics. **10**, 57-63 (2009).at <http://www.ncbi.nlm.nih.gov/pubmed/19015660>

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Readership Statistics

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Related Research

33 mRNA-Seq whole-transcriptome analysis of a single cell.
Fuchou Tang, Catalin Barbacioru, Yangzhou Wang, et al. (2009)
Nature Methods

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Mendeley Desktop

Video tutorials: https://www.mendeley.com/guides/videos

Which of the presented today tools you think you are going to use in your future studies/research work?

Poll is full and no longer accepting responses

"Mendeley" "Mendeley Desktop" "Mendeley" "Mendeley" "Mendeley" "Google Scholar, Mendeley"

"Mendeley , sciencedirect, scopus" "Google scholar" "Research Gate" "Scopus" "Researchgate"

"Mendeley" "Mendeley" "Mendeley" "Mendely, IWA publishing, Researchgate, Sciencedirect" "Mendeley"

"Mendeley" "Mendeley" "Mendeley" "Mendeley platform" "Google Scholar"

"Scopus mendeley Google scholar" "Google scholar, mendeley desktop"

"Sciencedirect" "arXiv, Mendeley, Google scholar"

Poll Everywhere

How to increase the visibility of your research?

Harsha Ratnaweera

Adapted from various sources

THT 311

Why?

- Activities aimed at promoting research are increasingly important in researchers' work. By making your research visible and accessible you increase chances of your research being noticed, used and having impact, thus increasing your own reputation and chances of success in your academic work.

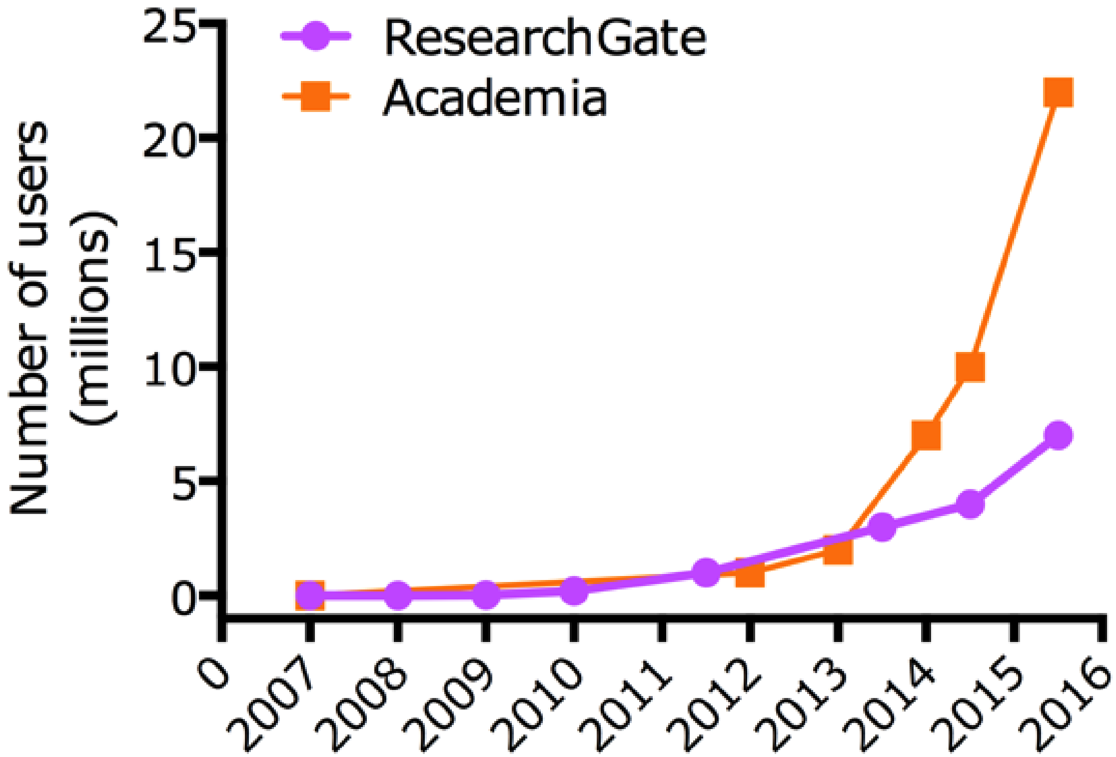
Some examples

- **Create and keep up to date online profile (or a web CV)**
- **Engage in social networking communities**
  - ResearchGate
  - Academia.edu
  - LinkedIn
  - Mendeley
  - GoogleScholar

Your CV

- https://europa.eu/europass/eportfolio/screen/cv-editor?lang=en
- https://standout-cv.com/blogs/cv-writing-advice-blog/115702276-example-of-a-good-cv

ResearchGate



LinkedIn

Nearly 740 million members in 200 countries and regions worldwide
176M+
United States
17M+
Canada
15M+
Mexico
163M+
Europe
UK
France
Italy
DACH
Spain
Netherlands
Belgium
Denmark
Hungary
Portugal
Romania
Sweden
Czech Rep.
Finland
Ireland
Poland
Norway
9M+
Colombia
47M+
Brazil
5M+
Chile
8M+
Argentina
2M+
Morocco
9M+
Turkey
1M+
Israel
5M+
Egypt
5M+
Nigeria
4M+
UAE
4M+
Saudi Arabia
2M+
Kenya
8M+
South Africa
74M+
India
52M+
Chinese Mainland
2M+
Republic of Korea
2M+
Japan
2M+
Hong Kong (SAR)
2M+
Taiwan
9M+
The Philippines
2M+
Singapore
5M+
Malaysia
17M+
Indonesia
2M+
New Zealand
11M+
Australia

Value of LinkedIn

- **1. You can tap into its powerful job board**
- **2. You can build your brand**
- **3. It can help rank your name on Google**
- **4. It maintains your list of contacts**
- **5. You can research companies and its employees**
- **6. It can help you tap into industry news**
- **7. Network, network, network!**

Scopus

Scopus Preview

Search for an author profile

Scopus is the world's largest abstract and citation database of peer-reviewed research literature. With over 22,000 titles from more than 5,000 international publishers.
You can use this free author lookup to search for any author; or, use the Author Feedback Wizard to verify your Scopus Author Profile.
Register for your unique ORCID and use Scopus to import your records.

Research publication writing

Harsha Ratnaweera

Adapted from Scribbr, Wiley and other sources

THT 311

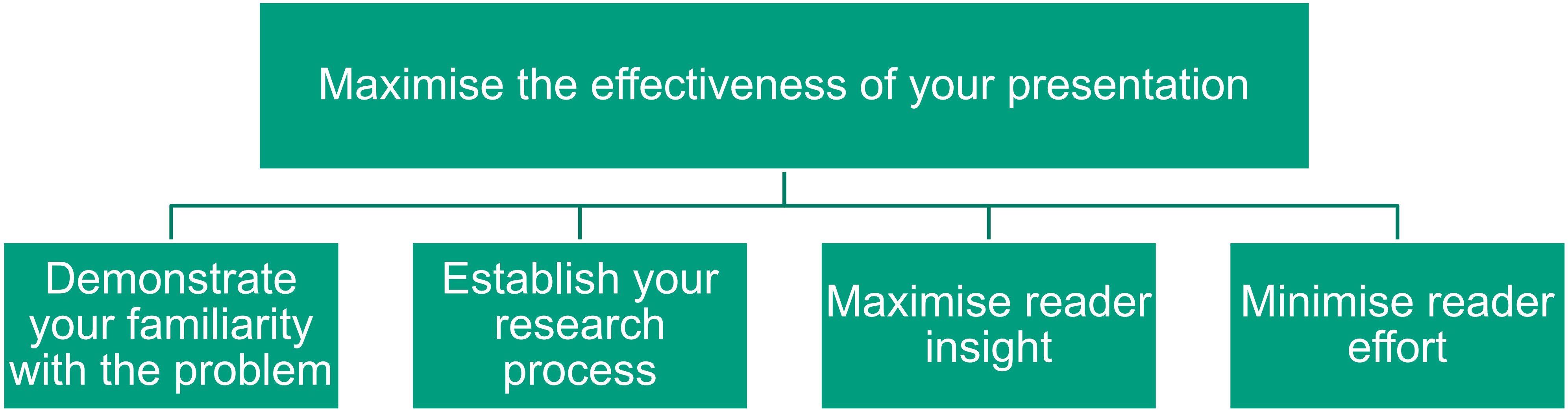
Research publications and reports

- A **research paper** is a piece of academic writing that provides analysis, interpretation, and argument based on in-depth independent research.

- An **academic essay** is a focused piece of writing that develops an idea or argument using evidence, analysis and interpretation.

- Research papers are similar to academic essays, but they are usually longer and more detailed assignments, designed to assess not only your writing skills but also your skills in scholarly research. Writing a research paper requires you to demonstrate a strong knowledge of your topic, engage with a variety of sources, and make an original contribution to the debate.

Objective of writing a report



Essay writing process

- **Preparation:** Decide on your topic, do your research, and create an essay outline.
- **Writing:** Set out your argument in the introduction, develop it with evidence in the main body, and wrap it up with a conclusion.
- **Revision:** Check the content, organization, grammar, spelling, and formatting of your essay.

Preparation for writing an essay

- **Understand your assignment:** What is the goal of this essay? What is the length and deadline of the assignment? Need any clarifications?
- **Define a topic:** try to pick something that you already know a bit about or/and that will hold your interest.
- **Do your research:** Read primary and secondary sources and take notes to help you work out your position and angle on the topic. Note the sources and the points
- **Come up with a thesis or a problem you plan to elaborate/solve.** A clear thesis is essential for a focused essay—you should keep referring back to it as you write.
- **Create an outline:** Map out the rough structure of your essay in an outline. This makes it easier to start writing and keeps you on track as you go. Follow commonly used structures if possible.

Common structure

- Title
- Name, affiliation
- Abstract
- Introduction/Background
- Method
- Results
- Discussion
- Conclusions
- References

- Preface
- Table of contents
- Table of Figures, tables
- Abbreviations
- Recommendations for future
- Acknowledgement
- Appendix

Conclusions:
Synthesis of arguments
Check if it answers the problem defined
Strong closing statement

Plagiarism

Ouriginal

What is Ouriginal?

Ouriginal is an award-winning software solution that combines text-matching with writing style analysis, enabling educators and users to assess the authenticity of any text. Our product helps create an environment which fosters fairness and sparks creativity among students, facilitating personal development by unlocking their full potential. Ouriginal can be seamlessly integrated into your current workflow, whether you use it through a learning management system (LMS) or as a stand-alone product.

Reference styles

- Reference styles are predefined rules describing how to cite sources and set up literature lists.
- The two most common types are author-year style (f. ex. Harvard, APA) or numeric style (f. ex. Vancouver).
- You can find these and many other styles in Mendeley, EndNote. Etc.
- Some scientific journals often have their own styles.

- https://www.nmbu.no/en/about-nmbu/library/write-and-cite/styles/node/37678

Research publications

- Producing research publications is a natural part for academia, researchers and research students
- CV, job applications, research project applications, promotions etc--
- There are “good” and “not so good” journals (predatory journals?)
- Open Access vs Subscription journals

Common reasons for rejection

- The manuscript fails the technical screening
- The manuscript does not fall within the journal’s Aims and Scope
- The research topic isn’t of great enough significance
- The research is over-ambitious
- A clear hypothesis hasn’t been established
- The manuscript is incomplete
- There are flaws in the procedures, presentation or analysis of the data
- Flaws in the manuscript’s arguments and/or conclusions
- Language, writing and spelling issues
- Plagiarism

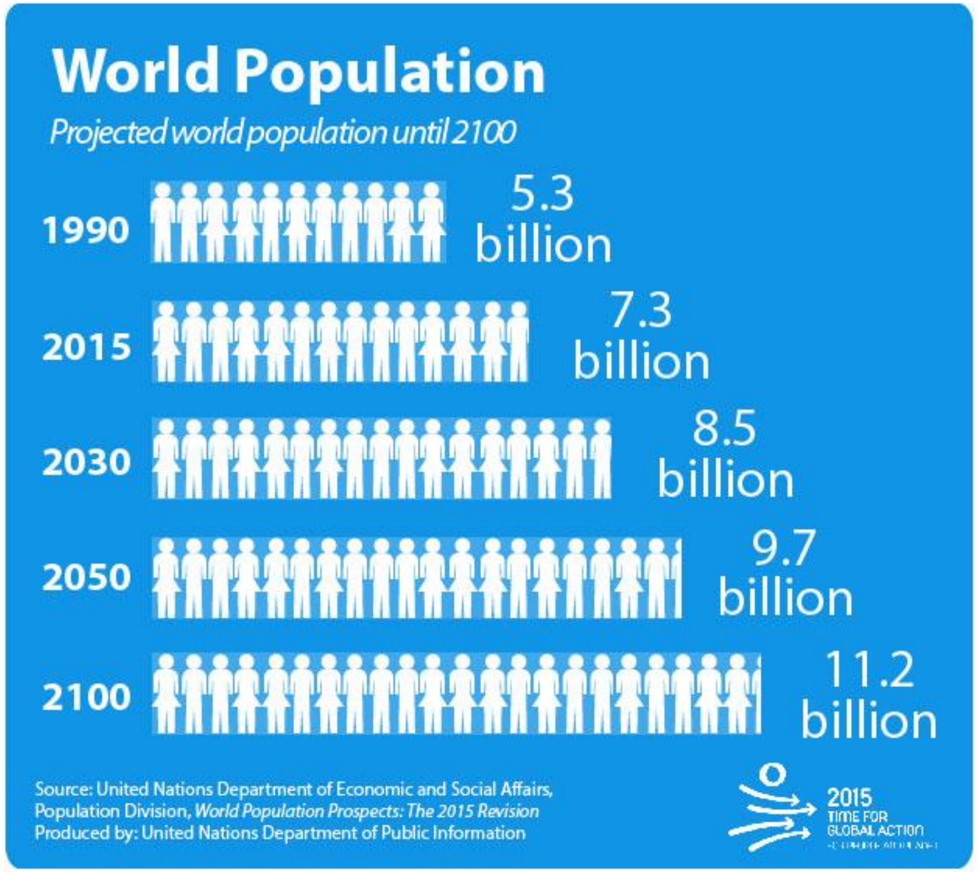
Contaminants of Emerging Concern *(CECs)*

What is contaminating our waters next?

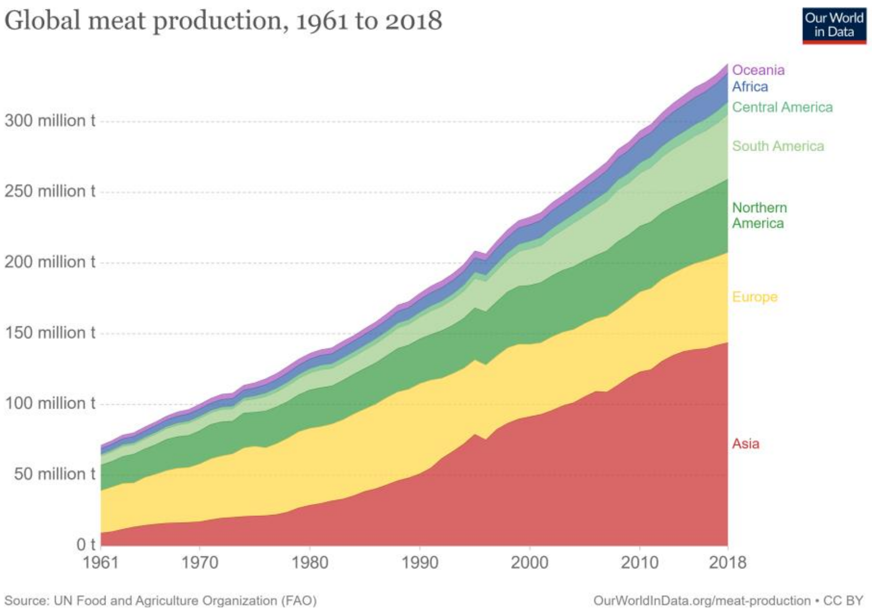
THT 311 25 June 2021

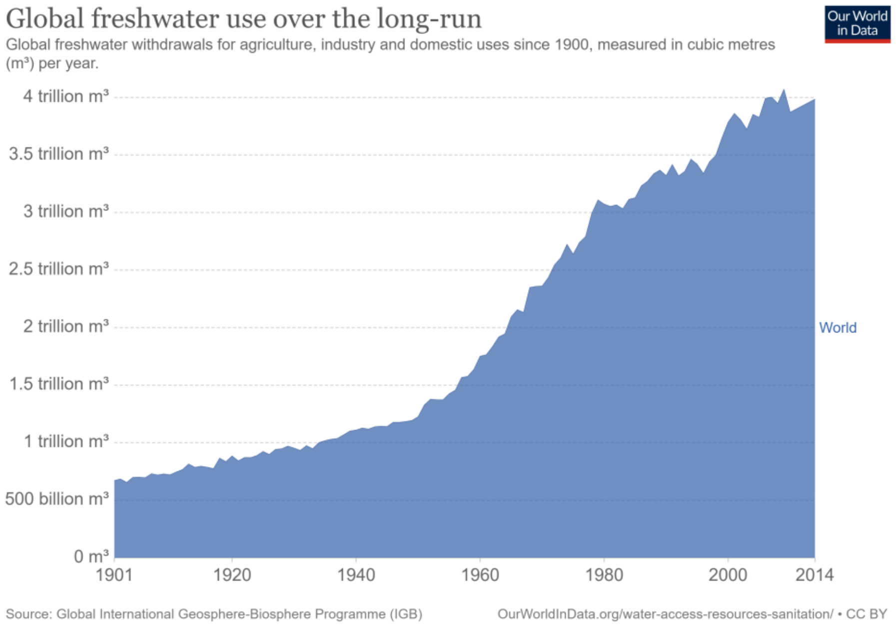
Agnieszka, Cuprys, Zakhar Maletskyi

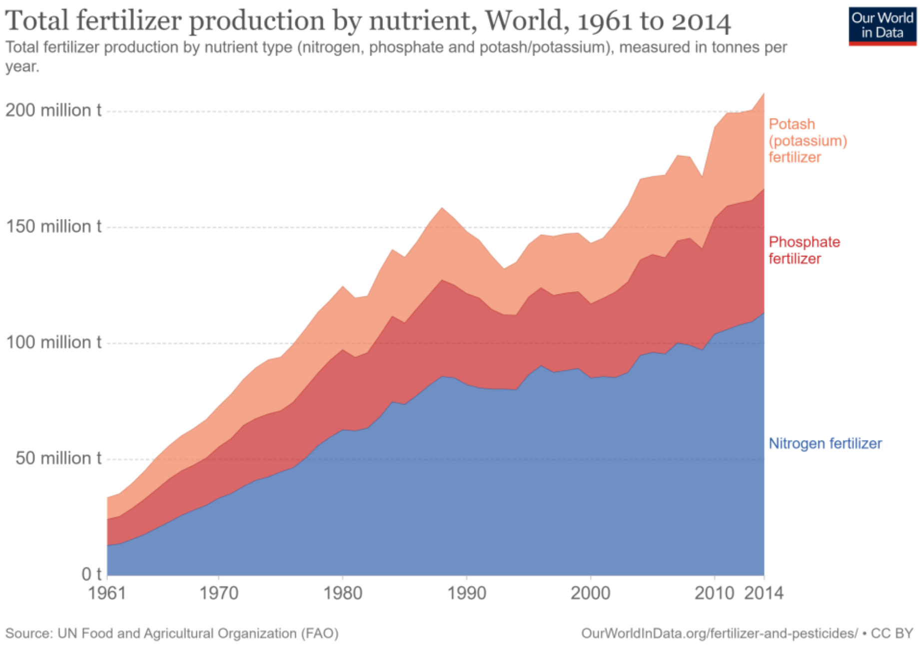
World population increase

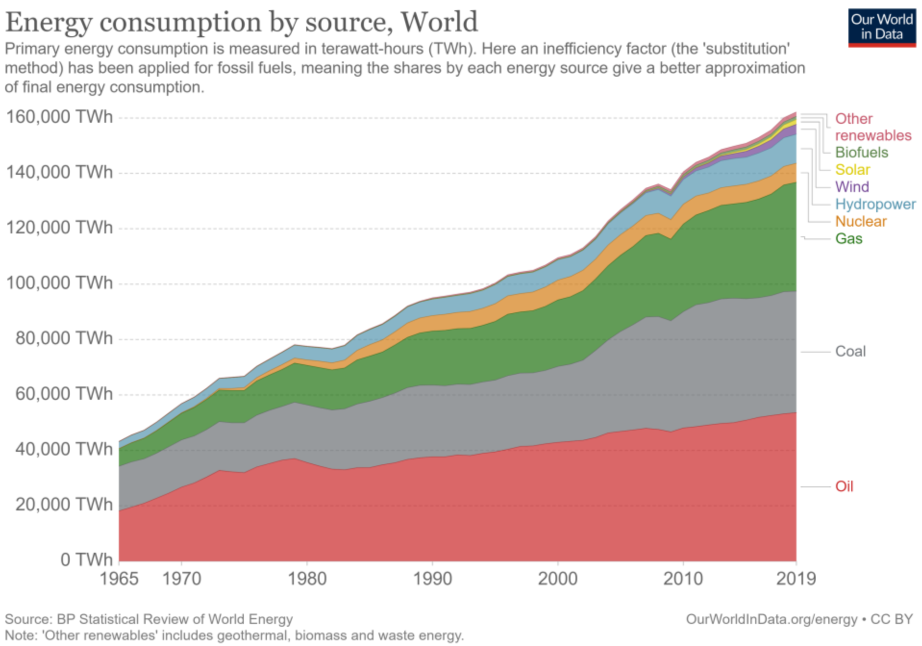


Our World in Data

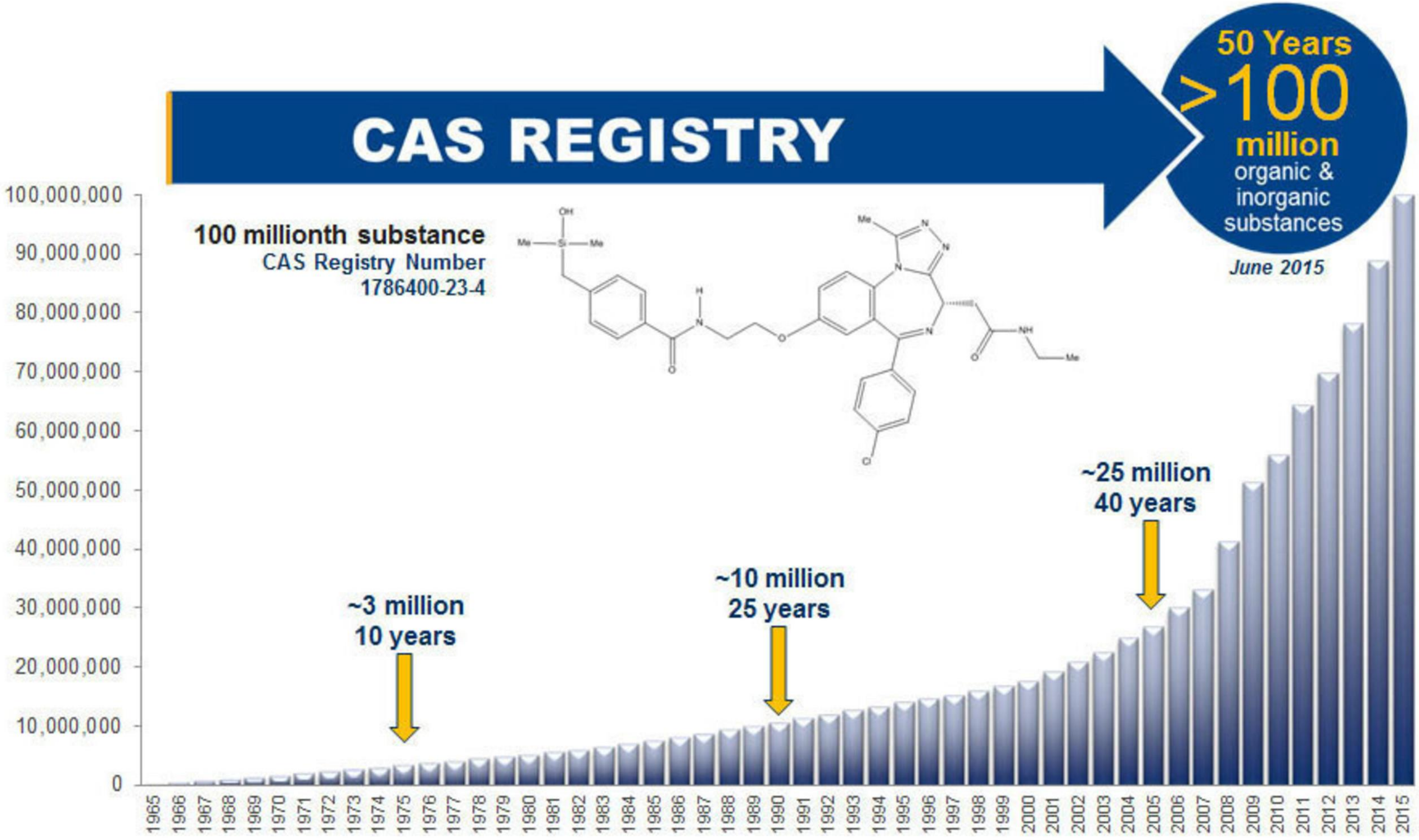






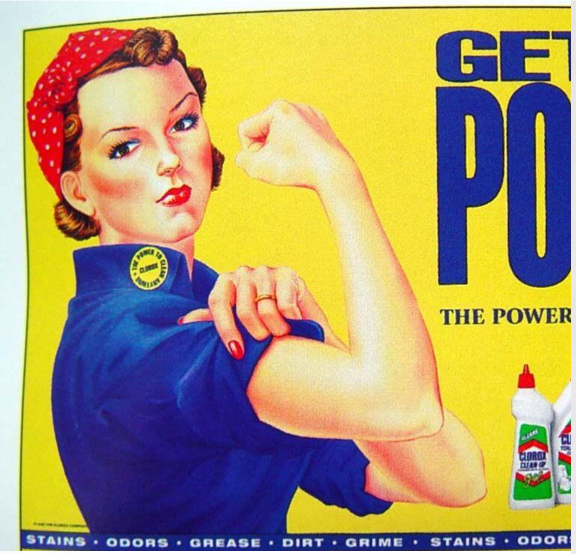


Increase in synthetic chemicals present in aquatic systems



What does this mean in practice?

Before…


THE POWER
STAINS · ODORS · GREASE · DIRT · GRIME · STAINS


FOR A
HOUSE
www.clorox.com


Zalo
100
EFFEKTIV
Zalo
100
NY
Zalo
Ultra

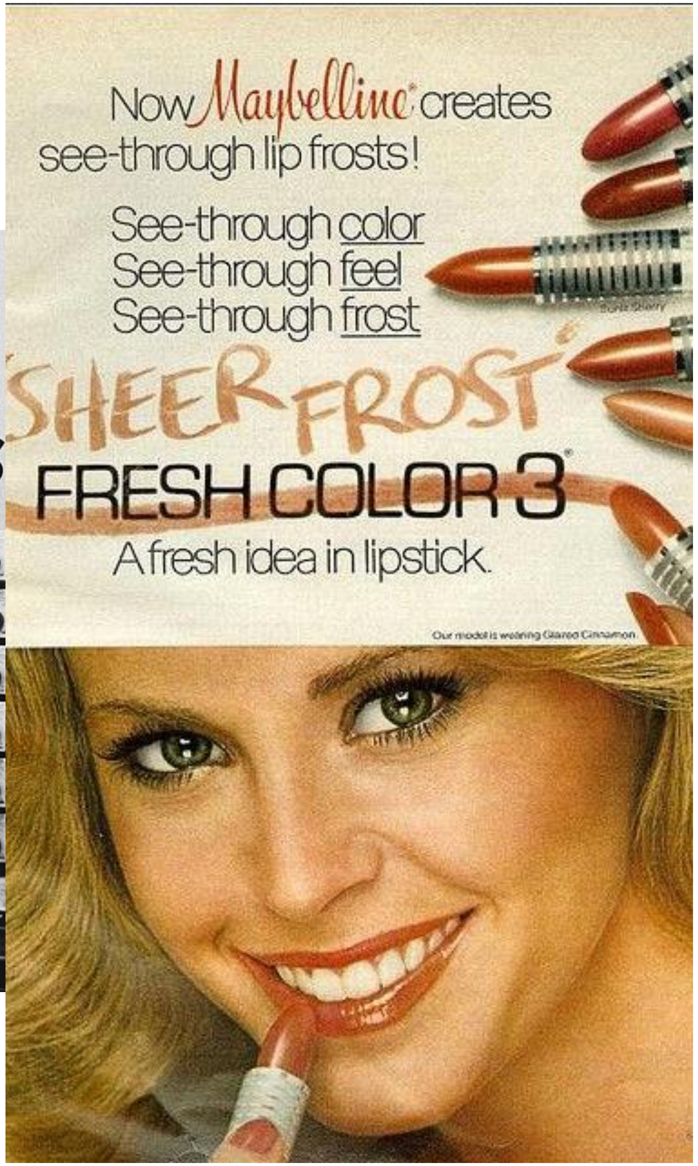

miracle
white
SUPER CLEANER
ry Miracle White
Super Cleaner

Now

Before…

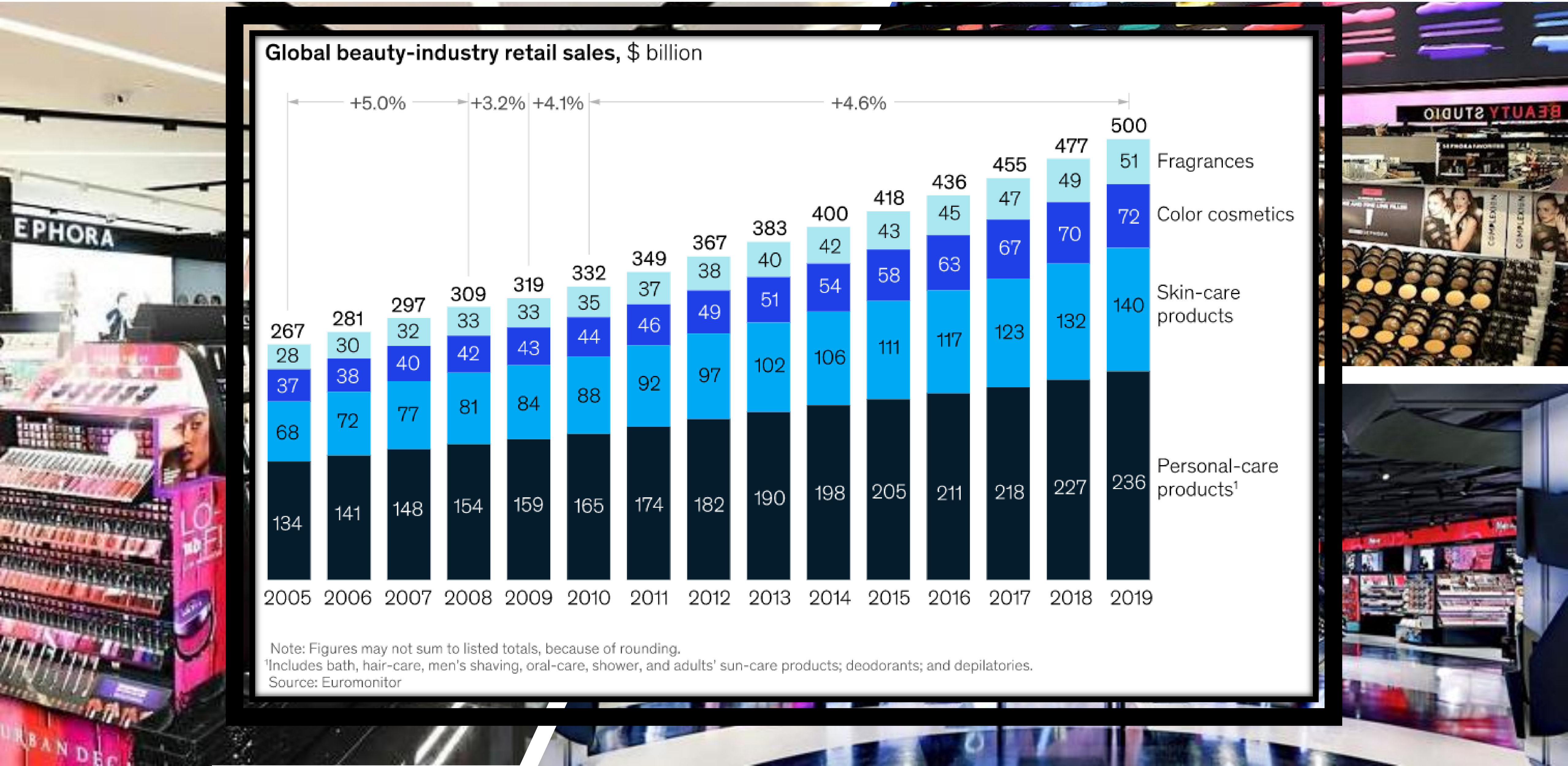
AVON
skin
freshener
AVON
's Makeup Look - Glamourdaze.com

CONSUMER VALUE STORES
Your Headquarters
FOR HEALTH and BEAUTY AIDS



Now Maybelline creates
see-through lip frosts!
See-through color
See-through feel
See-through frost
SHEER FROST
FRESH COLOR 3
A fresh idea in lipstick.

Now


Global beauty-industry retail sales, $ billion
+5.0%
+3.2%
+4.1%
+4.6%
2005: 267 — 28, 37, 68, 134
2006: 281 — 30, 38, 72, 141
2007: 297 — 32, 40, 77, 148
2008: 309 — 33, 42, 81, 154
2009: 319 — 33, 43, 84, 159
2010: 332 — 35, 44, 88, 165
2011: 349 — 37, 46, 92, 174
2012: 367 — 38, 49, 97, 182
2013: 383 — 40, 51, 102, 190
2014: 400 — 42, 54, 106, 198
2015: 418 — 43, 58, 111, 205
2016: 436 — 45, 63, 117, 211
2017: 455 — 47, 67, 123, 218
2018: 477 — 49, 70, 132, 227
2019: 500 — 51, 72, 140, 236
Fragrances
Color cosmetics
Skin-care products
Personal-care products[1]
Note: Figures may not sum to listed totals, because of rounding.
[1]Includes bath, hair-care, men's shaving, oral-care, shower, and adults' sun-care products; deodorants; and depilatories.
Source: Euromonitor
EPHORA
BEAUTY STUDIO
URBAN DEC

Soap

Conditioner

Shampoo

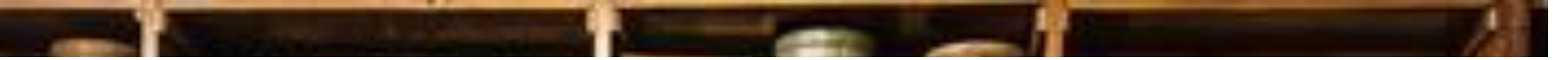
Face wash

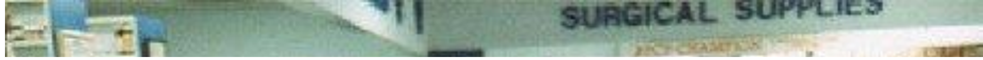
Dish wash

Body lotion

Deodorizer

Baby bath





Before…

Now

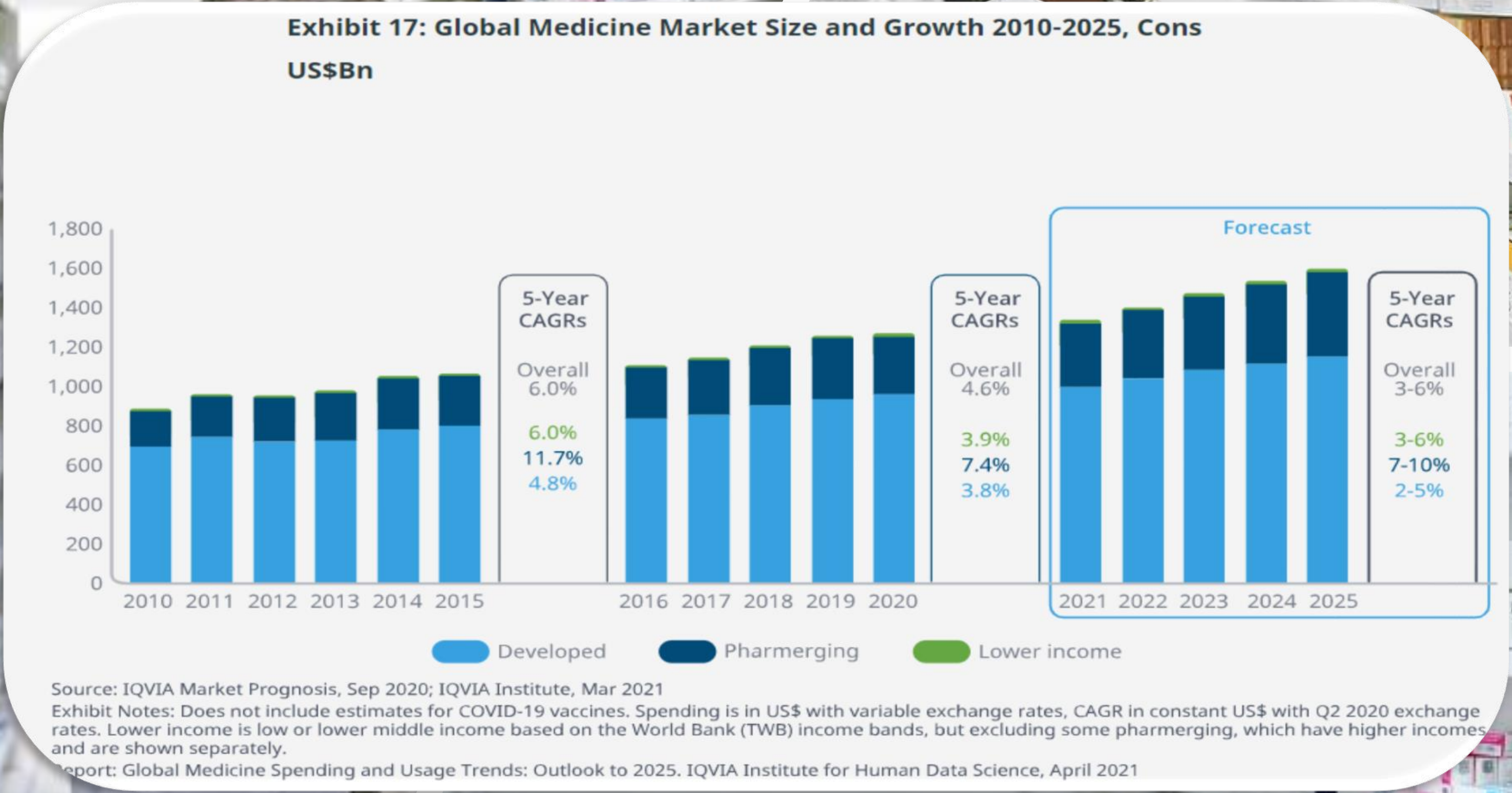
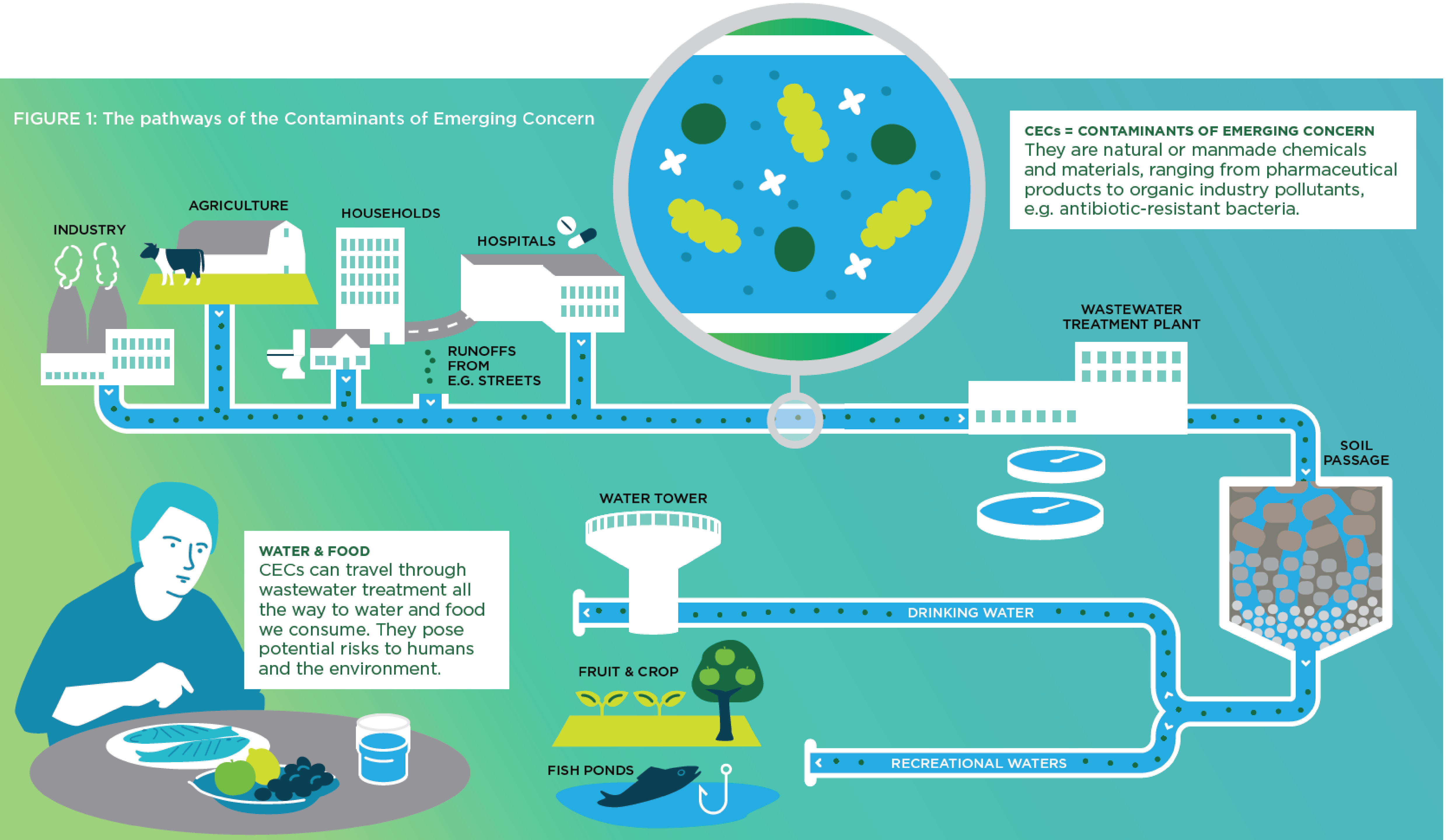
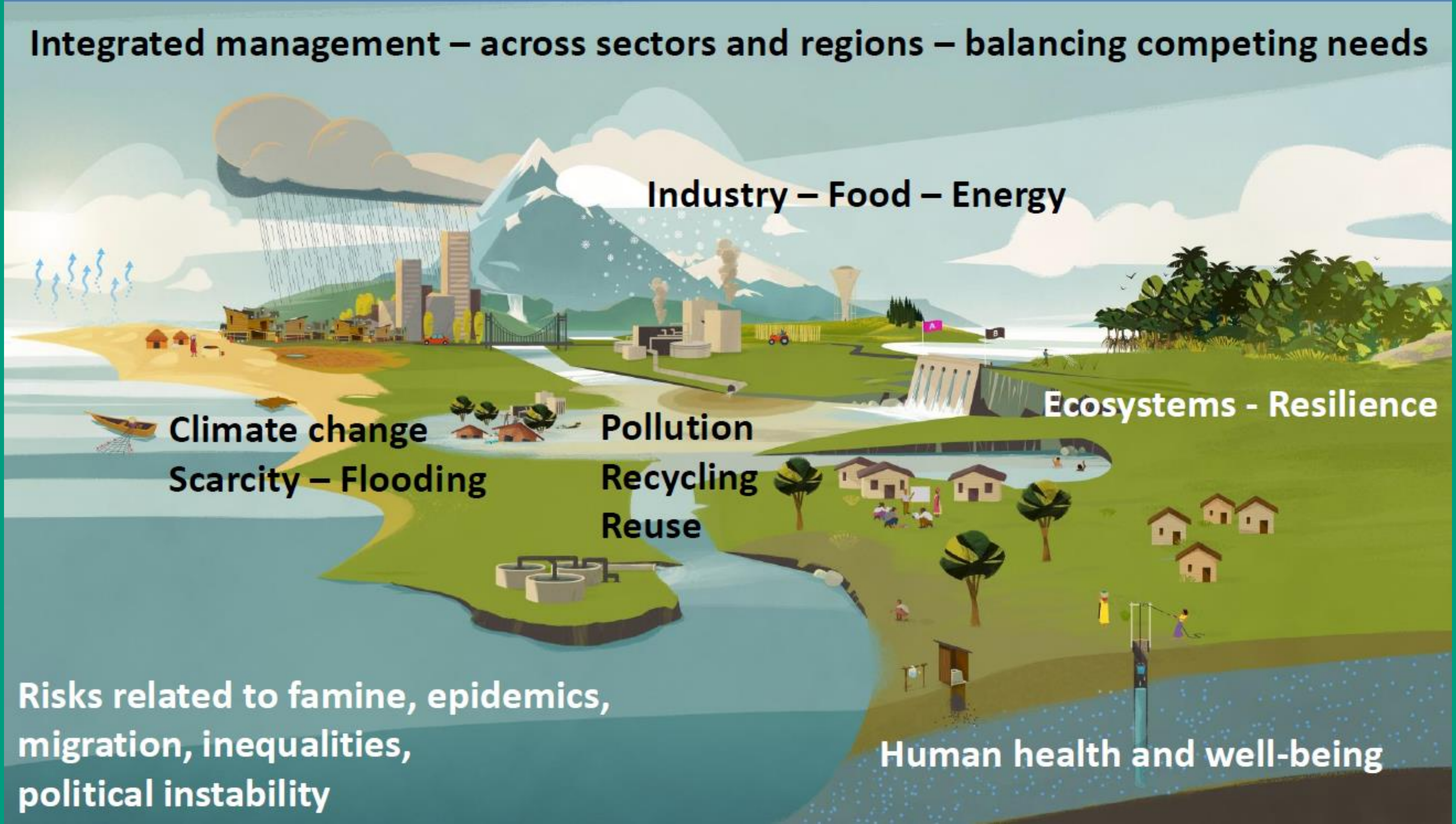


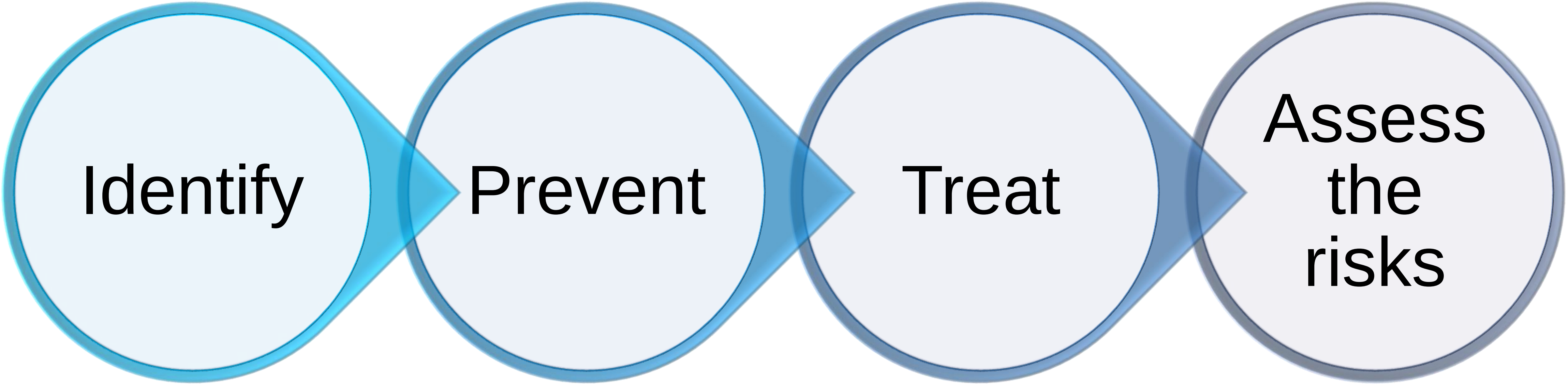
Exhibit 17: Global Medicine Market Size and Growth 2010-2025, Cons
US$Bn
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
2010 2011 2012 2013 2014 2015
5-Year CAGRs
Overall 6.0%
6.0%
11.7%
4.8%
2016 2017 2018 2019 2020
5-Year CAGRs
Overall 4.6%
3.9%
7.4%
3.8%
Forecast
2021 2022 2023 2024 2025
5-Year CAGRs
Overall 3-6%
3-6%
7-10%
2-5%
Developed
Pharmerging
Lower income
Source: IQVIA Market Prognosis, Sep 2020; IQVIA Institute, Mar 2021
Exhibit Notes: Does not include estimates for COVID-19 vaccines. Spending is in US$ with variable exchange rates, CAGR in constant US$ with Q2 2020 exchange rates. Lower income is low or lower middle income based on the World Bank (TWB) income bands, but excluding some pharmerging, which have higher incomes and are shown separately.
eport: Global Medicine Spending and Usage Trends: Outlook to 2025. IQVIA Institute for Human Data Science, April 2021



Water JPI, Policy Brief, 22 October 2018

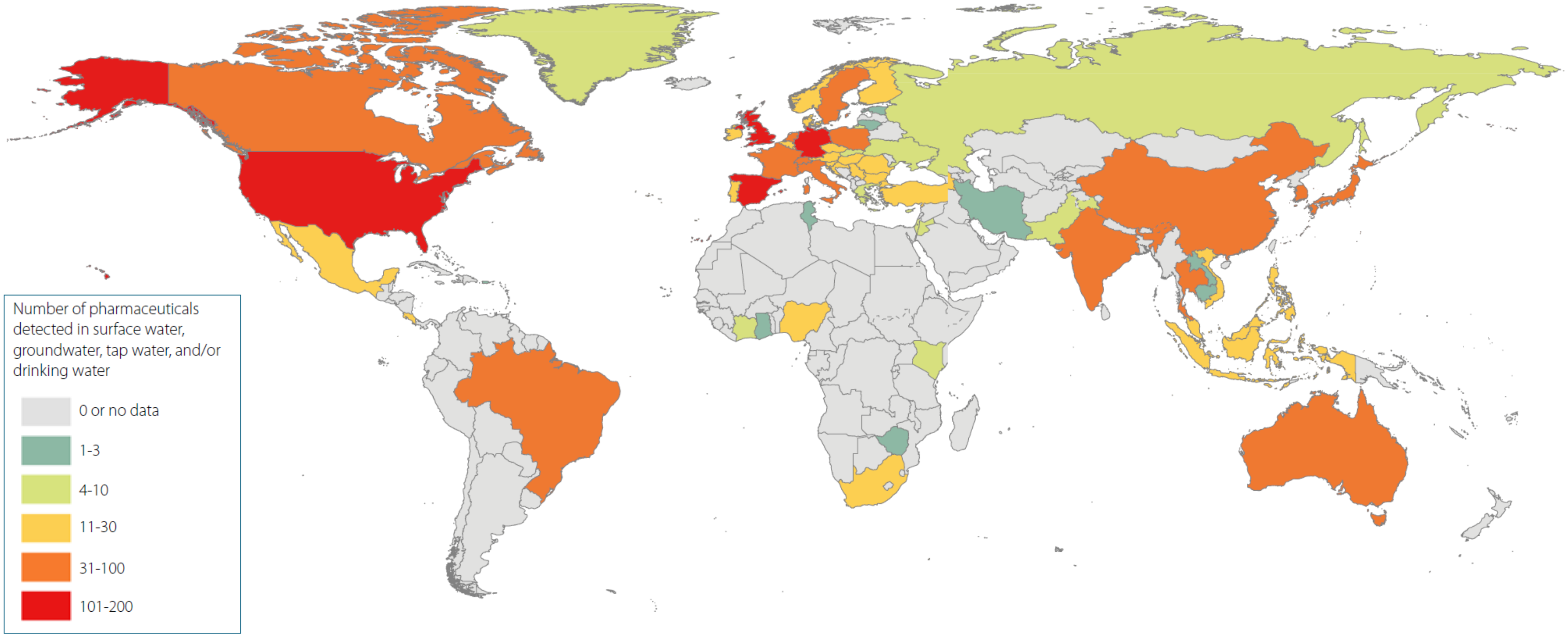
Water and sanitation at the core of sustainable development




Identify
Prevent
Treat
Assess the risks

1. Identify

1. Identify: **Pharmaceuticals**



1. Identify: **Pharmaceuticals**

4000

ACTIVE PHARMACEUTICAL INGREDIENTS

About 4,000 active pharmaceutical ingredients are being administered worldwide in prescription medicines, over-the-counter therapeutic drugs and veterinary drugs (Weber et al., 2014).

30-90%

ORAL DOSES EXCRETED AS ACTIVE SUBSTANCES

Pharmaceuticals administrated to humans or animals are excreted via urine and faeces, with 30 to 90% of oral doses generally excreted as active substances (BIO Intelligence Service, 2013).

6.5 %

PHARMACEUTICAL INDUSTRY ANNUAL GROWTH RATE

Projected growth rate of the pharmaceutical industry: 6.5% per year by 2022 (UN Environment, 2019).

CLIMATE CHANGE TO INCREASE RISK OF DISEASE

Millions of people are predicted to be newly at risk to mosquito-borne and tick-borne diseases under climate change. (Cavicchioli et al., 2019).

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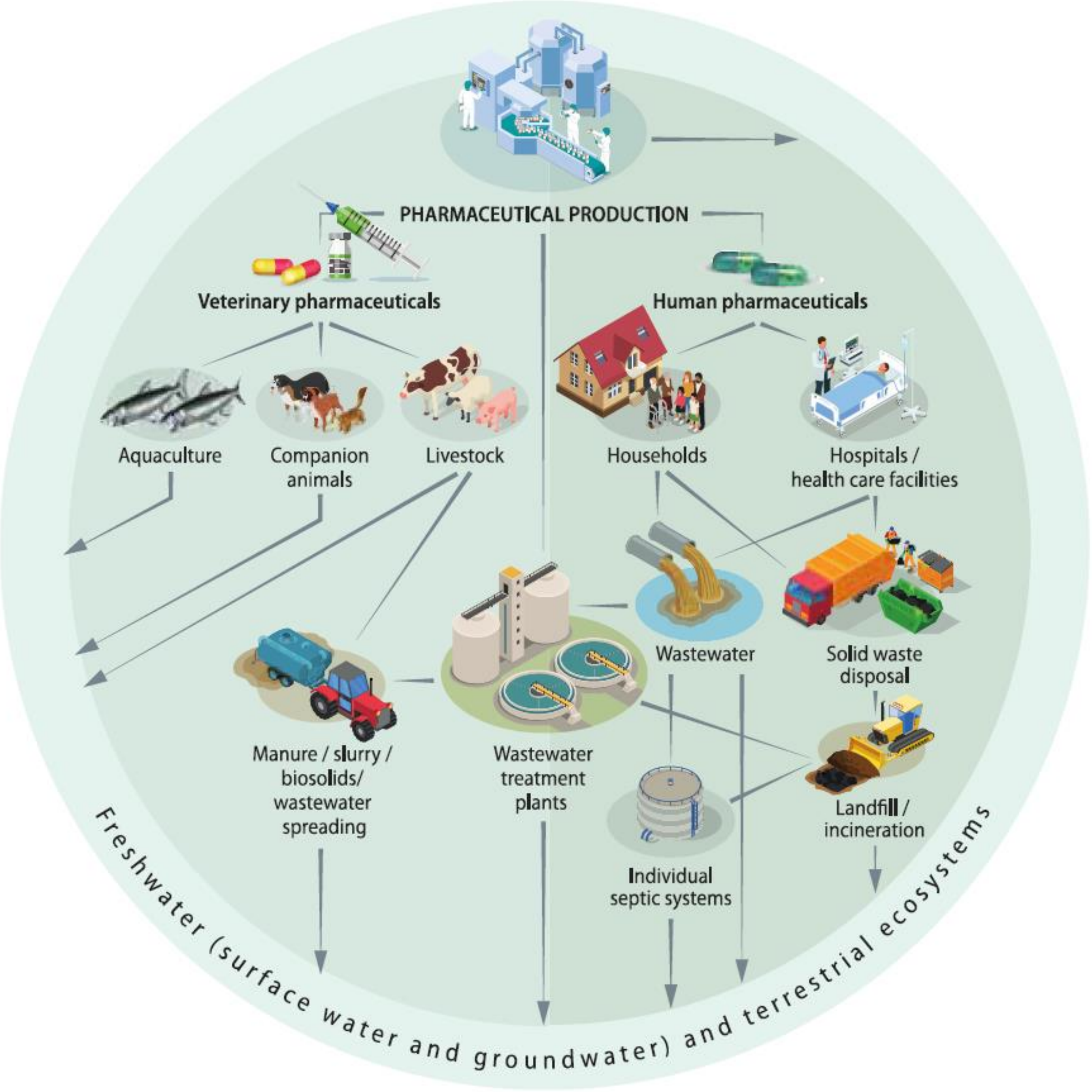

67 %

PROJECTED INCREASE IN LIVESTOCK ANTIBIOTICS WORLDWIDE BY 2030

Projected increase in antibiotics administered to livestock animals in feed: 67% worldwide by 2030 (from 2015 levels) (Van Boeckel et al., 2015). Much of this increase will come in emerging economies.

43-67 %

INCREASE IN PHARMACEUTICAL USAGE, GERMANY

In Germany, pharmaceutical usage is projected to increase by 43-67% by the year 2045 (from a baseline of 2015). An ageing population is thought to be the main driver (Civity, 2017).

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1. Identify: **Pharmaceuticals**

Sources	Pathways	Concentration patterns	Pharmaceutical properties	Receiving environment type (sinks)	Concentration, context-dependent factors
• Pharmaceutical manufacturing plants • WWTPs - Municipal - Hospitals - Industry • Agriculture (particularly intensive livestock farming) • Aquaculture • Septic tanks • Waste management facilities (landfills).	• **Point source** (WWTP discharge) • **Diffuse source** (i.e. agricultural runoff, leaching of septic tanks to groundwater).	• **Continuous** (e.g. WWTPs) • **Seasonal** (linked with farming practices and with seasonal influenza and allergies, water flow and temperature) • **Intermittent** (linked with rainfall events, stormwater overflow, irrigation patterns and pandemics).	• **Persistence** - Half life - Solubility - Metabolites - Transformation products • **Bioaccumulation** • **Toxicity** - Individual effects - Population effects - Additive effects - Mixture effects • **Mobility**	• Rivers • Lakes • Groundwater • Soil • Sediment • Coastal zones Oceans	• Medical, agriculture and veterinary practices • Illicit drug use • Consumption rates • Pharmaceutical properties • Disposal and waste management practices • WWTP technology, operation and removal efficiency • Receiving environment type • Climate • Drainage characteristics • Water flow variations • Sunlight, temperature • Presence of other pollutants • Exposure history • Disturbance regime • Food web structure

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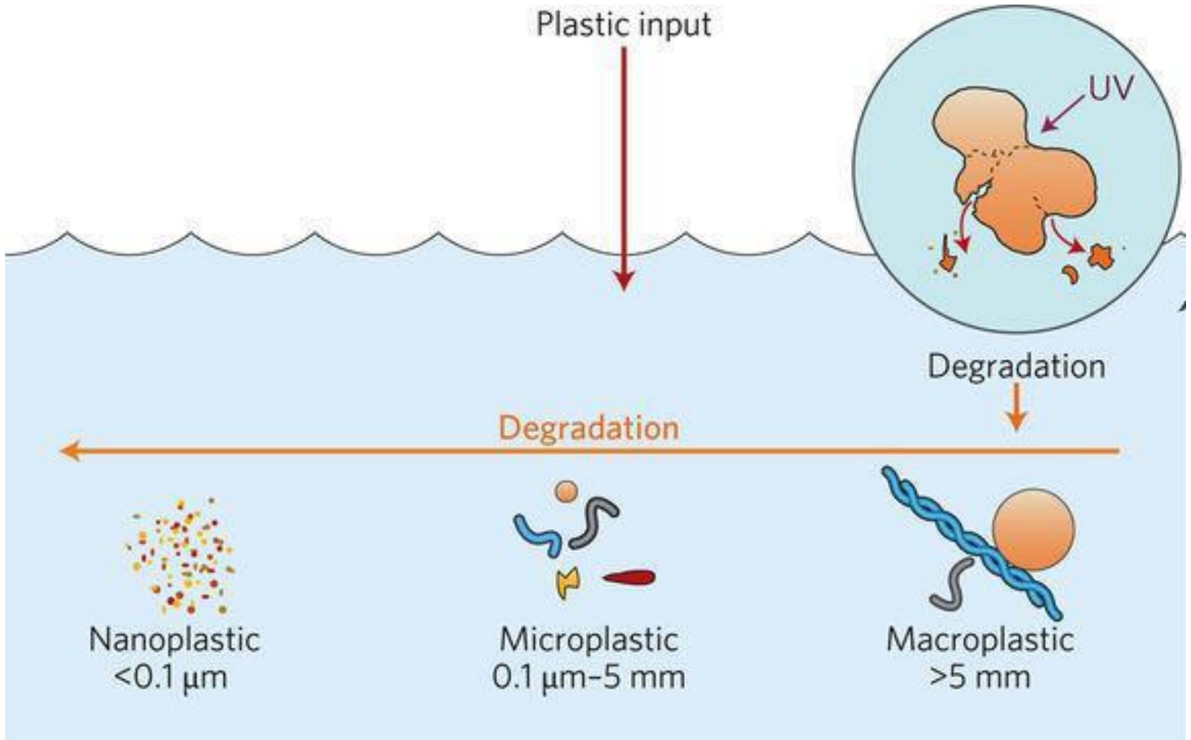
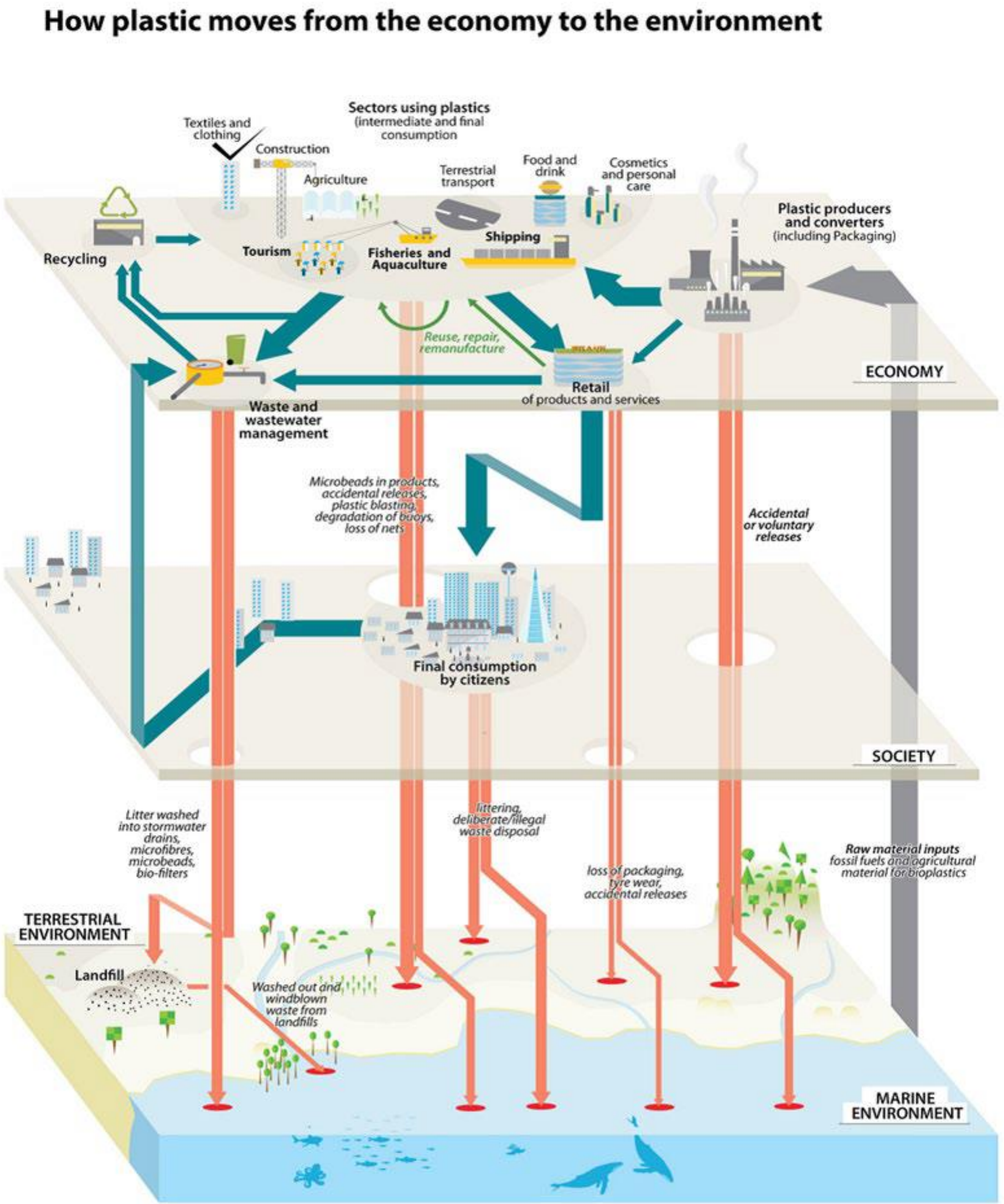
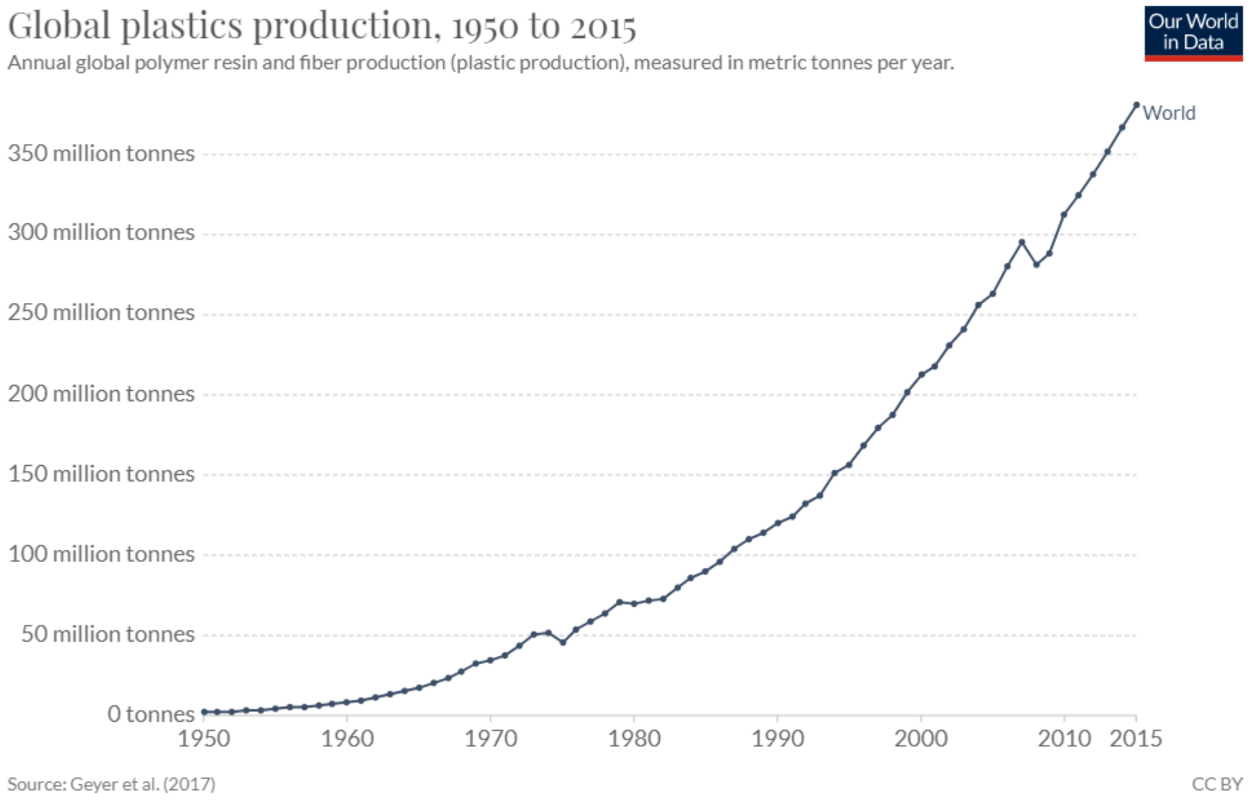
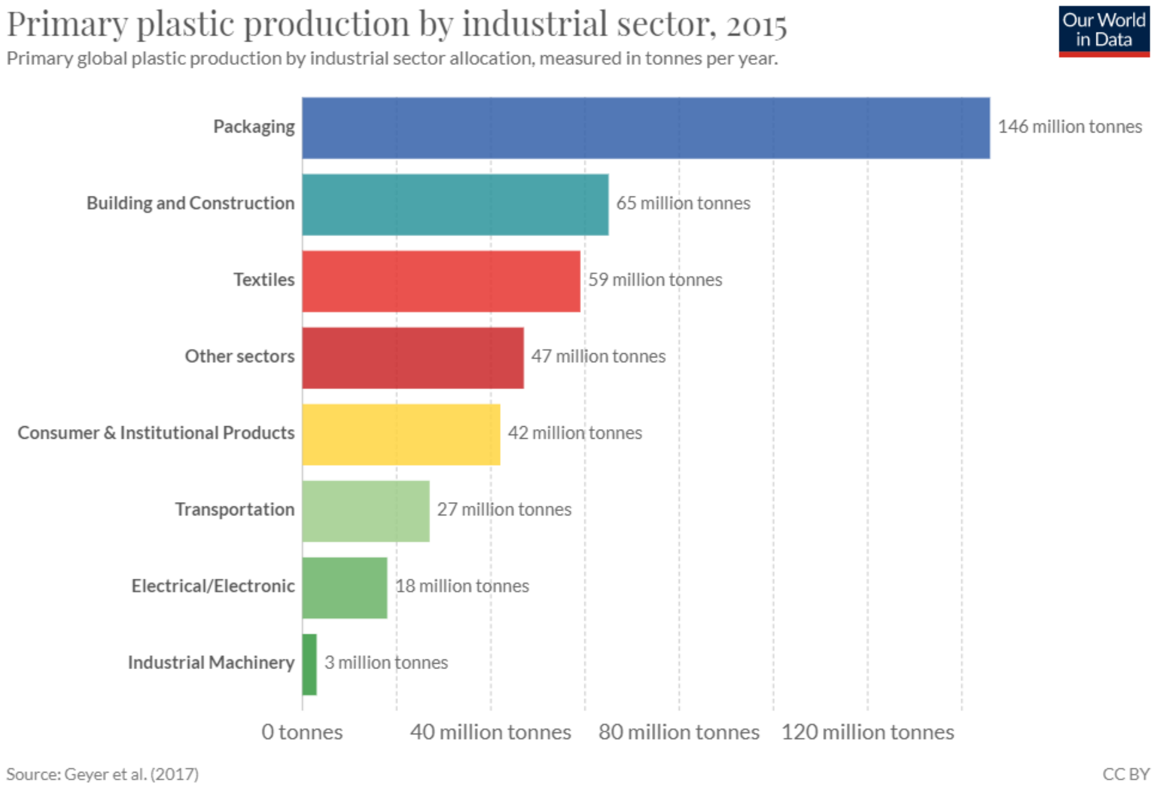
1. Identify: **Microplastics (MPs)**



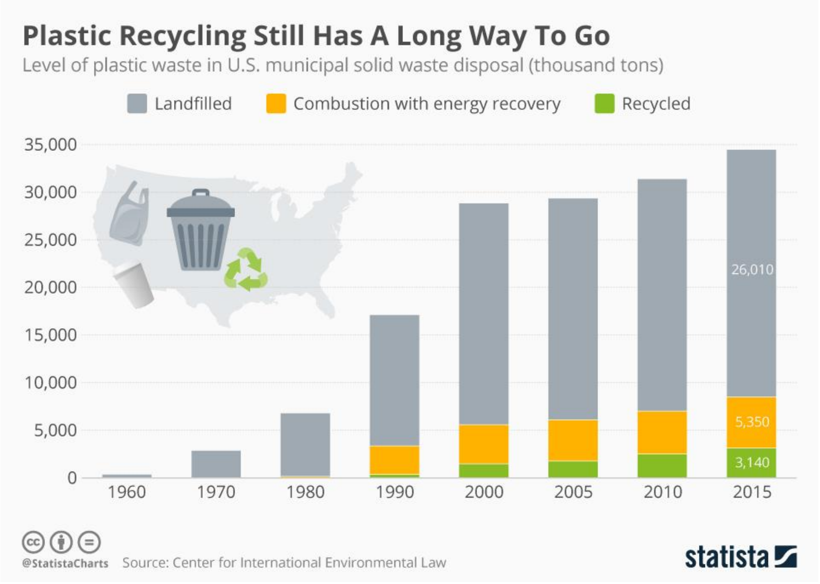




Global plastics production, 1950 to 2015
Our World in Data
Annual global polymer resin and fiber production (plastic production), measured in metric tonnes per year.
World
350 million tonnes
300 million tonnes
250 million tonnes
200 million tonnes
150 million tonnes
100 million tonnes
50 million tonnes
0 tonnes
1950
1960
1970
1980
1990
2000
2010
2015
Source: Geyer et al. (2017)
CC BY

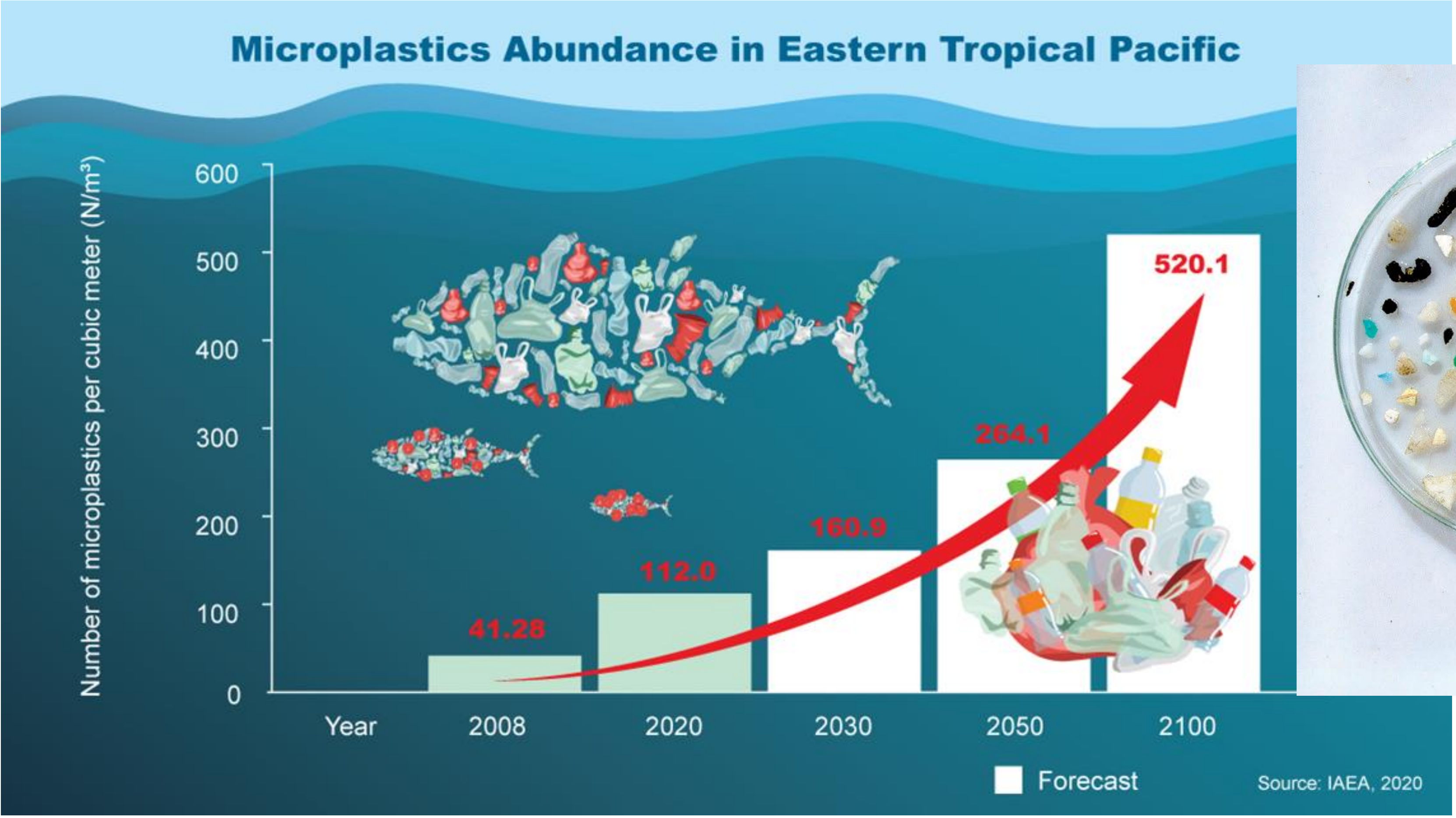


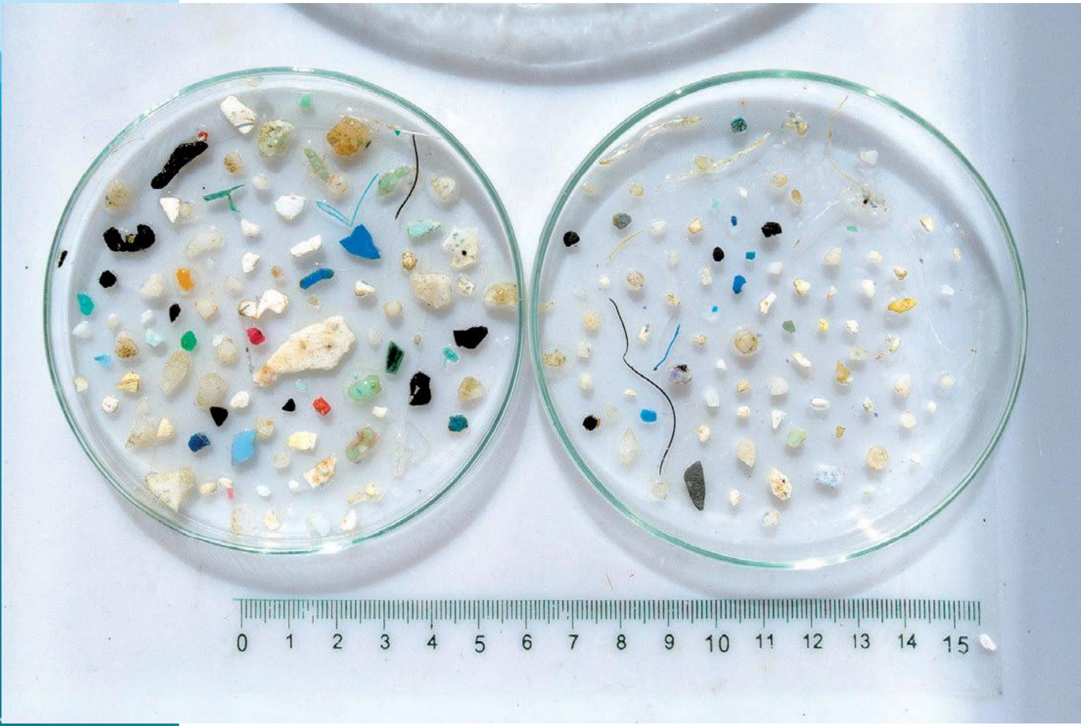
Primary plastic production by industrial sector, 2015
Our World in Data
Primary global plastic production by industrial sector allocation, measured in tonnes per year.
Packaging
146 million tonnes
Building and Construction
65 million tonnes
Textiles
59 million tonnes
Other sectors
47 million tonnes
Consumer & Institutional Products
42 million tonnes
Transportation
27 million tonnes
Electrical/Electronic
18 million tonnes
Industrial Machinery
3 million tonnes
0 tonnes
40 million tonnes
80 million tonnes
120 million tonnes
Source: Geyer et al. (2017)
CC BY



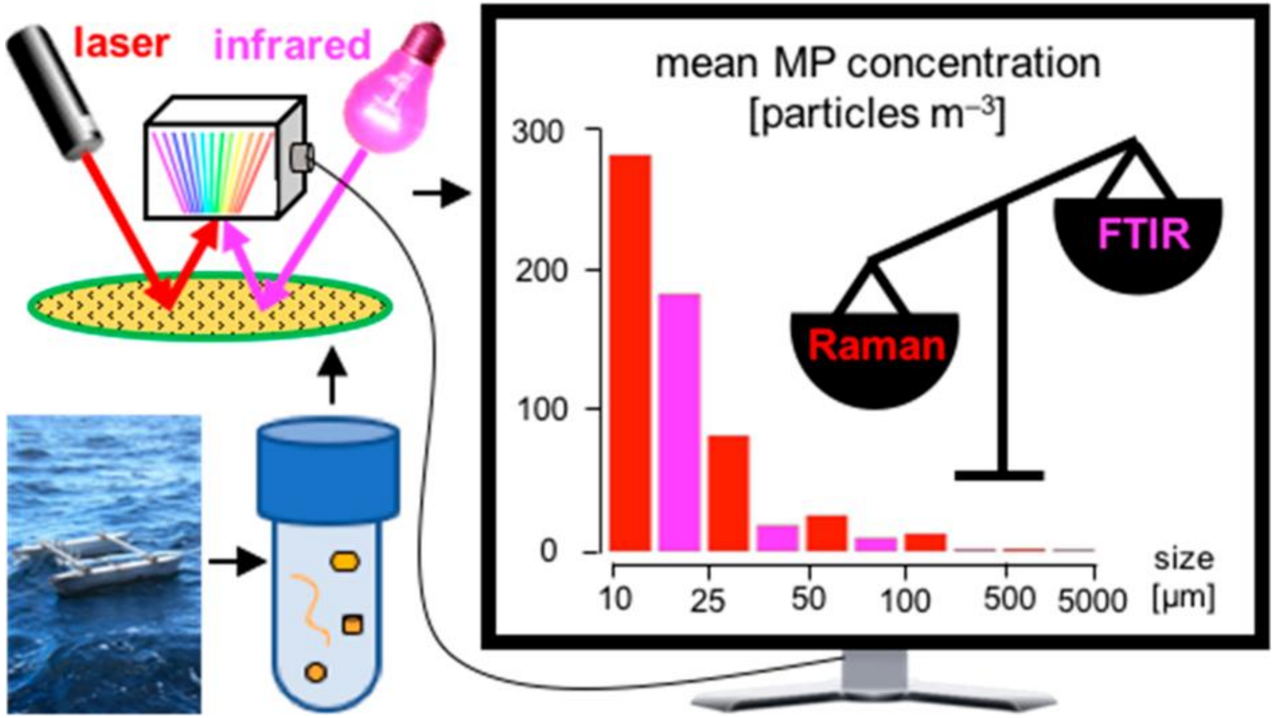
Plastic Recycling Still Has A Long Way To Go
Level of plastic waste in U.S. municipal solid waste disposal (thousand tons)
Landfilled
Combustion with energy recovery
Recycled
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
26,010
5,350
3,140
1960
1970
1980
1990
2000
2005
2010
2015
@StatistaCharts
Source: Center for International Environmental Law
statista

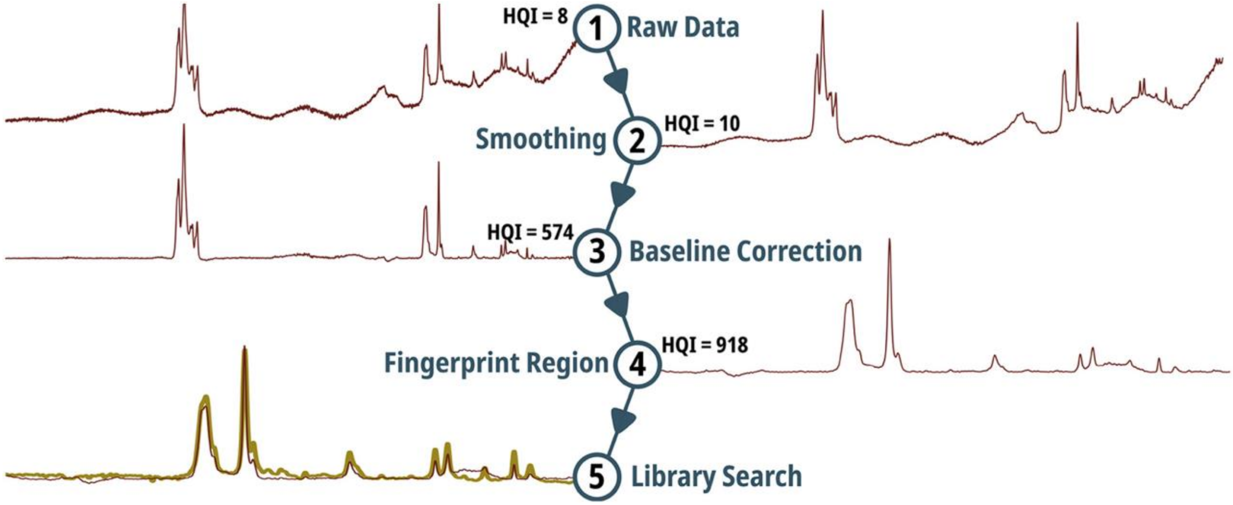
1. Identify: **MPs**

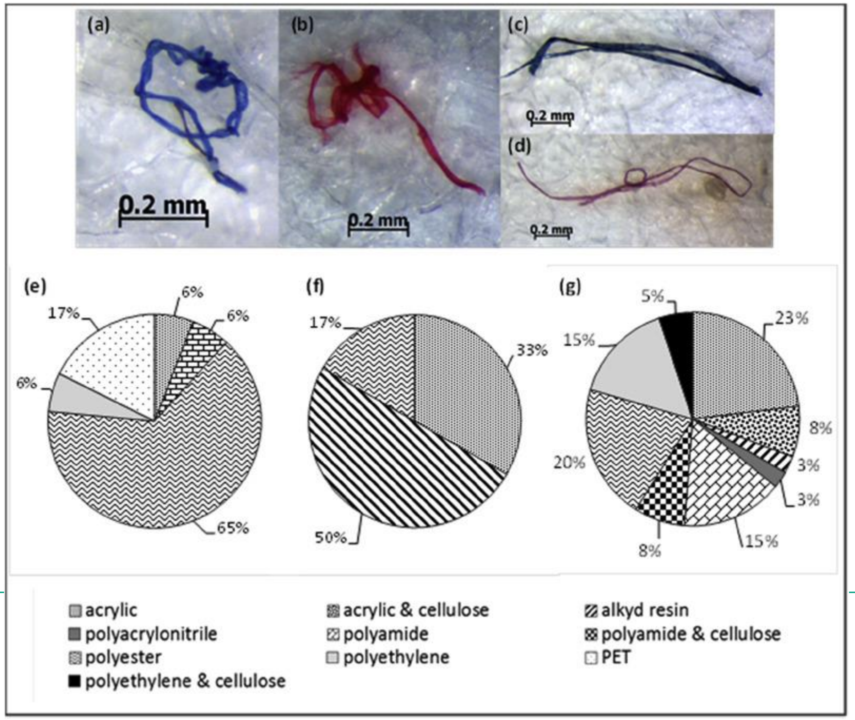




1. Identify: **MPs**







Credit: https://doi.org/10.1016/j.trac.2018.12.004 , https://doi.org/10.1016/j.envpol.2017.08.026

1. Identify: **MPs in sludge**

NIVA 7215-2017

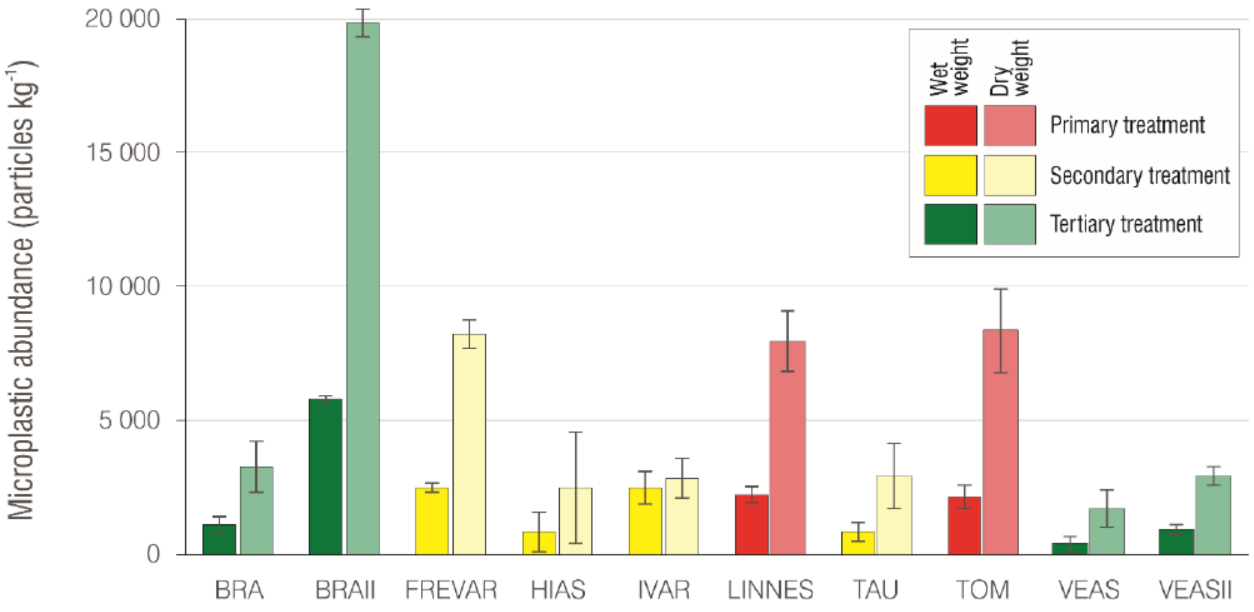
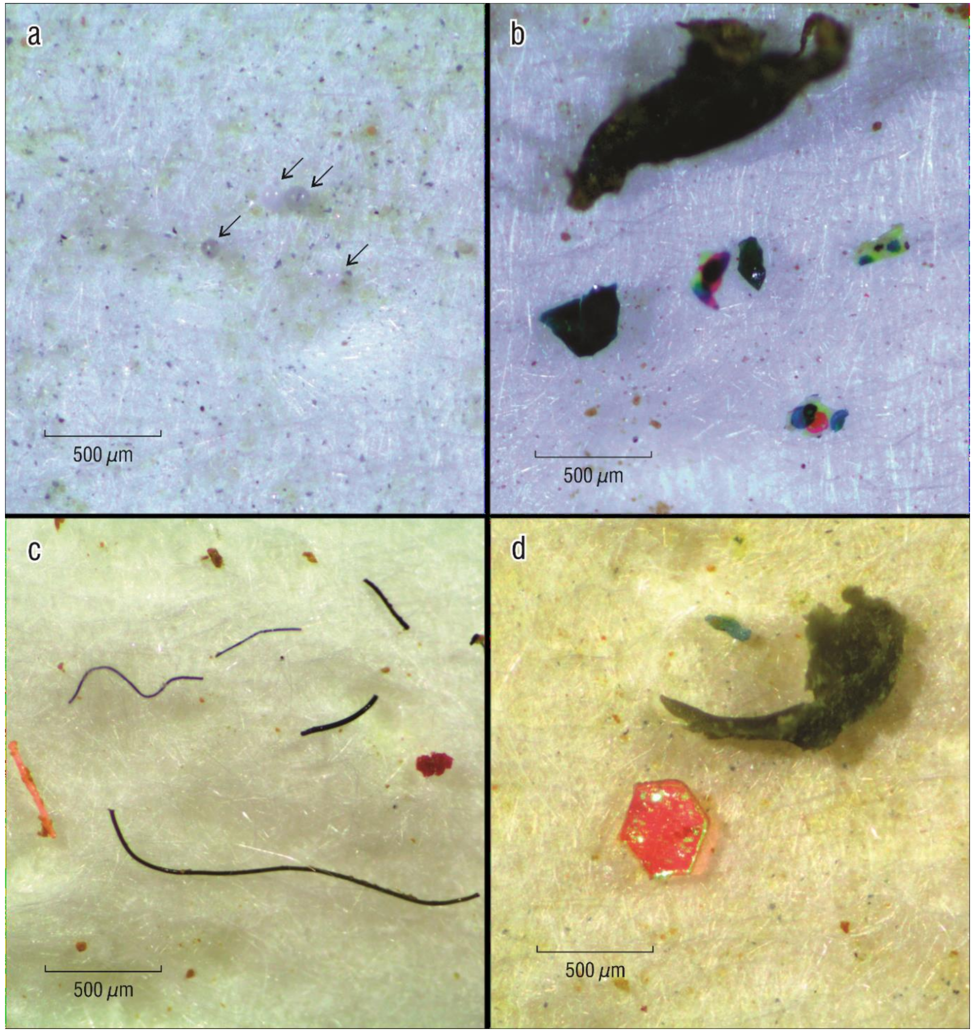
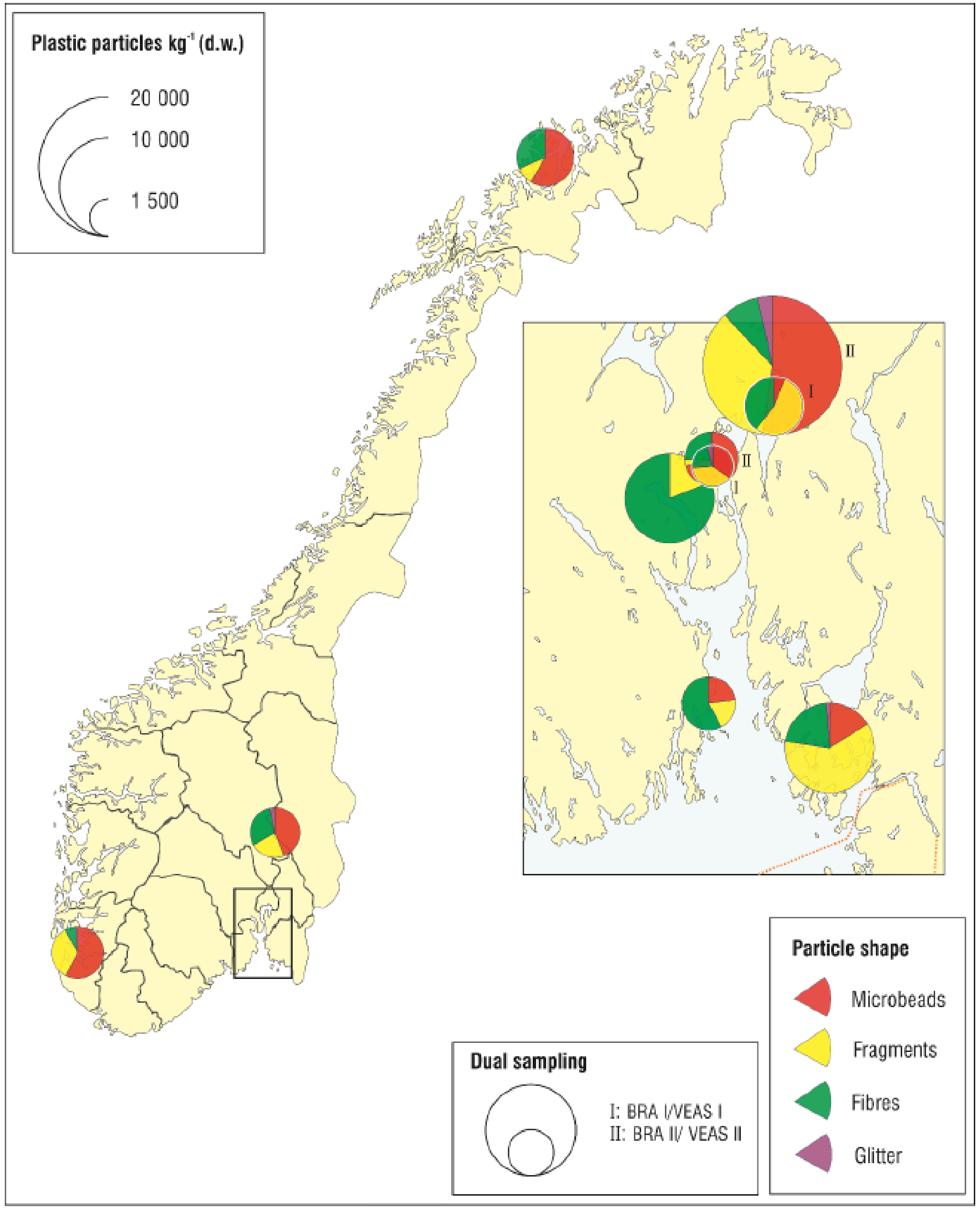
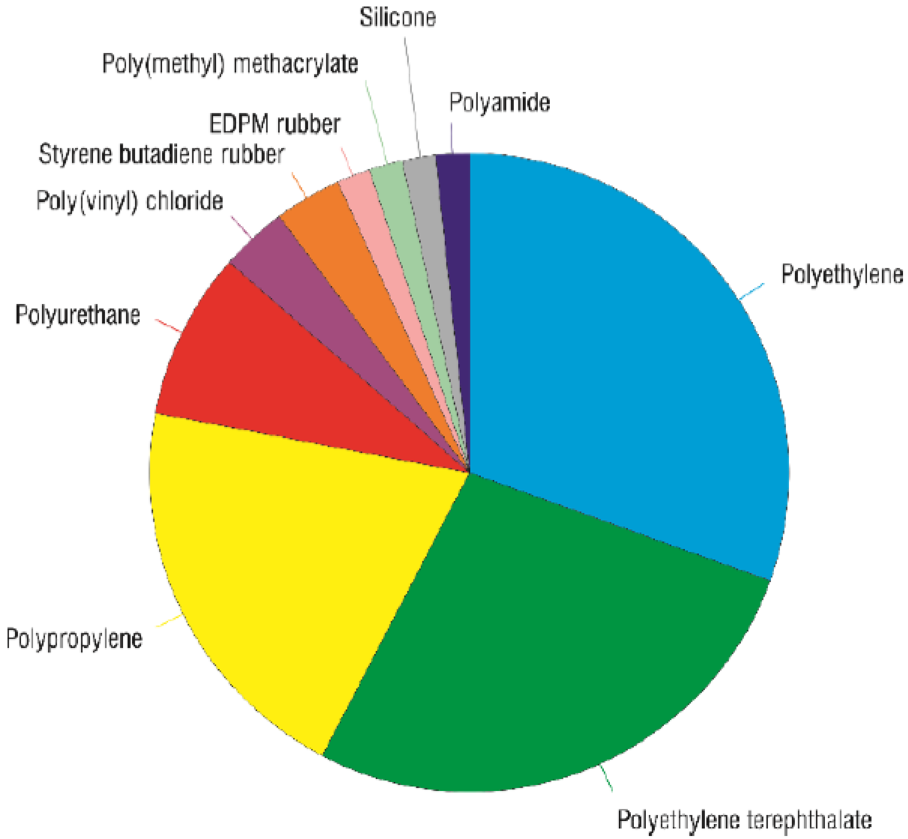


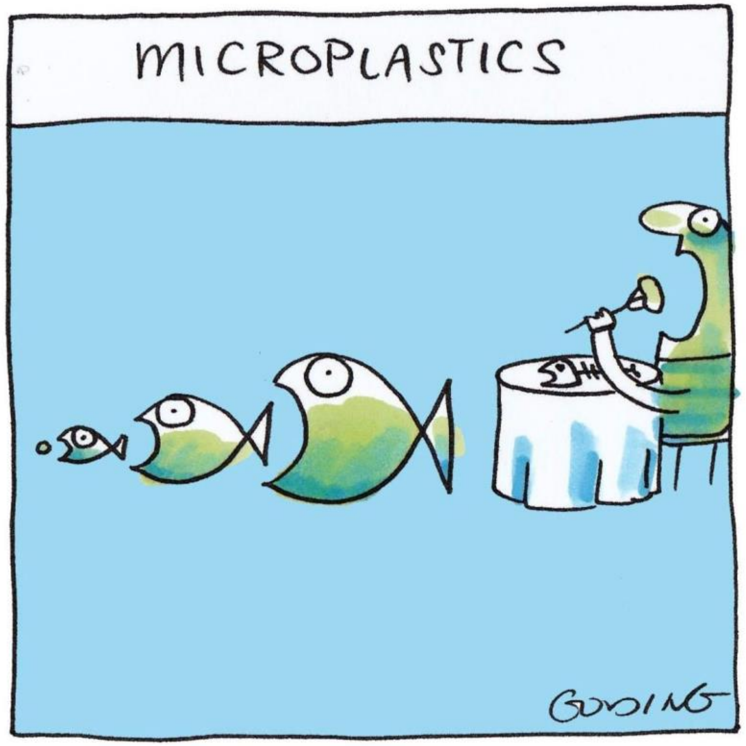
Figure 3. Microplastic abundances extracted from the ten sludge samples across eight sample locations. Abundances reported as particles per kg: wet weight (w.w) and dry weight (d.w).




Plastic particles kg-1 (d.w.)
20 000
10 000
1 500
II
I
II
I
Dual sampling
I: BRA I/VEAS I
II: BRA II/ VEAS II
Particle shape
Microbeads
Fragments
Fibres
Glitter


Silicone
Poly(methyl) methacrylate
Polyamide
EDPM rubber
Styrene butadiene rubber
Poly(vinyl) chloride
Polyethylene
Polyurethane
Polypropylene
Polyethylene terephthalate

1. Identify: **MPs – needs for research and guidance**



Analytical and sampling methods: standardised test method and agreed units of measurement to make direct comparisons and interference of conclusions possible.

In the framework of **possible standards and regulations for microplastics**, analytical methodologies should be in place that **enable large scale and rapid analysis**, hence support should be given to harmonisation exercises (e.g. from GWRC)

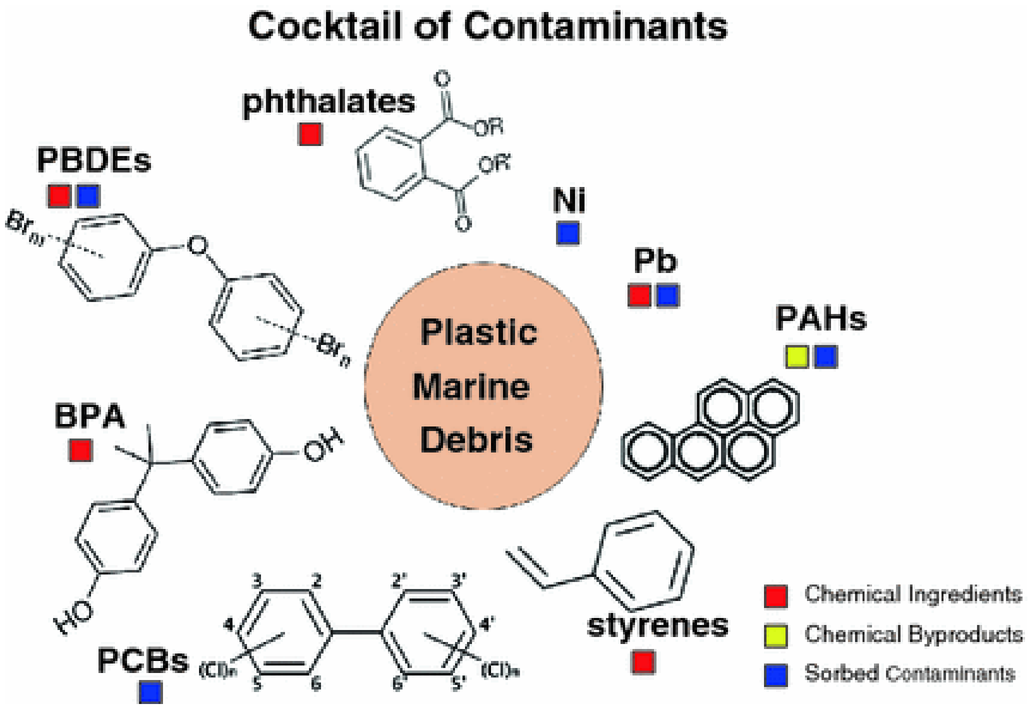
Develop and agree a clear **classification of microplastics**

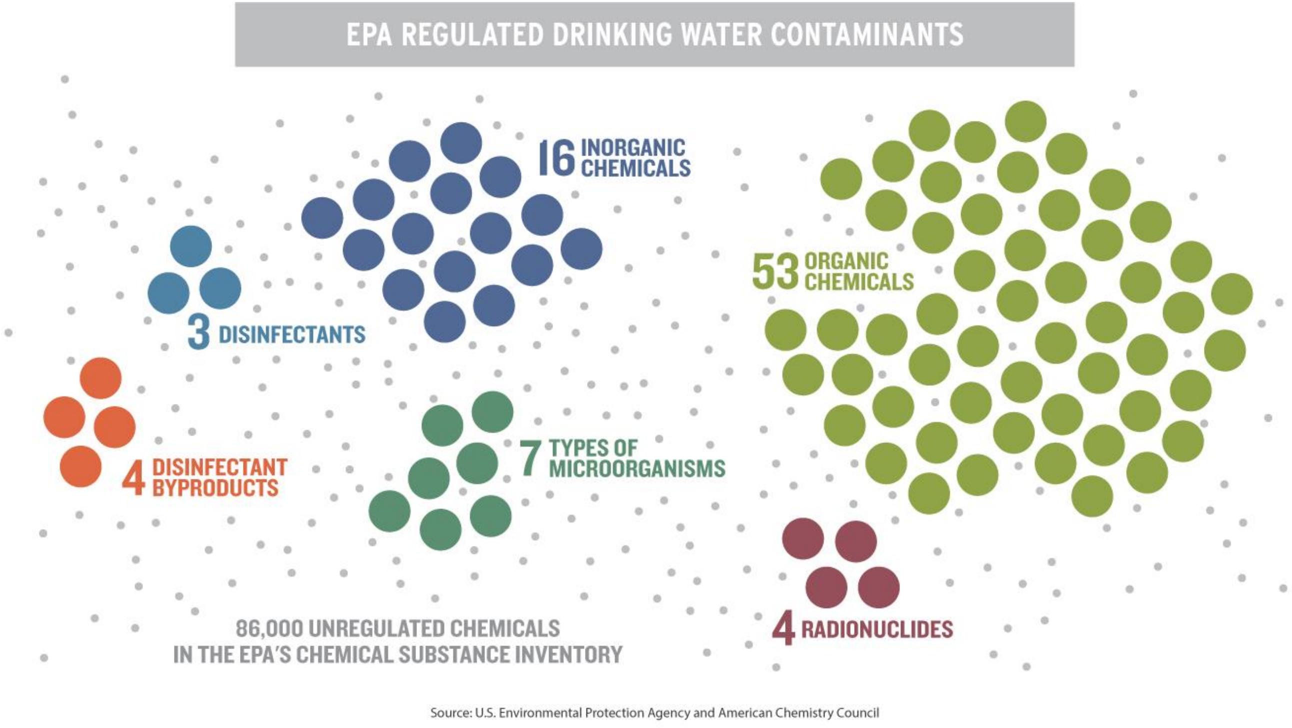
Establish **evidence base for presence/absence of microplastics in drinking water**

Toxicity/eco-toxicity of and risks associated with microplastics in drinking water, treated wastewater, sludge or soils

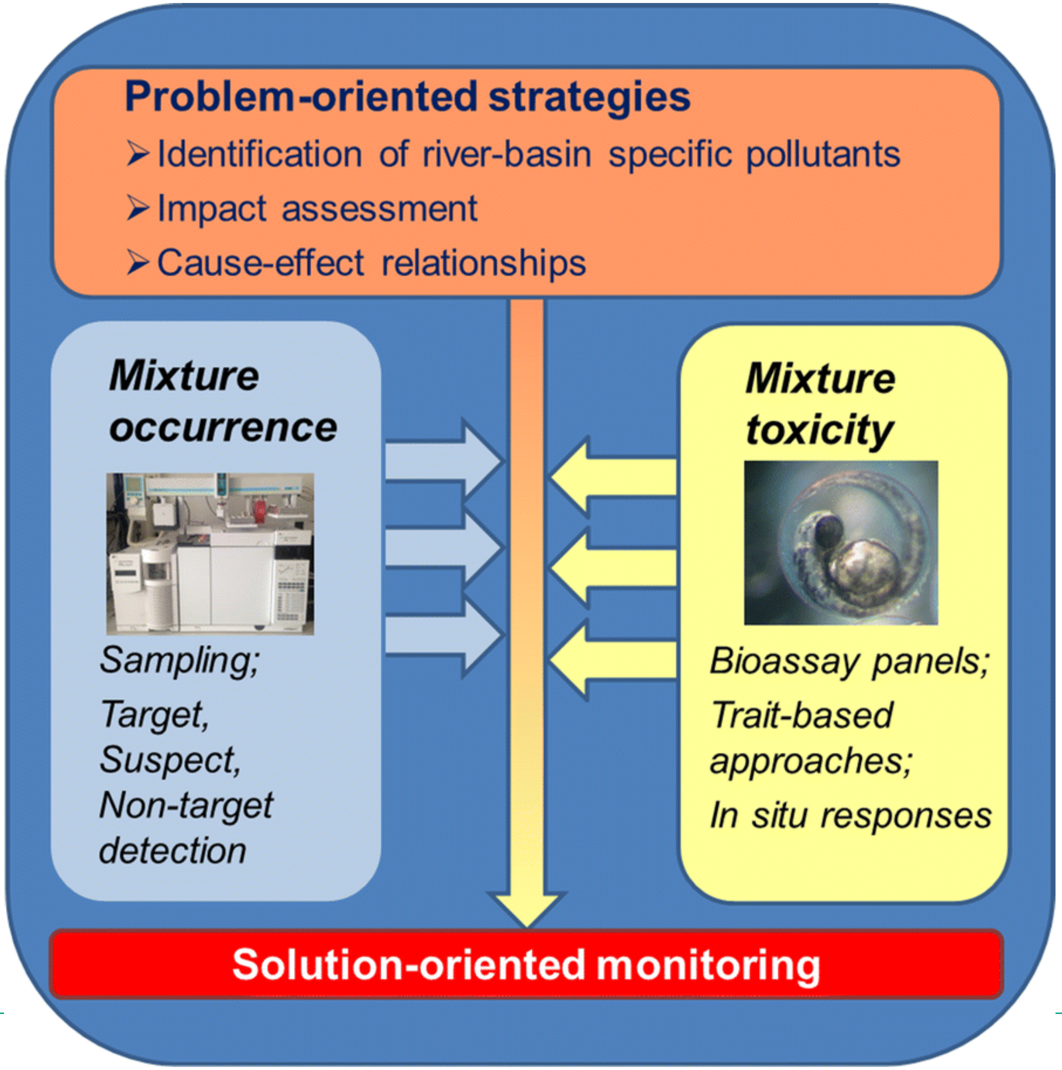
Sources and routes into the environment, including the water cycle and sludge route

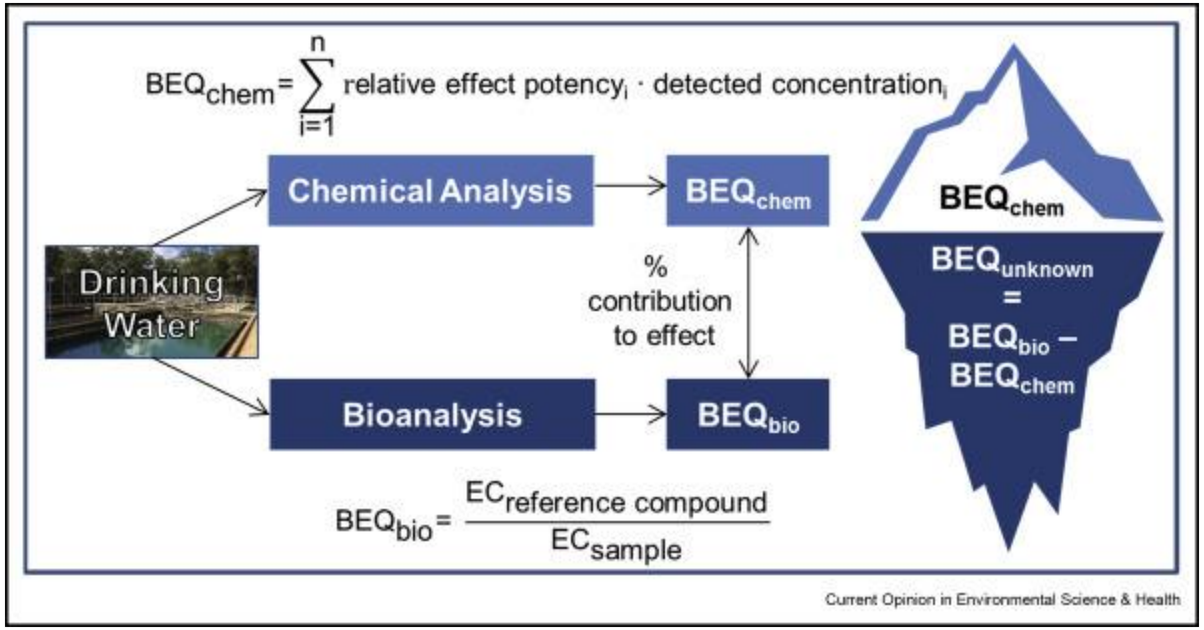
1. Identify: **Cocktail effects are unknown**





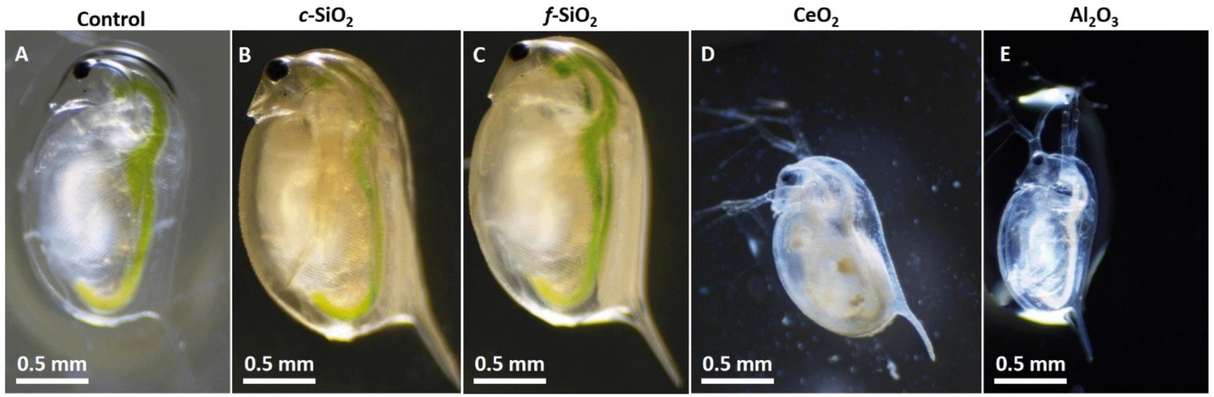
1. Identify: **Bioassays for combined effects**



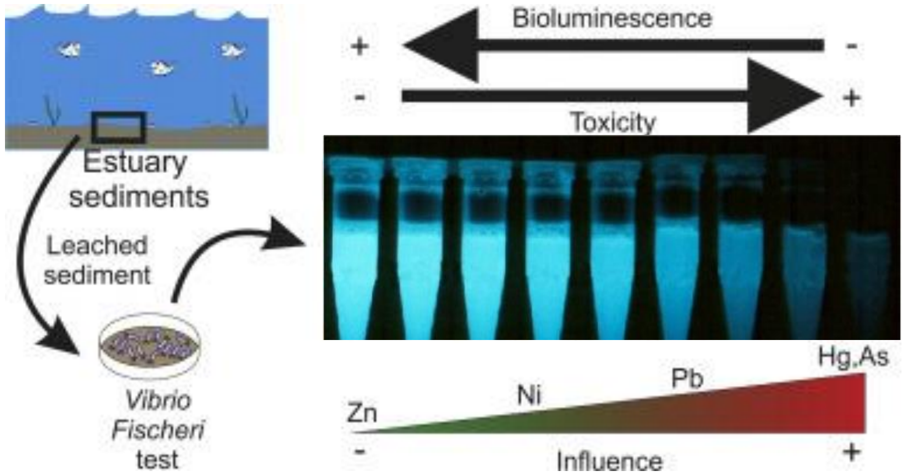


BEQ - Biological equivalent concentrations

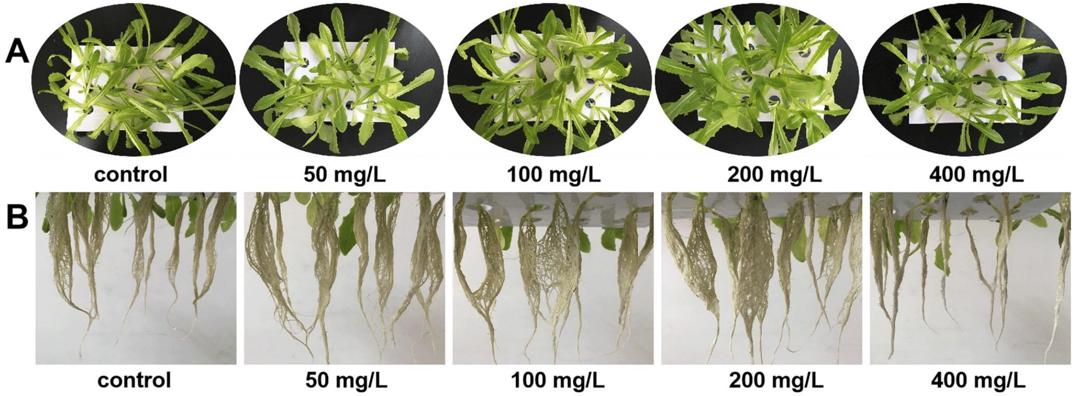
1. Identify: **Bioassays for combined effects**



Acute and chronic toxicity of metal oxide nanoparticles in chemical mechanical planarization slurries with *Daphnia magna*



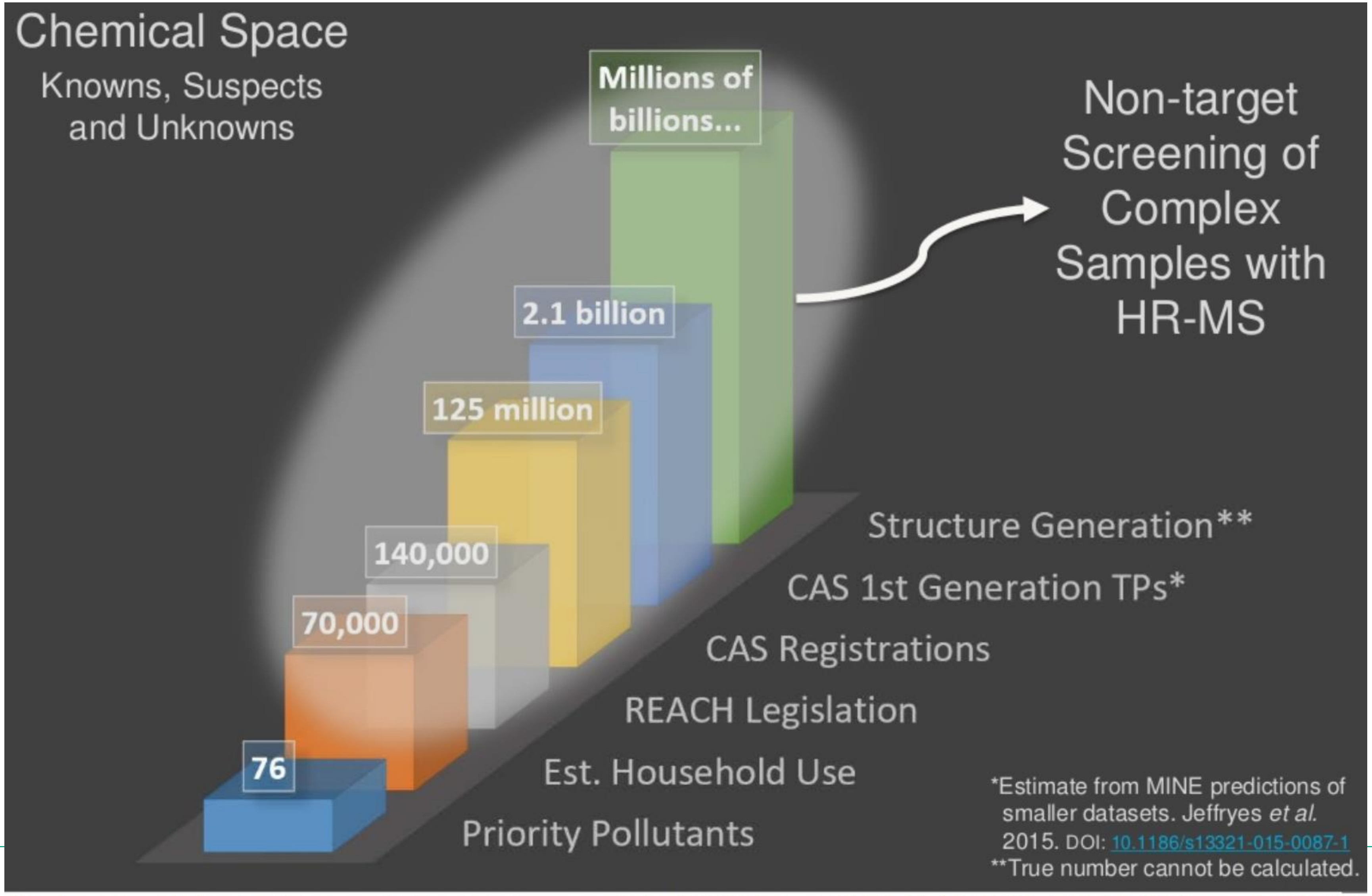
Assessment of the toxicity toward *Vibrio fischeri* in sediments



TiO_2 nanoparticle exposure on lettuce (*Lactuca sativa* L.)

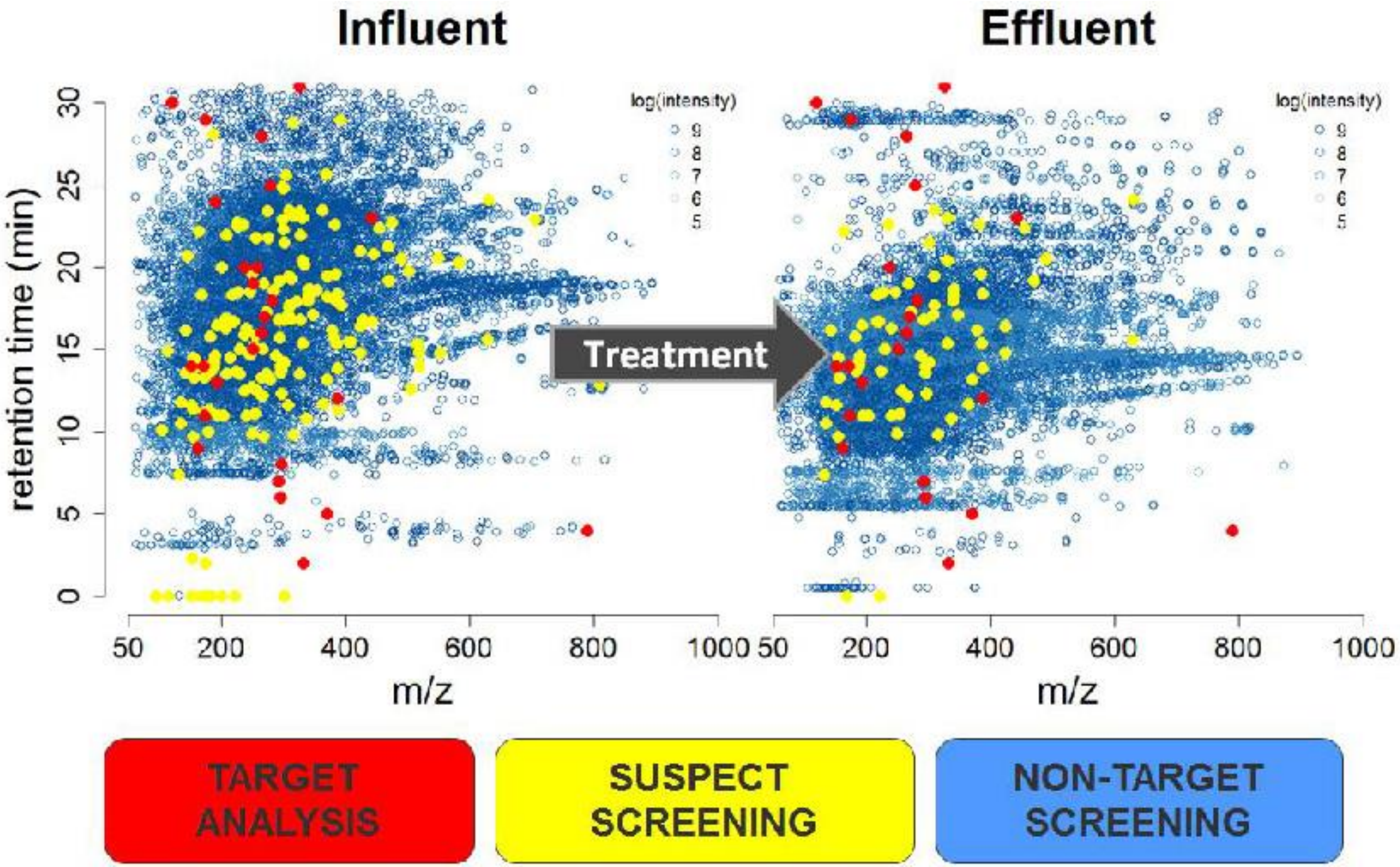
Credit: https://doi.org/10.1039/C9EN01215J , https://doi.org/10.1016/j.scitotenv.2019.01.086 , https://doi.org/10.1039/C7EN01079F

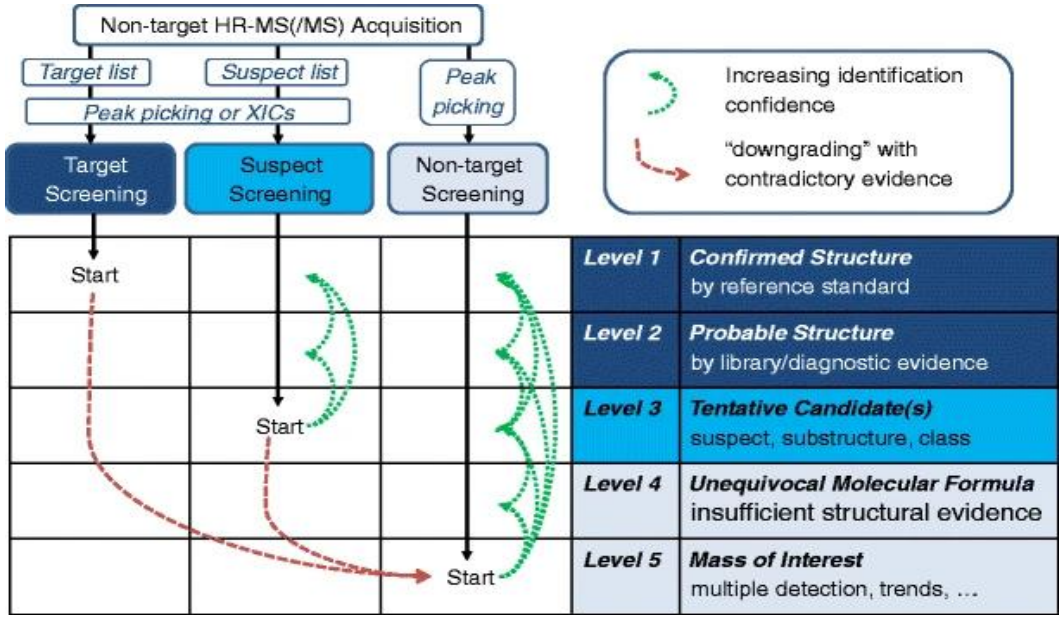
1. Identify: **Non-target screening**



Numbers from Hollender, Schymanski, Singer & Ferguson, 2018, ES&T Feature, 51:20, 11505-11512. DOI: 10.1021/acs.est.7b02184

1. Identify: **Non-target screening**





2. Prevent

2. Prevent:

Step in pharmaceutical life cycle	Relevant stakeholders	Mitigation options
Cross-cutting	Government, Industry	Monitoring, reporting, data sharing Harness new innovations in water quality monitoring Environmental quality norms
Design	Industry	Green pharmacy, biological therapies, personalised or precision medicines
Authorisation	Government, Industry	Legislation and guidance on environmental risk assessment and incorporation into authorisation process More stringent conditions for putting a pharmaceutical on the market that is of high-risk to the environment (e.g. increased risk mitigation options, eco-labelling, prescription only, post-approval monitoring)
Production	Industry, Government, Intergovernmental Organisations	Good manufacturing practices, regulation limits and disclosure of pharmaceutical wastewater discharge from supply chains Green public procurement with environmental criteria
Consumption (professional use)	Agriculture, Health sector, Government	Emission prevention through: • improved human and animal health and well-being • improved diagnostics, avoided prescriptions • improved hygienic standards and stable management • personalised medicines, vaccinations • prescription of environmentally-friendly pharmaceutical alternatives
Consumption (over-the-counter purchases/ self-prescription)	Health sector, Industry, Consumers	Eco-labelling on pharmaceutical products to improve consumer choice and awareness
Collection and disposal	Solid waste utilities, Industry	Education campaigns to avoid disposal of pharmaceuticals via sink or toilet Public pharmaceutical collection schemes for unused drugs Extended producers responsibility schemes Improved manure management by passive storage or anaerobic fermentation in biogas plants
Wastewater treatment	Wastewater utilities	Upgrade of wastewater treatment plants
Drinking water treatment	Drinking water utilities	Upgrade of drinking water treatment plants Water safety planning

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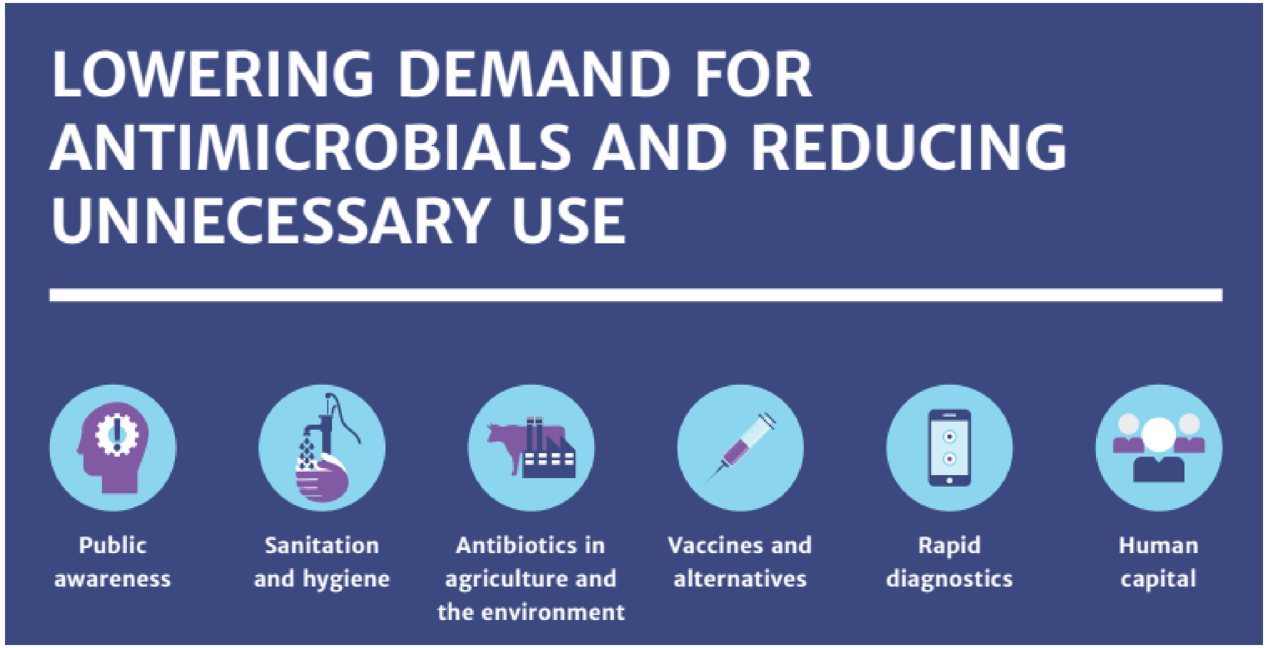
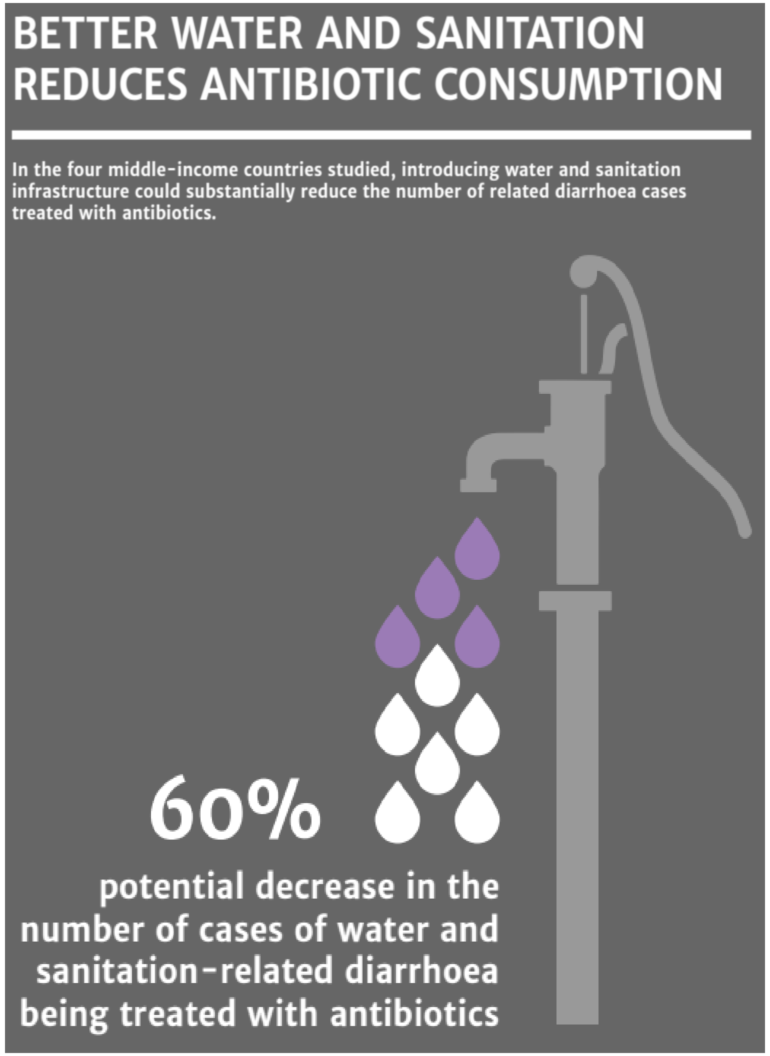
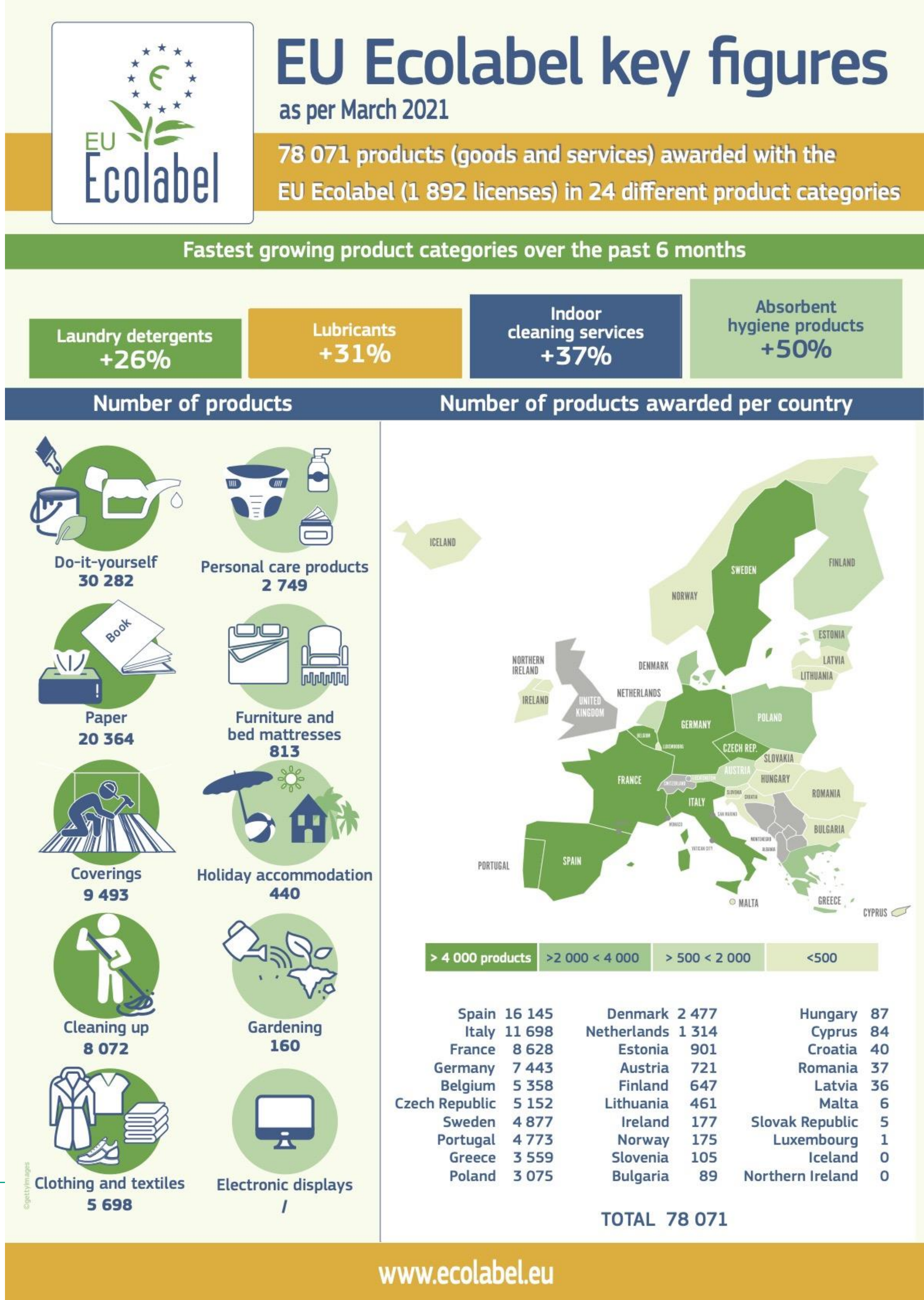
2. Prevent





Review on Antimicrobial Resistance: Tackling drug-resistant infections globally, 2016

2. Prevent: Certification and ecolabels



3. Treat

3. Treat: **Pharmaceuticals**

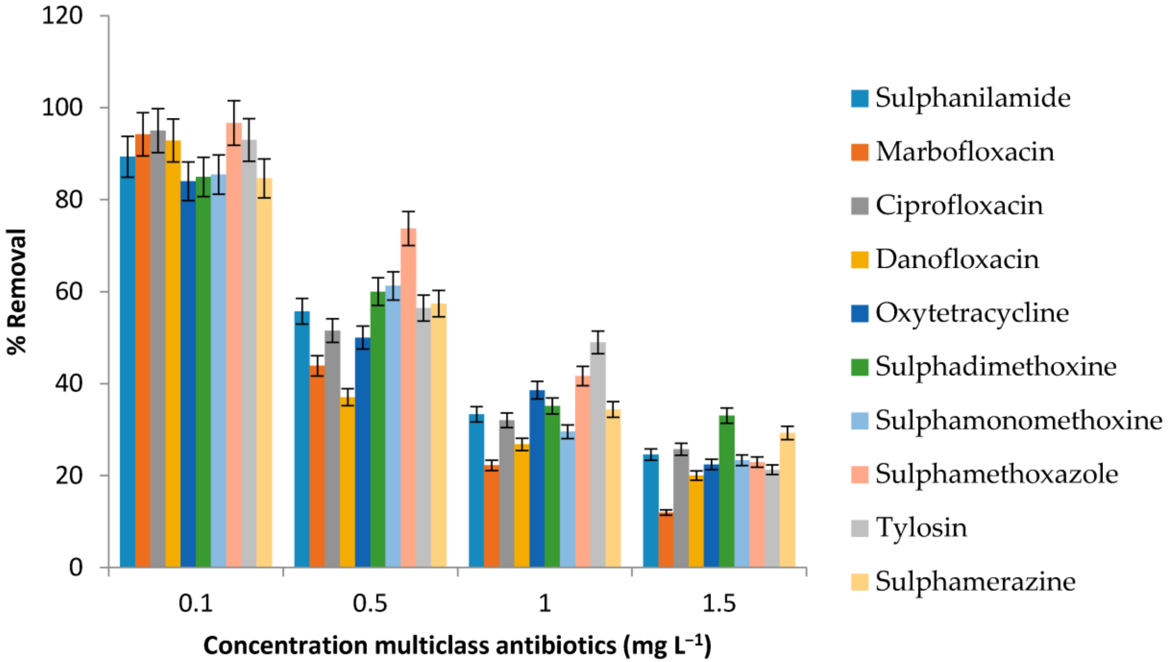
13%

OF WASTEWATER TREATMENT PLANTS IN THE UNITED KINGDOM HAVE HIGH PHARMACEUTICAL CONCENTRATIONS IN EFFLUENT

In the United Kingdom, ethinyloestradiol, diclofenac, ibuprofen, propranolol and the macrolide antibiotics are present at high enough concentrations in the effluent of 890 wastewater treatment plants (13% of all plants) to cause adverse environmental effects in surface waters (Comber et al., 2018).

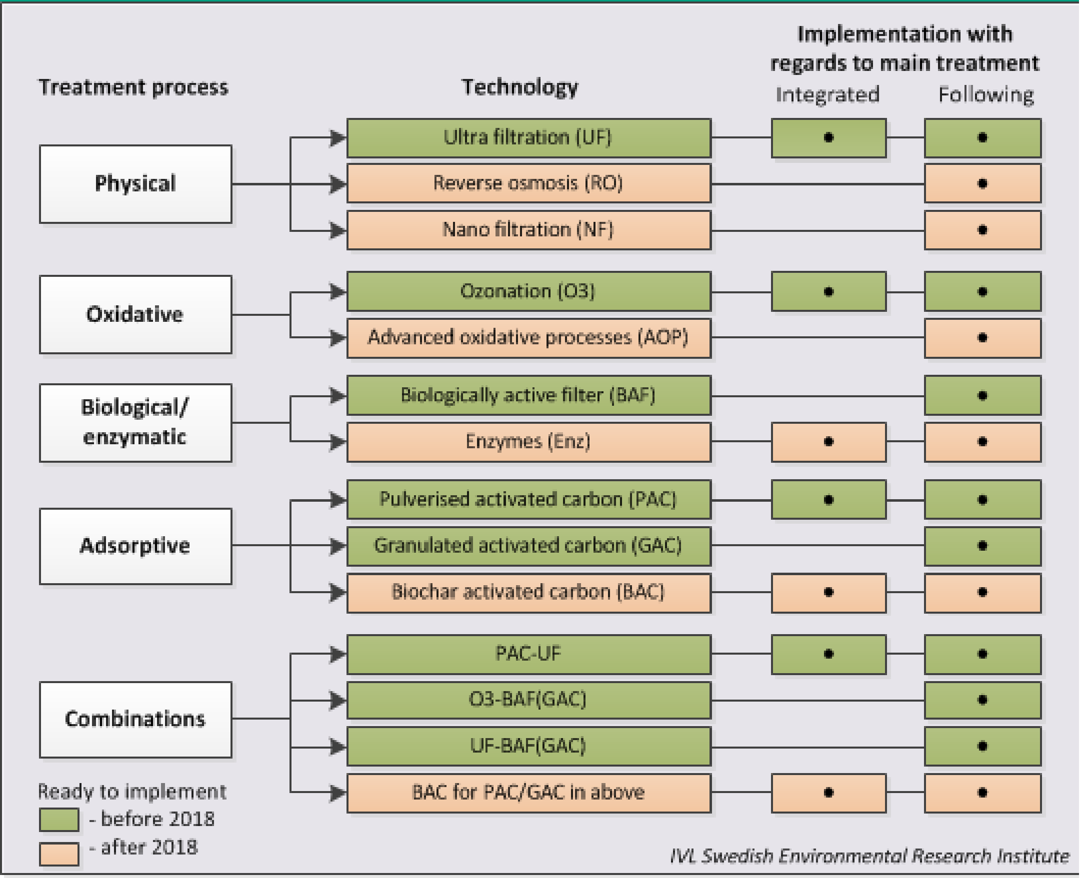
THE REMOVAL OF PHARMACEUTICALS IS LIMITED BY WASTEWATER TREATMENT PLANT UPGRADES

Upgrading wastewater treatment with new technologies will not solely solve the problem of pharmaceuticals in water. They are limited by their removal efficiencies, high capital investment and operation costs and increased energy consumption. They do not capture diffuse sources of pharmaceutical pollution (e.g. from agriculture and aquaculture).



OECD Policy Brief on Pharma
Credit: https://doi.org/10.3390/w11030595

3. Treat: **Pharmaceuticals**



	Treatment technology/combination							
Pharmaceutical	**UF**[1]	**GAC**	**PAC**[2]	**BAF**[3]	**O_3**[4]	**PAC-UF**	**O_3-BAF (GAC)**	**UF-BAF (GAC)**
Azithromycin	-	(+++)	+++	+++	+	+++	+++	+++
Ciprofloxacin	-	+++	+++	+++	++	+++	+++	+++
Clarithromycin	-	(+++)	(+++)	(+++)	(+)	(+++)	(+++)	(+++)
Diclofenac	-	+++	+++	+++	+++	+++	+++	+++
E2 (17β-estradiol)	-	+++	+++	+++	+++	+++	(+++)	+++
EE2 (17α-ethinyl estradiol)	-	+++	+++	+++	+++	+++	(+++)	+++
Erythromycin	-	(+++)	(+++)	(+++)	(+)	(+++)	(+++)	(+++)
Ibuprofen	-	+++	+++	+++	++	+++	+++	+++
Carbamazepine	-	+++	+++	+++	+++	+++	+++	+++
Levonorgestrel	-	(+++)	(+++)	(+++)	(+++)	(+++)	(+++)	(+++)
Metoprolol	-	+++	+++	+++	+++	+++	+++	+++
Oxazepam	-	+++	+++	+++	++	+++	+++	+++
Propranolol	-	+++	+++	+++	(+++)	+++	+++	+++
Sertraline	-	+++	+	+++	++	+	+++	+++
Sulfamethoxazole	-	+++	+++	+++	+++	+++	+++	+++
Trimethoprim	-	+++	(++)	+++	+++	(++)	+++	+++

- = No treatment; + = 0-<20%; ++ = 20-<80%; +++ = >80% removal efficiency; ( ) = Expected efficiency based on the substance's properties and the technology's treatment mechanism.

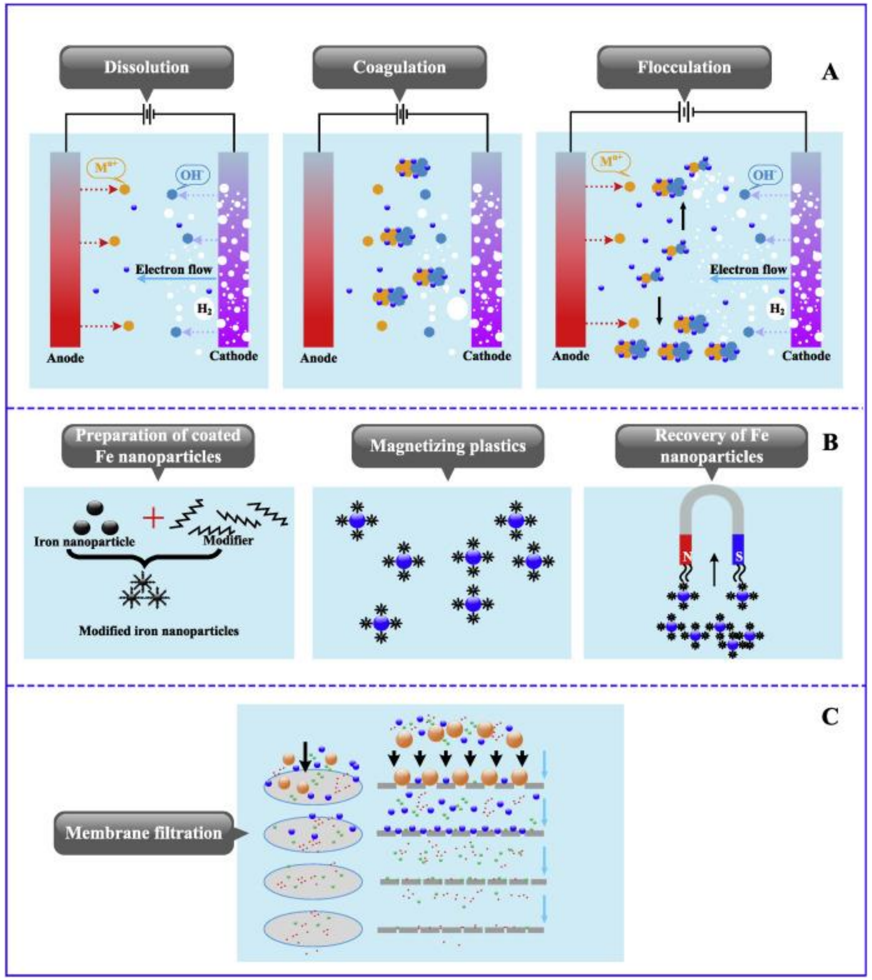
3. Treat: **Pharmaceuticals**

	Treatment technology/combination							
	UF	**GAC**	**PAC**	**BAF**	**O_3**	**PAC-UF**	**O_3-BAF (GAC)**	**UF-BAF (GAC)**
Robust treatment	☺	☺	☺	😐	☺	☺	☺	☺
Tested technologies in full scale	☺	☺	☺	☺	☺	😐[1]	☺	😐[1]
Requires little maintenance/monitoring	😐	😐	😐	😐	😐	😐	😐	😐
The solution works without using other technologies	😐	☺[2]	😐[3]	😐[2]	😐[2]	😐	😐[2]	😐
Appropriate facility size	No restriction							
Little space is required[5]	☺/😐[4]	😐	☺/😐[4]	☺/😐[4]	☺	☺/😐[4]	😐	☺/😐[4]

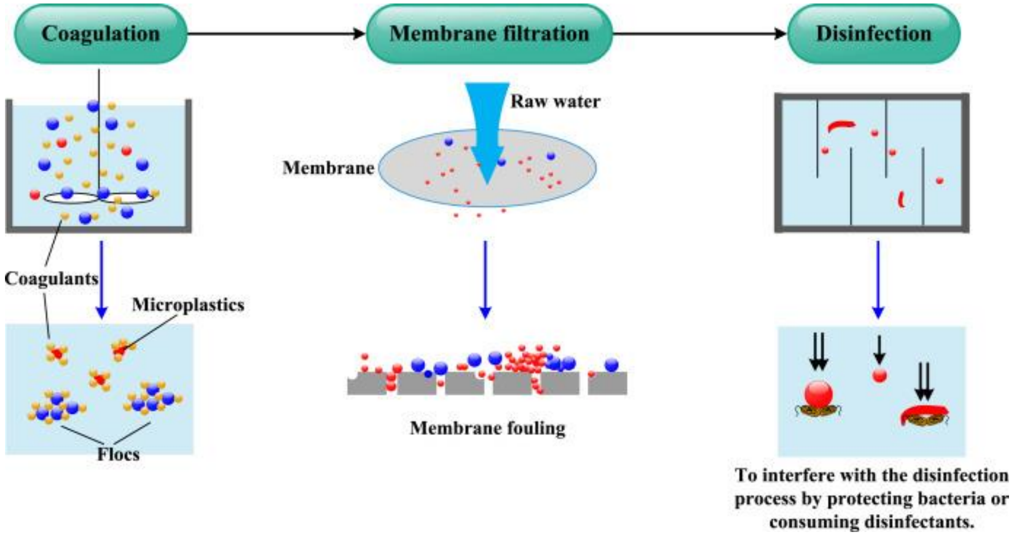
☺ = Positive reply; 😐 = Neither positive nor negative; ☹ = Negative reply.

3. Treat: Microplastics

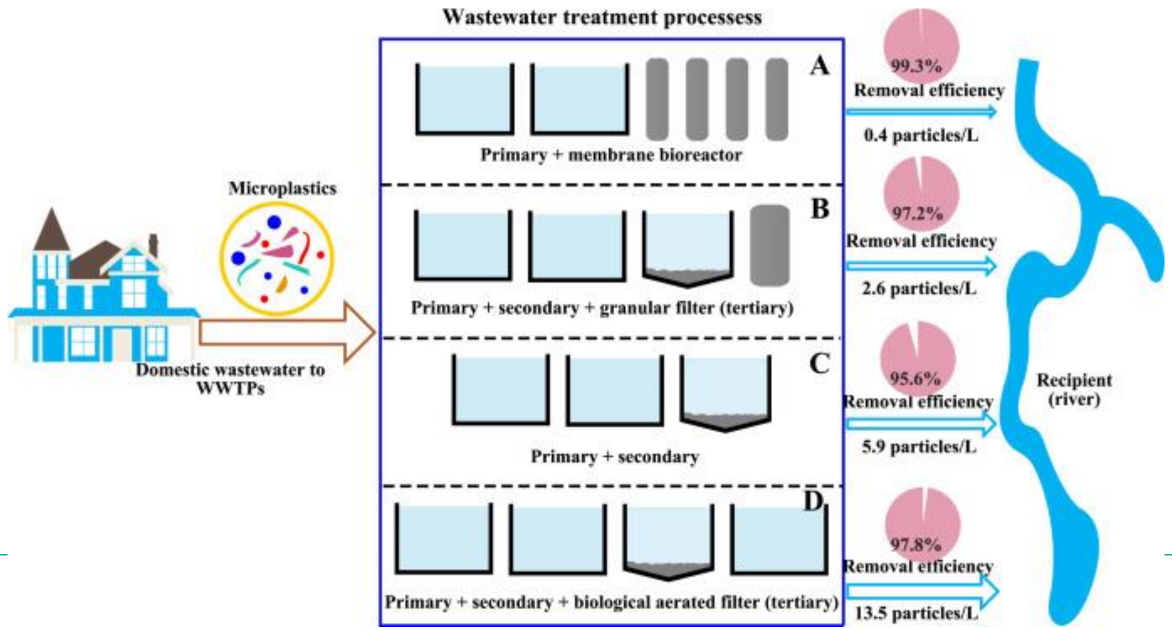
STRATEGY



CHALLENGES



Removal efficiency



Credit: https://doi.org/10.1016/j.chemosphere.2020.126612

Advanced treatment processes: contaminants removal, residuals, by-products, applicability and costs

Process	Nutrients removal	TSS removal	TDS removal	Pathogens removal	Metals removal	CEC removal	Residuals and/or By-products	Operator skill based on current application	Relative complexity of technology	Maturity level of technology	Cost (capital + O&M)
MBR	Low/High	High	No/Negligible	Medium	No/Negligible	Low	Sludge	Low	Low/Medium	Medium/High	Medium/High
Granular media filtration	Low	High	No/Negligible	Low/Medium	No/Negligible	No/Negligible	Backwashing water	Low	Low	High	Low
Coagulation	Low	High	No/Negligible	Low/Medium	High	No/Negligible	Backwashing water and sludge	Low	Low	High	Low
GAC/PAC adsorption	Low	Low/Medium	No/Negligible	Low	Low/Medium	Low/High	Exhausted GAC/PAC	Low	Low	High	Medium
O_3/BAC	Low/Medium	Medium	No/Negligible	Low/Medium	No/Negligible	Low/High	Limited by-products thanks to BAC	Low/Medium	Medium	Low/Medium	Medium/High
MF/UF	Low	High	No/Negligible	Medium	No/Negligible	No/Negligible	Backwashing water	Low	Low	High	Low
NF/RO	High (N, P)	Low	High	High/Medium	High	High	Concentrate	Low/Medium	Medium	High	High
Chlorination	Low	No/Negligible	No/Negligible	High/Medium	No/Negligible	Low/Medium	By-products (e.g. THM, HAA)	Low	Low	High	Low
Chloramination	No/Negligible	No/Negligible	No/Negligible	Low/Medium	No/Negligible	Low	By-products (e.g. HAA, NDMA)	Low/Medium	Low	High	Low
UV disinfection	No/Negligible	No/Negligible	No/Negligible	High	No/Negligible	Low	No/Negligible	Low/Medium	Low	High	Low/
Ozonation	Low	Low/Medium	No/Negligible	High/Medium	No/Negligible	High	By-products (e.g. bromate, NDMA)	Medium	Medium	High	Medium
UV/H_2O_2	No/Negligible	No/Negligible	No/Negligible	High	No/Negligible	High	By-products (e.g. CEC transformation products)	Low/Medium	Medium	High	Medium
Other AOPs (e.g. photocatalysis)	No/Negligible	No/Negligible	No/Negligible	High/Medium	No/Negligible	High	By-products (e.g. CEC transformation products)	Low/High	High	Low/Medium	Medium/High
SAT	Low	Medium	Low	Low/Medium	Low/Medium	Low/Medium	No/Negligible	Low	Low	Medium	Low
Riverbank filtration	Low	Medium/High	Low	Low/Medium	Low/Medium	Low/Medium	No/Negligible	Low	Low	Medium	Low
Constructed wetlands	Low	Medium	No/Negligible	Low/Medium	Low/Medium	Low/Medium	Biomass	Low	Low	Medium	Low

Credit: https://doi.org/10.1016/j.coesh.2018.02.003

Elimination of micropollutants on the sewage treatment plant Schönau, Cham Switzerland

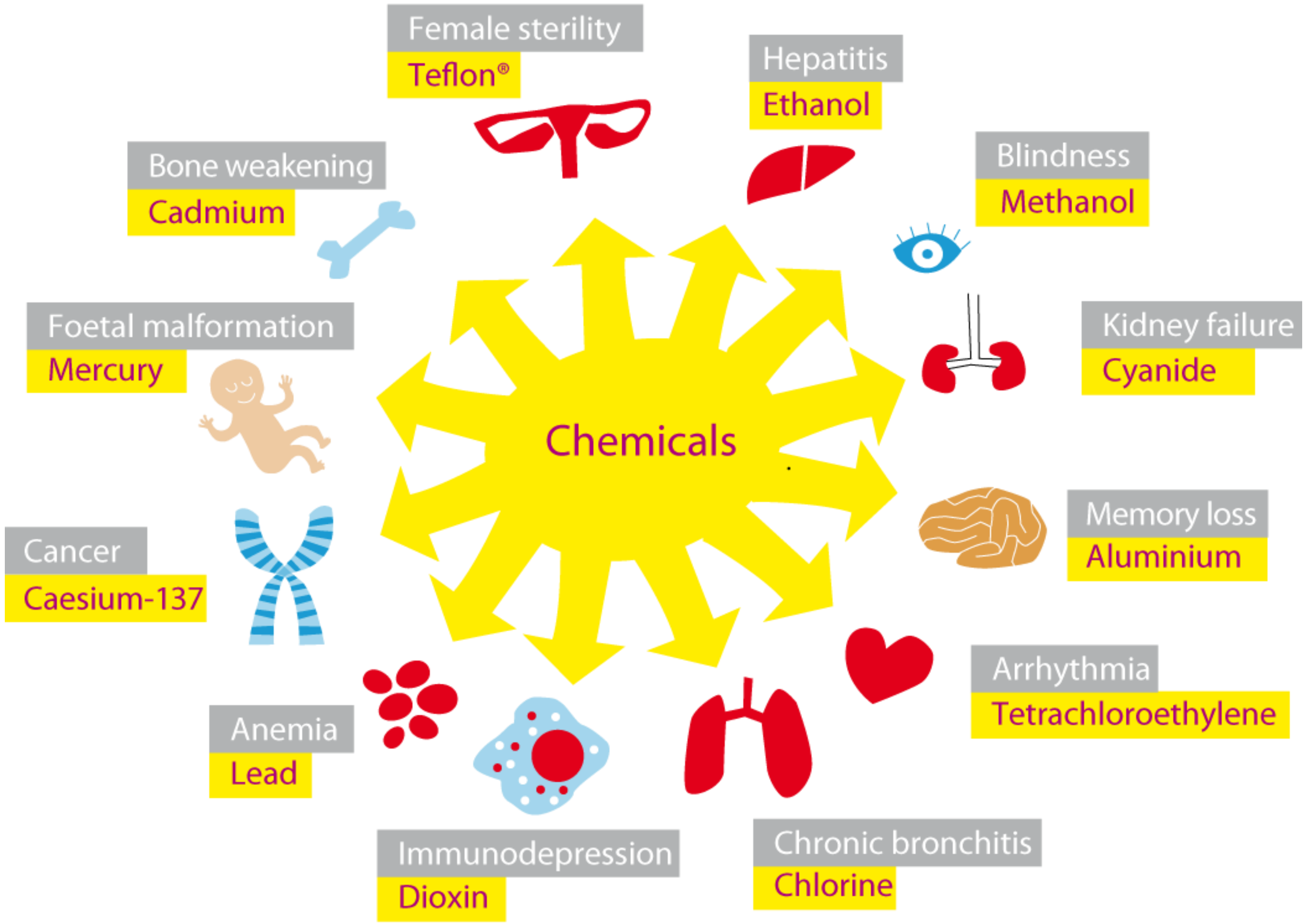
https://www.youtube.com/watch?v=2qfiYExqnIk

Micropollutants removal from wastewater with H_2O_2/UV-C technology

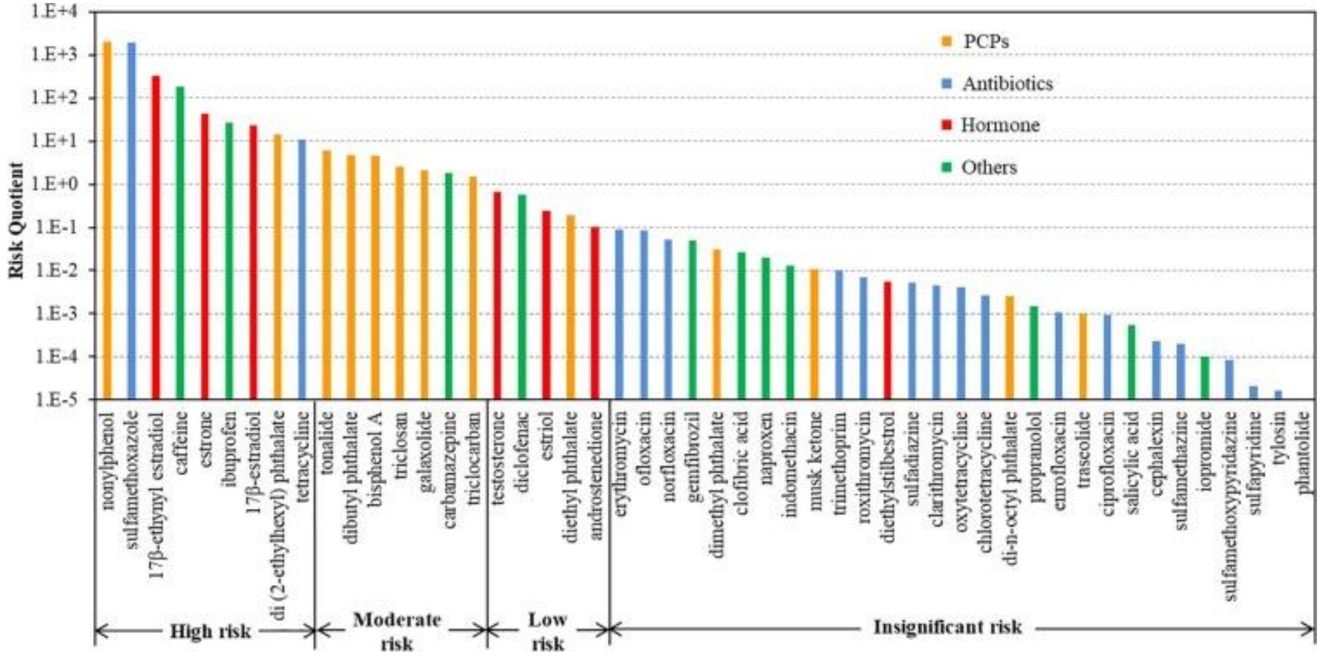
https://www.youtube.com/watch?v=J7dqHJZR6PE

4. Assess the risk

4. Assess the risk



4. Assess the risks: **emerging contaminants**



Risk ranking of PPCPs, based on effect concentration for the most sensitive species and the median concentrations in surface waters

Emerging contaminant	Ecology effect	Human health effect	References
Engineered nanoparticles	Toxic to bacteria, plants, fish, earthworm (growth, mortality, reproduction, gene expression),	Cytotoxicity, oxidative stress, inflammatory effects, in lungs, genotoxicity, carcinogenic effects, granulomas, thickening of alveolar wall, and augmented interstitial collagen staining	(Boczkowski and Hoet, 2010, Maurer-Jones et al., 2013, Pauluhn, 2010)
Endocrine disruptors	Toxic to wildlife, human	Alter reproductively relevant, sexually-dimorphic neuroendocrine system, alter endogenous steroid levels, etc., diabetes, problems in the cardiovascular system, abnormal neural behaviours and linked to obesity.	(Frye et al., 2012, Braun and Hauser, 2011, Vandenberg et al., 2013)
Ionic liquids	Inhibitory effects on a variety of bacteria and fungi, influencing the growth rate of algae, toxic to invertebrates, fish and frogs	Adverse effects on neuronal process, cytotoxicity,	(Thuy Pham et al., 2010, Wang et al., 2010, Li et al., 2012, Li et al., 2009)
Perfluorinated compounds	Bioaccumulation in fish and fishery products	Accumulate primarily in the serum, kidney and liver, potentially adverse effects on developmental, reproductive systems and other damaging outcomes	(US EPA, 2014, Danish Ministry of the Environment, 2015)

Credit: https://doi.org/10.1016/j.envint.2019.105454, https://doi.org/10.1016/j.chemosphere.2016.03.068

4. Assess the risks: **Pharmaceuticals**

88 %

OF HUMAN PHARMACEUTICALS ARE WITHOUT ENVIRONMENTAL TOXICITY DATA

88% of human pharmaceuticals do not have comprehensive environmental toxicity data. Whilst pharmaceuticals are stringently regulated for efficacy and patient safety, the negative effects they may have in the natural environment have not yet been sufficiently studied and are not covered by an international agreement or arrangement.

10 %

OF PHARMACEUTICAL PRODUCTS HAVE A POTENTIAL ENVIRONMENTAL RISK

An estimated 10% of pharmaceutical products have a potential environmental risk (Küster and Adler, 2014).

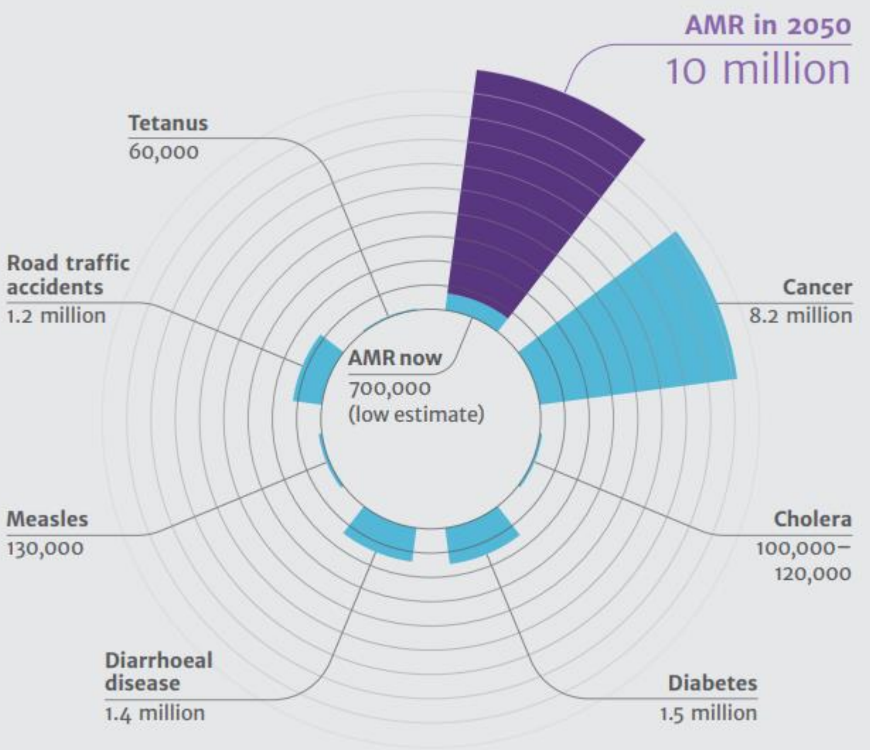
Box 1. **Antimicrobial resistance: an urgent, global health crisis**

Antimicrobial resistance (AMR) is a global health crisis with the potential for enormous health, food security and economic consequences. AMR is the ability of a microbe to resist the effects of medication that could once successfully destroy or inhibit the microbe.

Drug resistant infections already cause an estimated 700,000 deaths each year globally. If no action is taken, this is projected to increase to 10 million per year by 2050 – that is more than the number of people dying from cancer. A continued rise in AMR is projected to lead to a reduction of 2-3.5% in GDP globally, with a cumulative cost of up to USD 100 trillion.

The mis- and over-use of antibiotics is an important contributing factor of AMR; up to 50% of the antibiotics prescribed for human use are considered unnecessary. The number is even greater in the agriculture and aquaculture sectors, where they are mainly administered as a growth promoter and as a substitute for good hygiene. The environment becomes a reservoir for resistant genes, as well as an arena for the development and spread of resistance to pathogens.

Deaths attributable to AMR every year compared to other major causes of death



OECD Policy Brief on Pharma

The Review on Antimicrobial Resistance, Chaired by Jim O'Neill, 2014

Policy development

Policy developments

The European Green Deal is about **improving the well-being of people**. Making Europe climate-neutral and protecting our natural habitat will be good for people, planet and economy. No one will be left behind.

The EU will:

- Become climate-neutral by 2050
- Protect human life, animals and plants, by cutting pollution
- Help companies become world leaders in clean products and technologies
- Help ensure a just and inclusive transition

INDUSTRY

Support industry to innovate and to become global leaders in the green economy

European industry only uses **12%** recycled materials

Policy developments

Towards Zero Pollution means:

« For the health of our citizens, our children and grandchildren, Europe needs to move towards a zero-pollution ambition »

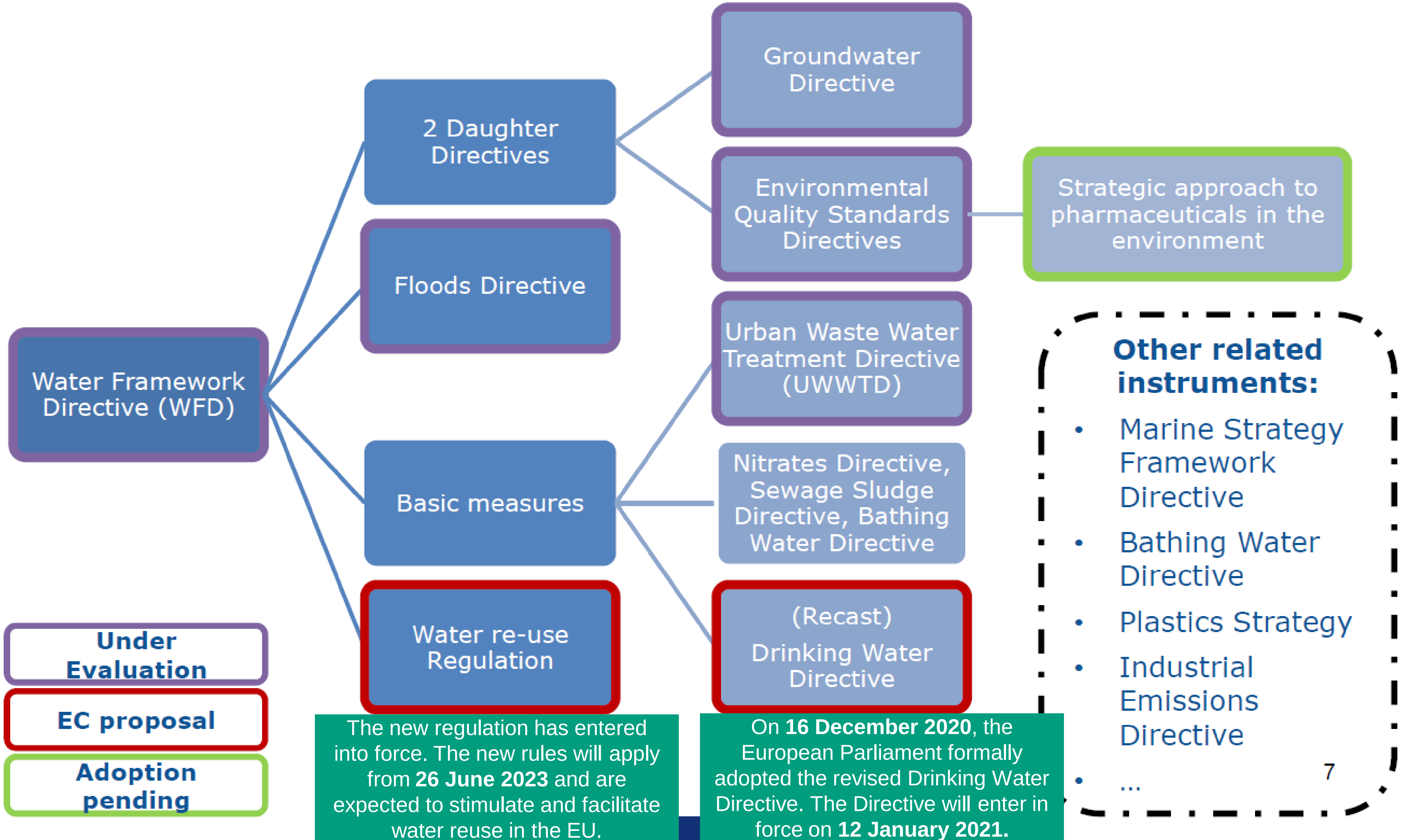
This entails a cross-cutting strategy for the protection of citizens' health from environmental degradation and pollution addressing:

- ✓ Air and water quality
- ✓ Hazardous chemicals
- ✓ Industrial emissions
- ✓ Pesticides and endocrine disruptors

EU water acquis

European Commission

European Commission, Directorate General for Environment
Units C.1 and C.2
Brussels, 22 October 2019



Policy Development: Surface Water Watchlist

1st (2015)

- 17-Alpha-ethinylestradiol (EE2)
- 17-Beta-estradiol (E2), Estrone (E1)
- Diclofenac
- 2,6-Ditert-butyl-4-methylphenol
- 2-Ethylhexyl 4-methoxycinnamate
- Macrolide antibiotics
- Methiocarb
- Neonicotinoids
- Oxadiazon
- Triallate

2nd (2018)

- 17-Alpha-ethinylestradiol (EE2)
- 17-Beta-estradiol (E2), Estrone (E1)
- Macrolide antibiotics
- Methiocarb
- Neonicotinoids
- Metaflumizone
- Amoxicillin
- Ciprofloxacin

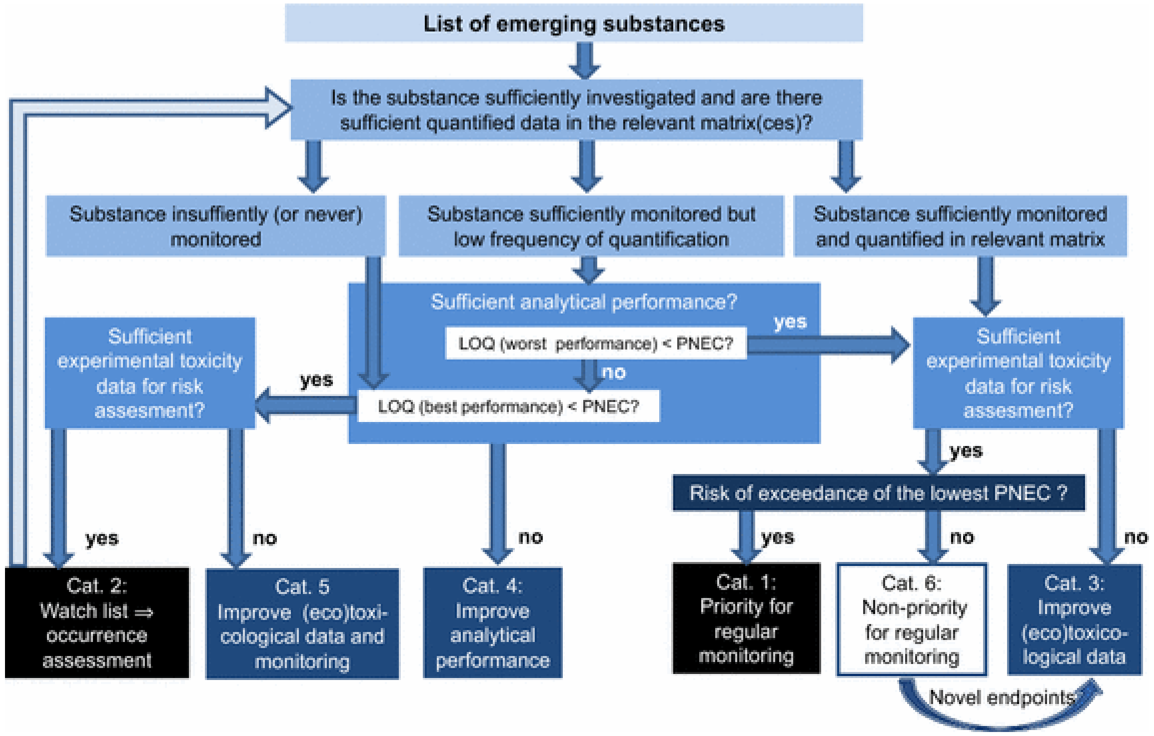
3rd (2020)

- Metaflumizone
- Amoxicillin
- Ciprofloxacin
- Sulfamethoxazole
- Trimethoprim
- Venlafaxine and O-desmethylvenlafaxine
- Clotrimazole, Fluconazole, Imazalil, Ipconazole, Metconazole, Miconazole, Penconazole, Prochloraz, Tebuconazole, Tetraconazole
- Dimoxystrobin
- Famoxadone

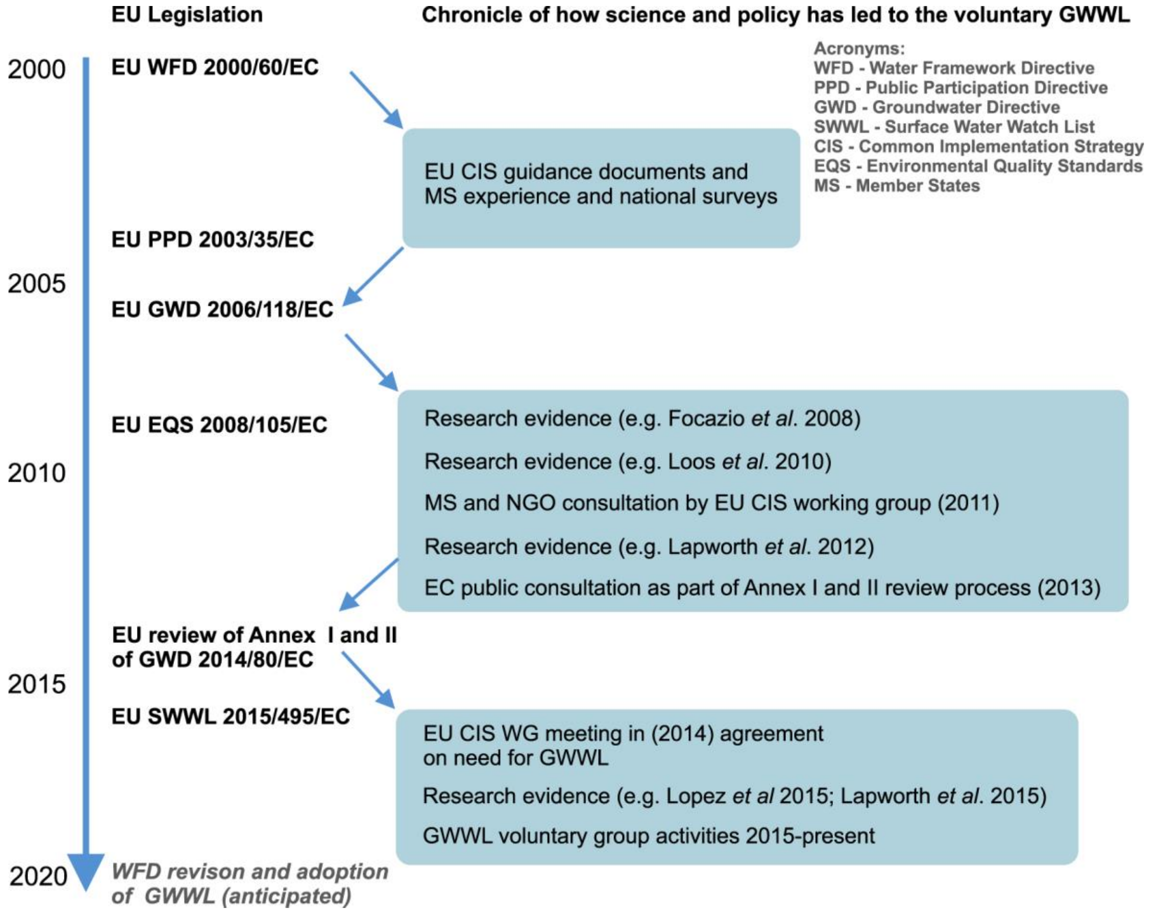
Personal care products, pharmaceuticals, hormones, pesticides

Policy Development

Prioritization scheme of the NORMAN network



Groundwater watch list (GWWL)



Credit: Dulio, V., *et al. Environ Sci Eur* **30,** 5 (2018), Dan J Lapworth et al Environ. Res. Lett. 14 035004 (2019)

Water legislation evaluation – Fitness Check

October 2017	• Publication of roadmaps (WFD, FD) • Finalisation of terms of reference (contract-support study)
April 2018	• Launch support study – Fitness Check
September 2018	• Launch of public consultation – until 11 March 2019 (~386,000 replies) • Launch of targeted consultation and experts workshops
October 2018 –June 2019	• **Targeted consultation with relevant stakeholders – until 29 March + interviews** • First 2 workshop – October 2018 • Workshops on validation of findings (10 April , 3 June) • Focus Groups: One specific on Groundwater (29 April)
End of 2019	• Finalisation of support study • Commission report on Fitness Check

Cooperation **Fitness Check - UWWTD evaluation**

On 23 October 2020, an Inception Impact Assessment was launched. This initiative addresses the findings of the Fitness Check in relation to chemical pollution and the legal obligation to regularly review the lists of pollutants affecting surface and groundwaters. **The feedback period ended on 20 November 2020.**

Review of the drinking water directive

On 16 December 2020, the European Parliament formally adopted the revised Drinking Water Directive. The Directive entered in force on 12 January 2021, and Member States will have two years to transpose it into national legislation.

Key features of the revised Directive are:

- Reinforced water quality standards which are more stringent than WHO recommendations.
- Tackling emerging pollutants, such as endocrine disruptors and PFA's, as well as microplastics - for which harmonised analytical methods will be developed in 2021.
- A preventive approach favouring actions to reduce pollution at source by introducing the "risk based approach". This is based on an in-depth analysis of the whole water cycle, from source to distribution.
- Measures to ensure better access to water, particularly for vulnerable and marginalised groups.
- Measures to promote tap water, including in public spaces and restaurants, to reduce (plastic) bottle consumption.
- Harmonisation of the quality standards for materials and products in contact with water, including a reinforcement of the limit values for lead. This will be regulated at EU level with the support of the European Chemicals Agency (ECHA).
- Measures to reduce water leakages and to increase transparency of the sector.

Updated/new Parameters

→Based on WHO Report

Risk-based approach

→ Monitoring only where substances are detected

<u>Improved health</u> protection

<u>Limited costs</u> for water suppliers

Better alignment with Water Framework Directive


PLASTIC TRASH CHOKING SEA
BOTTLENOSE DOLPHIN !!..
MIKE LUCKOVICH

Questions?

Surface water quality issues

integrated water resources management

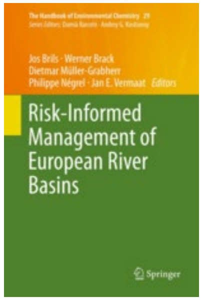
water quality management

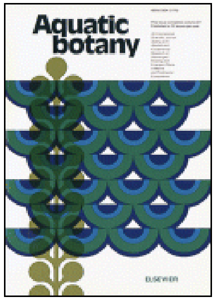
Jan Vermaat

content

1. Let me introduce myself
2. Water Quality issues
    - What is water quality?
    - History
    - Causes, effects and types of water pollution
3. Integrated Water Resources Management
    - Water is a special renewable resource
    - Shortage and overuse, now and in the future
    - Upstream-downstream, sectoral, national and international
    - What to integrate, actually?
    - Any progress? River basin organisations
4. Water Quality Management
    - Management for what purpose?: ‘boatable, fishable, swimmable’
    - Indicators and their (mis-)use; tools for the manager
    - Any progress made?
5. Concluding remarks

Jan Vermaat?





- Research dean Faculty Env Sci & Nat Res. (MINA)
- Before:
  - dept head Env. Sci. (IMV) 2014-2017
  - prof Earth Sciences and Economics, IVM, VU Amsterdam;
  - lecturer UNESCO-IHE Delft;
  - PhD Wageningen Agric Univ
  - Research interests: water quality, landscape ecology, biogeochemistry, wetlands, ecosystem services

water quality issues

What is water quality – your views please

Punch, (1835) Old father Thames

what is water quality? use matters

- Depends on use

- Purpose of water use:

World view: free for all or scarce resource

sectoral strength < >
economic value of a m^3 used

  - Navigation/transport
  - Power generation
  - Industrial cooling or process water
  - Cattle watering
  - Fish rearing, fisheries
  - Agricultural irrigation
  - Human household process water (lawns, cars, toilets, dishes)
  - Human drinking water
  - Human recreation: swimming, boating …
  - Amenity: a sun sinking in the sea, …, or pure nature

water quality and use

Use affects quality	Sewage discharge, stormwater run-off, manure, fertilizer and pesticide leaching, cooling water, mine and factory effluents
Quality affects use	Drinking water, process water, livestock watering, aquaculture, irrigation, swimming, wildlife, fisheries
Some uses have less direct effect on wq	Hydropower, navigation, recreative boating, low-intensity fishing

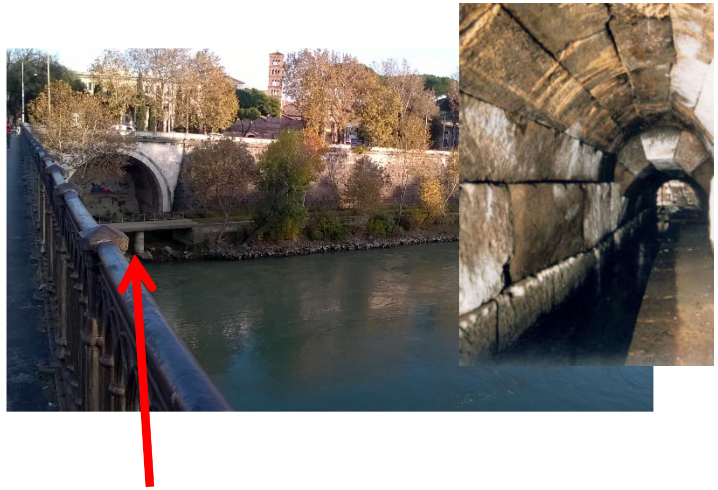
water quality criteria for different uses

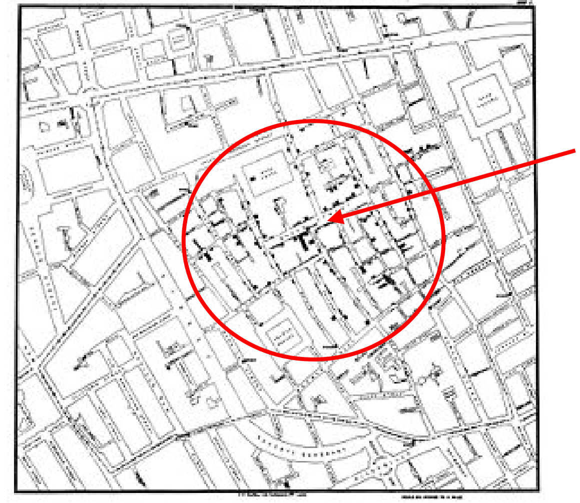
sectoral use	criteria?
Navigation/transport	
Power generation	
Industrial cooling or process water	
Cattle watering, fish rearing, fisheries	
Agricultural irrigation	
Human household process water	
Human drinking water	
Amenity: recreation, the view	

Sectoral use is not static

example Vaarajoki (Finland): big rocks first removed but now returned: why?

history 1





- We knew, actually, …..
- The Romans already constructed aquaducts and sewage systems for good reasons: the Cloaca Maxima, for example, is operational since 600 BC
- Public health and clean drinking water were essential

- John Snow (1854): "The result of the inquiry, then, is, that there has been no particular outbreak or prevalence of cholera in this part of London <u>except</u> among the persons who were in the habit of drinking the water of the above-mentioned pump well." (start of epidemiology)

history 2

Old Father Thames

Foodweb issues and human toxicity

From Helmer et al Global Freshwater Quality

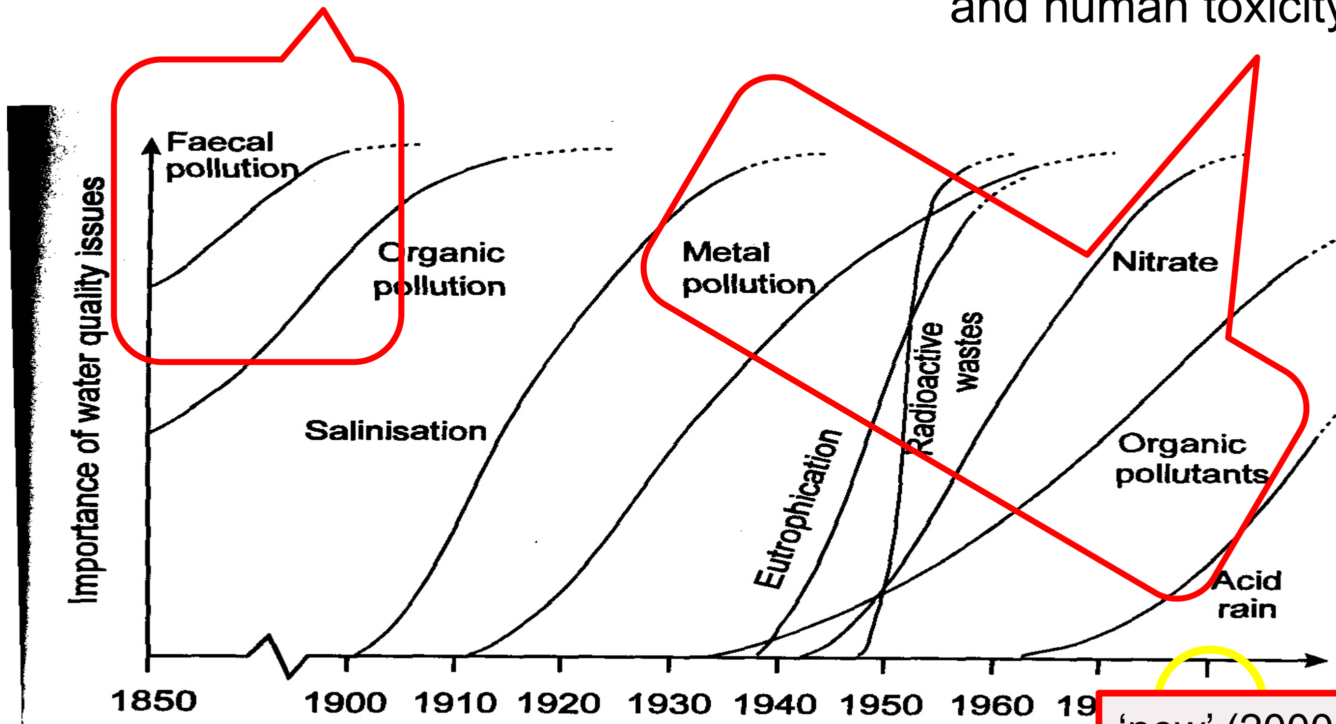


Figure 1.3 The sequence of water quality issues arising in industrialis
(After Meybeck and Helmer, 1989)

'new' (2000+), emerging:

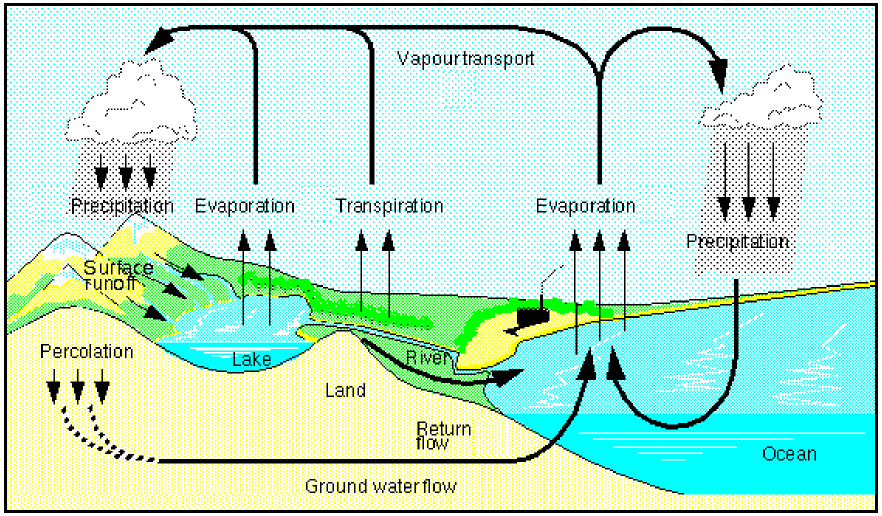
- endocrine disruptors
- microplastics

- Human health and economy are prime concern
- Ecosystem concern comes second
- Time plot: mix of rising awareness, and emergence of true problems

history 3

- So, water quality has declined, early in history and more so recently
- Due to many different types of pollutants from very different sources
- Different pollutants: different mechanisms, and different effects …. Different sources and mechanisms: different management options (lecture 3)

water type matters!



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

category	% volume	% world area	renewal time
atmosphere	0.001		7-11 d
river channels	0.0001		7 d
freshwater lakes	0.009	2	330 d
saline lakes and inland sea	0.008		1-4 y
soil water	0.005		?
deeper ground water	0.62		80-300 y
ice caps and glaciers	2.15		12,000 y
ocean	97.2	70	300-11,000 y
sum	99.9931	72	

- Water type matters: river, lake, brackish lagoon, sea, ground water …
- Dilution is not always a solution to pollution
- Rather loading versus ‘natural’ breakdown capacity
- Critical load is or should be an important concept

point and diffuse sources

- Point sources: with a pipe - factories, power plants, sewage outlets, feedlots
- Non-point sources: farm fields, streets, deposition from the air, yards, lawns and golf courses

sources of pollution

point and diffuse sources

Table 1.4 Anthropogenic sources of pollutants in the aquatic environment

Source	Bacteria	Nutrients	Trace elements	Pesticides/ herbicides	Industrial organic micropollutants	Oils and greases
Atmosphere		x	xxxG	xxxG	xxxG	
Point sources						
Sewage						
Industrial effluen						
Diffuse sources						
Agriculture						
Dredging						
Navigation and harbours	x	x	xx		x	xxx
Mixed sources						
Urban run-off and waste disposal	xx	xx	xxx	xx	xx	xx
Industrial waste disposal sites		x	xxx	x	xxx	x

x Low local significance
xx Moderate local/regional significance

These are important pollutants,
What is their effect?
Which one do you miss?

BOD, viruses, parasites, medicinal residuals, plastics

From Helmer et al Global Freshwater Quality

downstream a point source

- Aquatic ecosystems have a "natural" absorptive capacity, also for very 'difficult' toxic substances
- example shows what happens downstream a sewage outfall
- Depends on volume, flushing, microbial activity, sediment retention [….]

Question: What happens at other point sources?

From: Hynes (1963) The biology of polluted waters

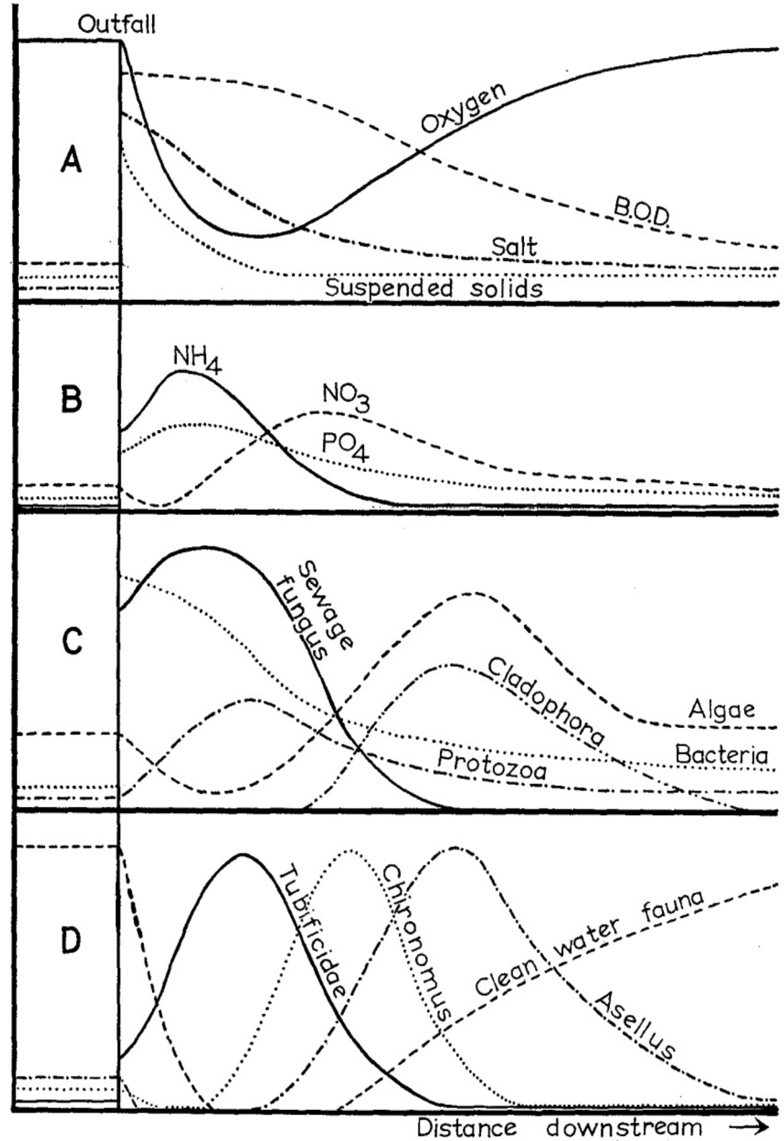
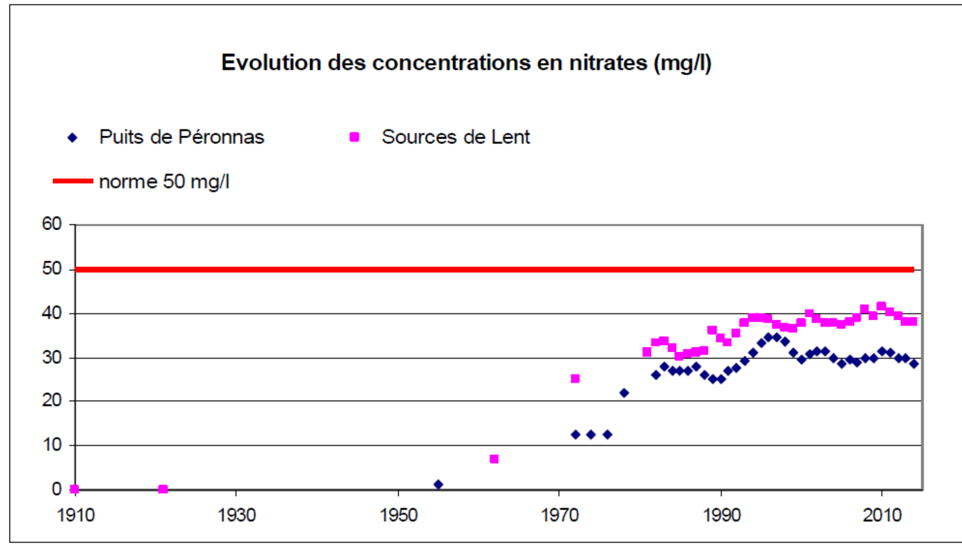


FIG. 16. Diagrammatic presentation of the effects of an organic effluent on a river and the changes as one passes downstream from the outfall. A & B physical and chemical changes, C Changes in micro-organisms, D Changes in larger animals.

diffuse pollution

- Also here: ecosystems have a “natural” absorptive capacity, even for difficult substances

- Nitrate leaching to aquifers
- Nutrient overloading of surface waters

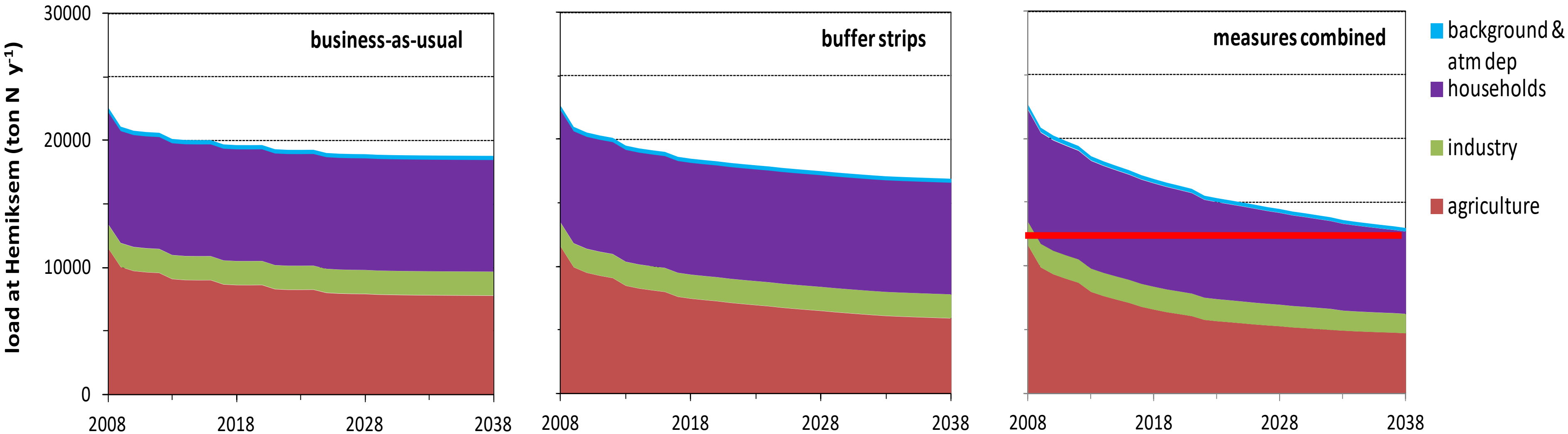


Évolution des teneurs en nitrates exprimées en mg/l de NO_3

Time series of drinking water well NO_3 in Bourg-en-Bresse (SE France)

Discussion: can we see climate change as a form of diffuse pollution?

point and diffuse sources combine



- Example: we modelled Nitrogen loading to the Belgian river Scheldt, to evaluate economic efficiency of different measure packages (improve wwtp's, reduce cattle, buy buffer strips)
- Red line is target for the Water Framework Directive, the Eus common water quality regulation

Question: what is point and what diffuse?

* Vermaat et al (2012) Ecol & Soc

eutrophication

- Plants require nutrients (N, P), but excessive loading stimulates excessive plant growth
- Excess plants? Cyanobacteria (some very toxic, interfere with drinking water, also in Norway), duckweed, water hyacinth, filamentous algae

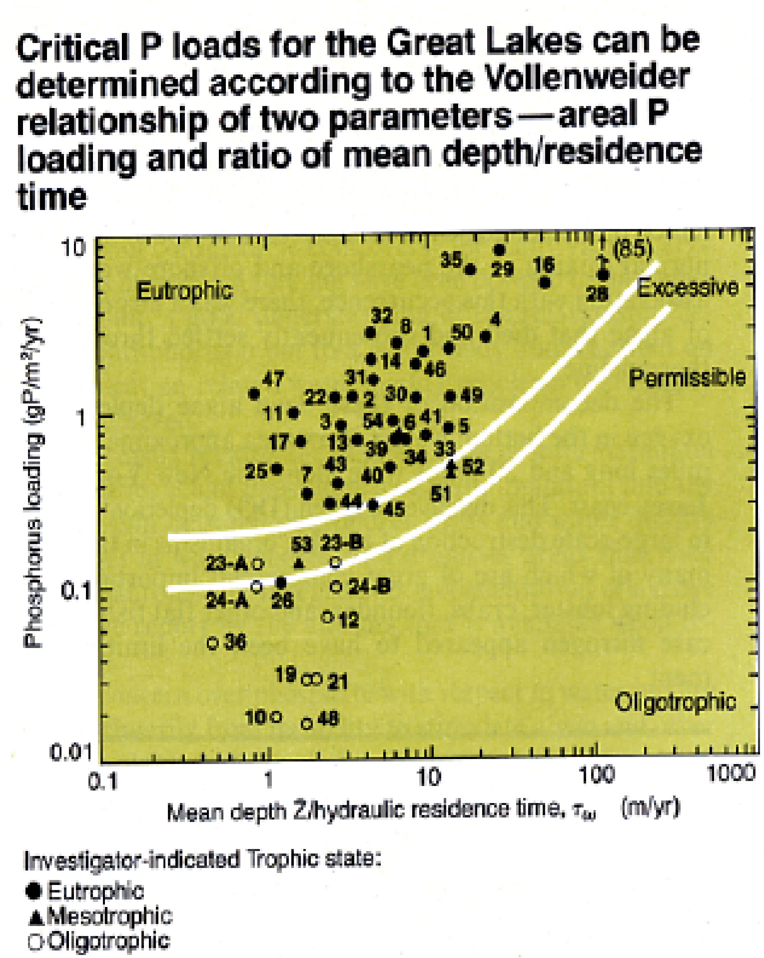
- When plants die and decompose, oxygen levels decline, and we are back to the BOD issue

Too much algae. **(Top)** Removing macroalgal blooms at the Olympic Sailing venue, China. **(Middle)** Seagrasses covered with attached algae in a Danish estuary. **(Bottom)** Non–N2-fixing cyanobacteria blooms in Lake Okeechobee, Florida, U.S.A.

eutrophication 2: critical load

- Intuitively not difficult actually: larger volumes that are more frequently flushed can cope with higher loads
- A well-established concept, but often authorities find concentrations (mg/L) easier than loads (kg/ha/yr; USA abbreviation = TMDL).

Question: Why concentrations preferred?

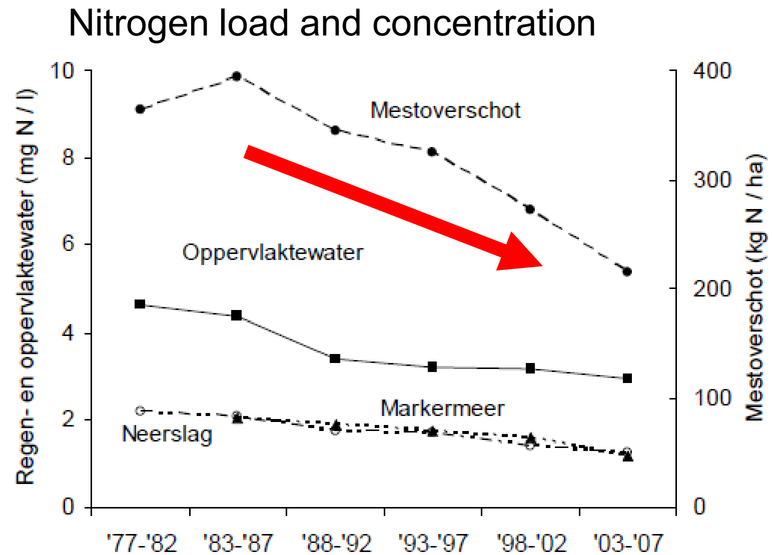


From Lee et al. (1978), Science

quick-and-dirty typology WQ issues

Issue (pollutant type)	Consequence in water body (STATE CHANGE)	Consequence for human society (IMPACT)
Type 1: organic loading (faeces)	• Low oxygen • faecal bacteria	• Fish kills, • Human disease and mortality
Type 2: excessive nutrient loading	• Eutrophication = increased algal growth and changing species • Turbid water • toxic micro-algae (cyanobacteria) • Mass decay then low oxygen	• Direct human health (nitrate & nitrite) • Disappearance desired species • Drinking water • Again fish kills
Type 3: toxic metals, pesticides and micropollutants	• Disappearance sensitive species • Foodweb accumulation	• Indirect ecosystem effects • Human food and drinking water
Type 4: thermal pollution	• Low oxygen • Disappearance sensitive species	• Fish kills • Indirect ecosystem effects
Type 5: hydromorphological change	• Form changes: flow and ecossytem function changes	• Many direct and • Indirect ecosystem effects

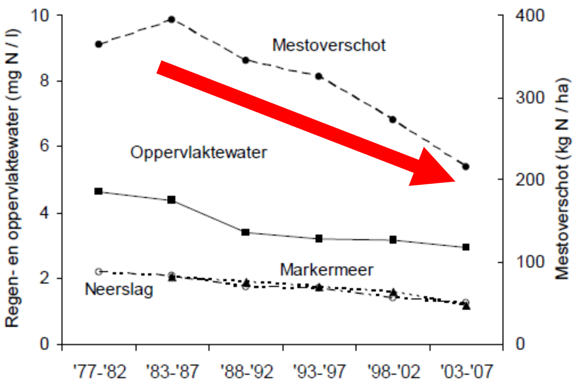
what have we done?



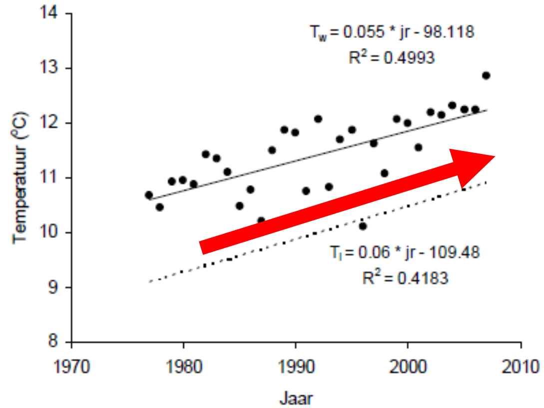
- Regulation: laws, enforcement (fines and subsidies), communication to the public, monitoring
- Investment: sewage works, sewer systems, on-farm and on-plant technology
- So loads decline

what have we done?

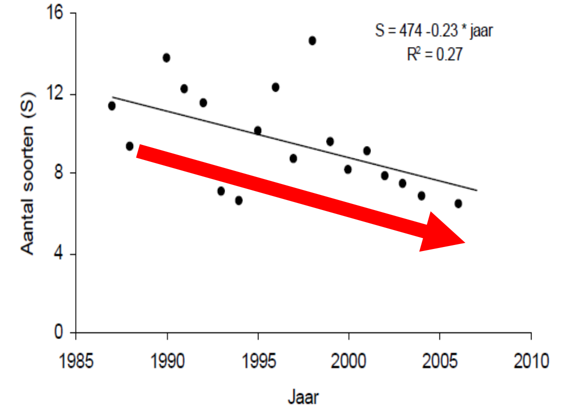
Nitrogen load and conc



water and airtemp



waterplant diversity



- Regulation, investment: loads decline

- But in the meantime: temperature rises, new pesticides are used and biodiversity indicators are not improving at all.
- Load actually stil high: 200 kg N/ha/y is not 'circular' or 'equilibrium'
- A challenge for politicians and policy makers!
- For example: Danish farmers have effectively overturned policy

water quality issues - conclusions

- Water quality for what?
- Historically: for us, human health and human use
- We traced some pollutant types from their source
- Noted the ‘natural’ cleaning capacity of aquatic systems, up to a limit: critical load
- We saw that awareness and abatement policy only got off the ground when the problems were really felt in society (by those with votes)

water quality issues

integrated water resources management

water quality management

Jan Vermaat

content

1. Let me introduce myself
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   - What is water quality?
   - History
   - From the mountains to the sea
3. Integrated Water Resources Management
   - Water is a special renewable resource
   - Shortage and overuse, now and in the future
   - Upstream-downstream, sectoral, national and international
   - What to integrate, actually?
   - Any progress? River basin organisations
4. Water Quality Management
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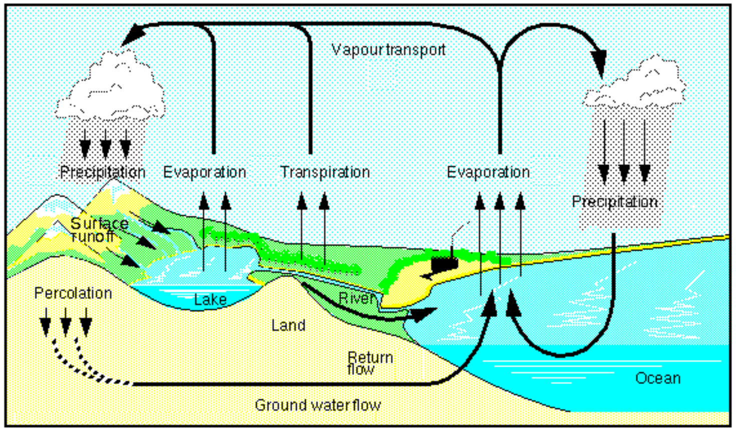
   - Any progress made?
5. Concluding remarks

water is a '±' renewable resource



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

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ice caps and glaciers	2.15		12,000 y
ocean	97.2	70	300-11,000 y
sum	99.9931	72	

- We can use only a tiny fraction ('limited'),
- With very rapid turn-over rates
- It is renewable if ………… it 'returns' in the same state (=Quality)

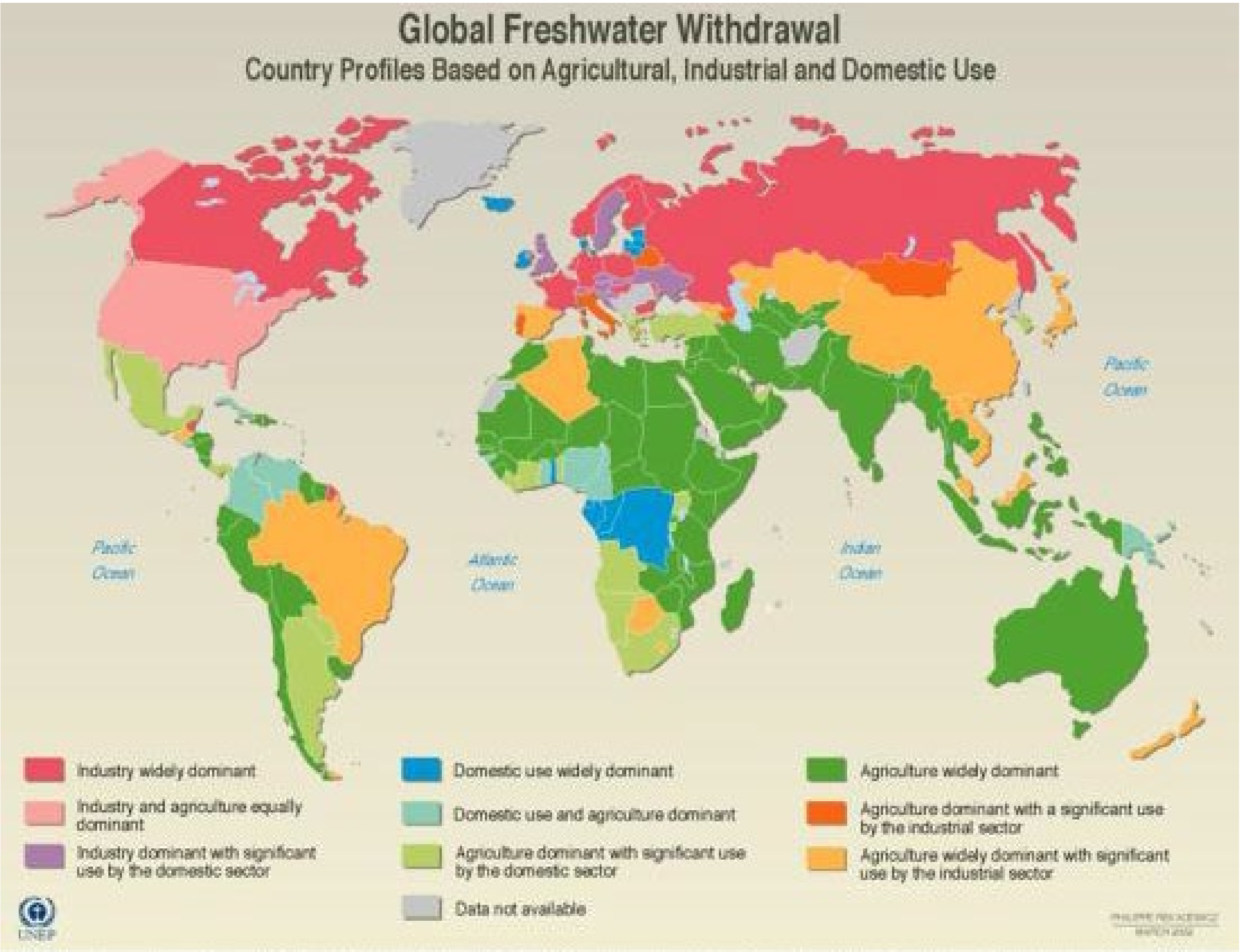
water as a resource

- For what? We can repeat the list from the previous lecture, but will use cruder sectors agriculture, domestic and industrial

- Purpose of water use:
  – Navigation
  – Power generation
  – Industrial cooling or process water
  – Cattle watering
  – Fish rearing, fisheries
  – Agricultural irrigation
  – Human household process water (lawns, cars, toilets, dishes)
  – Human drinking water
  – Amenity: a sun sinking in the sea, …, or pure nature

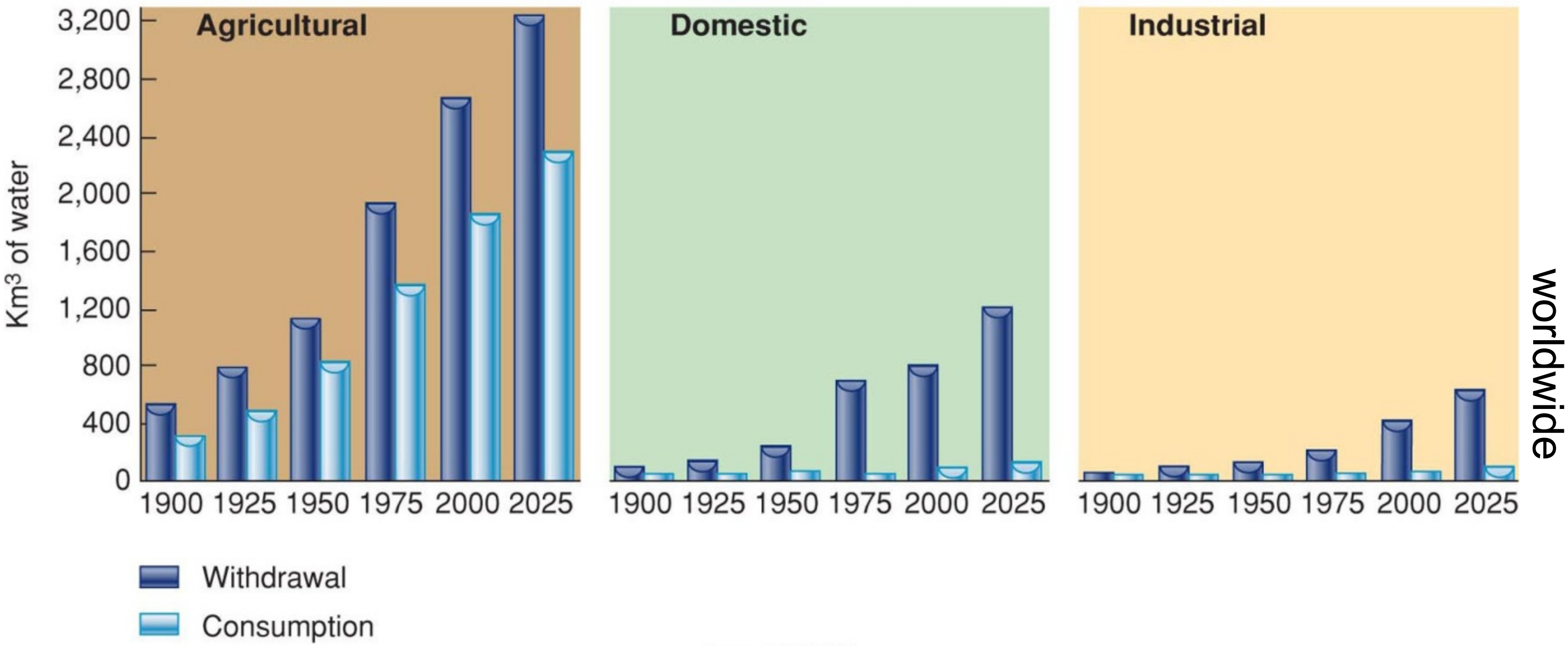
major freshwater users

- Differs between countries and climate zones
- Worldwide, agriculture claims 85%



Source: Based on data fromTable FW1 in *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

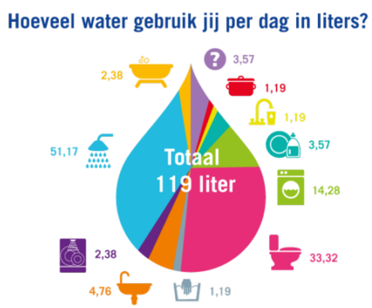
withdrawal > true consumption

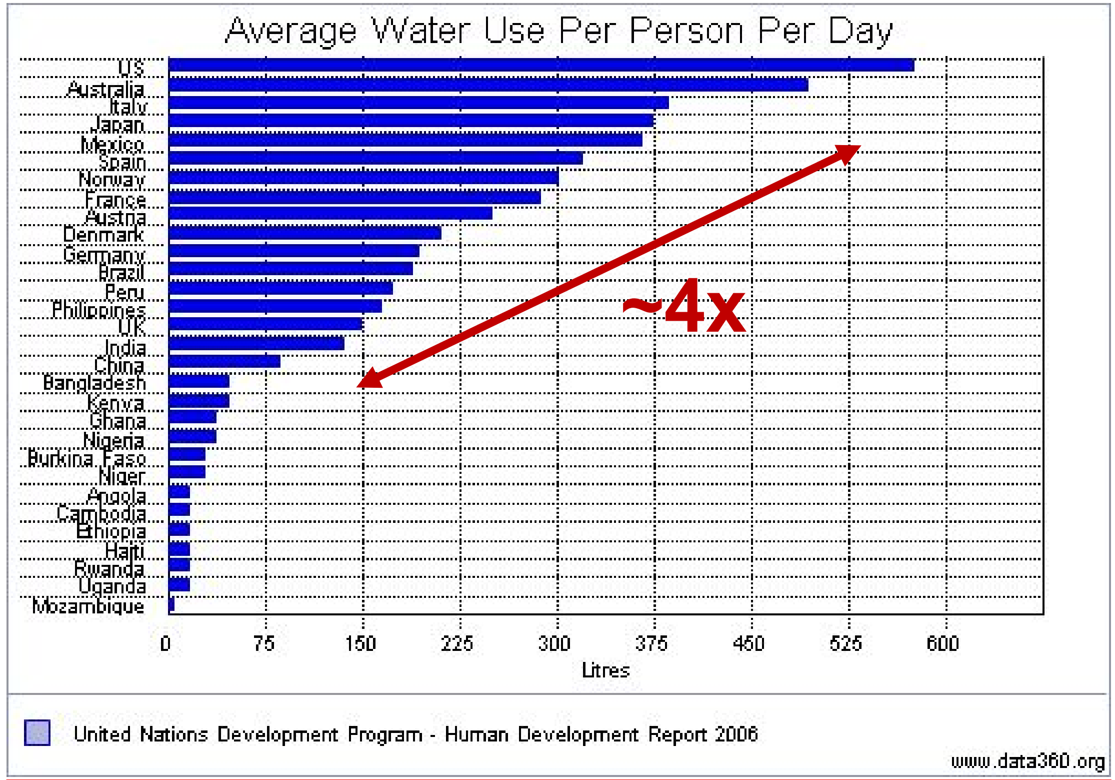


Source: UNEP, 2002

- Spillage in domestic and industrial use relatively high
- Optimization possible to necessary (depending on your political position)

individual domestic water consumption

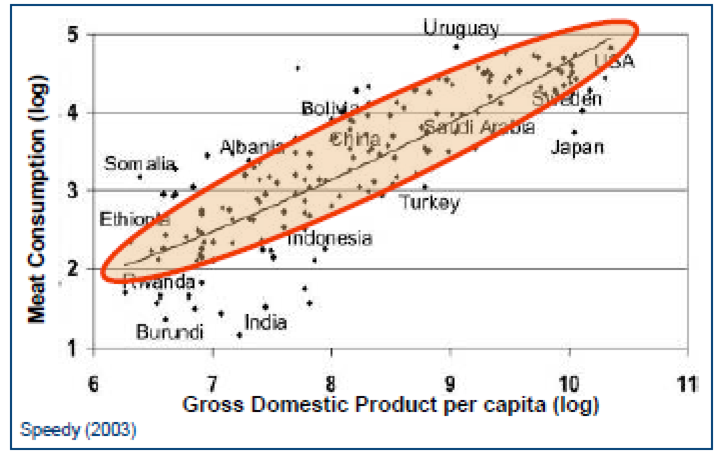


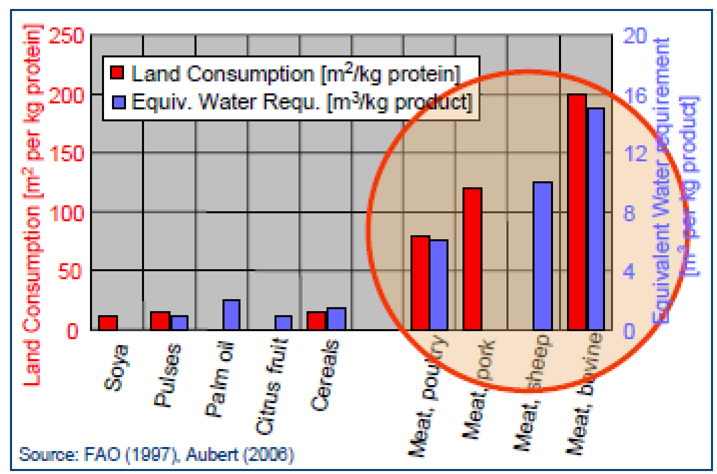


MDG > SDGs but still:
Between 1990 and 2015, 2.6 billion people gained access to improved drinking water: this target ~ achieved.

- Room for improvement
- Note: Millennium Goal for without acces to safe drinking water and basic sanitation, worldwide

and our diets require more water when we eat more animal protein





Picture borrowed from Borchardt

What if it does not 'return in the same state (Quantity & Quality)'?

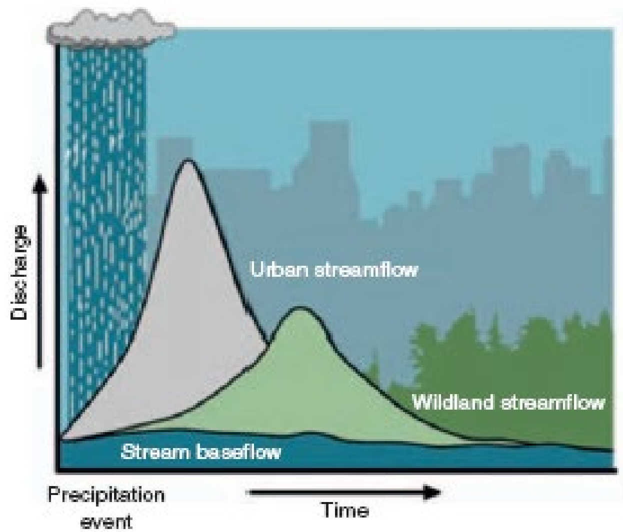
a thought exercise: a rain-fed river, like the Loire in France (110000 km^2, high JFM > 1350, low JAS < 400 $m^3 s^{-1}$), what is the effect of ..

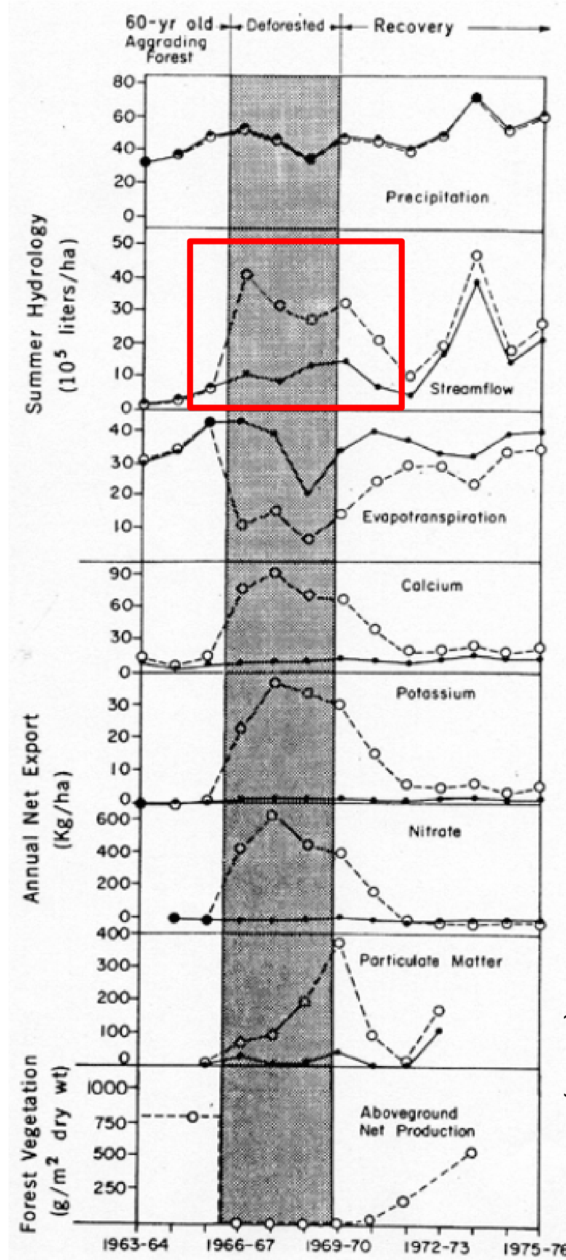
sectoral use	Too much	Too little	Poor quality
Navigation			
Power generation			
Industrial cooling or process water			
Cattle watering, fish rearing, fisheries			
Agricultural irrigation			
Human household process water			
Human drinking water			
Amenity: the view			

causes of too much or too little water

- Natural variability in weather (and climate)
- Direct or indirect effects of human actions
  - Upstream changes in water use
  - Simple continuation of excessive use
  - Upstream changes in land use
  - Upstream changes in the geomorphology of river and floodplain (civil engineers: hydromorphology)
  - Altered rainfall patterns due to climate change

causes of too much or too little water: example





Bormann & Likens (1978) Science

- Land use change affects river discharge pattern, and water quality
- This is the classical Hubbard Brook experiment: a first order catchment in Eastern USA. Still highly relevant.

climate change: rainfall patterns

Christensen et al., IPCC (2007), comparing 2090-99 vs 1990-99: ‘average’ rain does not change everywhere

Regional variability:

- Norway more rain, Spain less
- Models agree for the north but not for the south: problem!

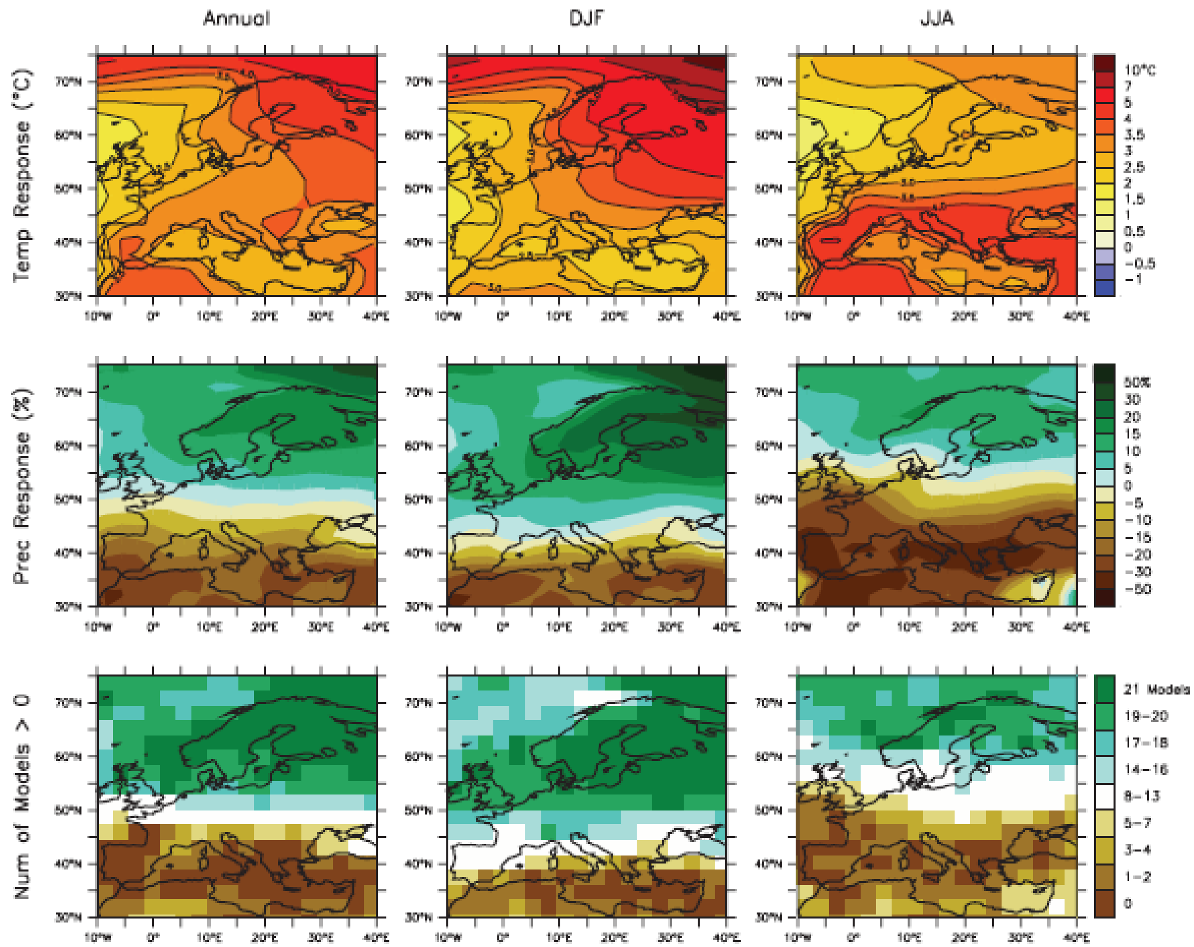
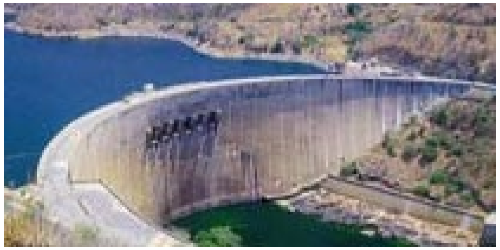


Figure 11.5. *Temperature and precipitation changes over Europe from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.*

875

conflicts over water?



- Upstream/downstream international (Yamuna/Ganges, Euphrate, Nile, Mekong, Rhine, Danube ..)
  - Rhine case: Rotterdam Harbour sued industries around Basel in 1990ies
- Upstream/downstream within a country, among sectors
  - Loire: agriculture vs oyster cultures; Meuse: industrial discharges B vs. drinking water NL; many, also Norway: hydropower vs fisheries)
  - ‘Upper Parana dams in Brazil have reduced 1000s of commercial fishermen to marginalized poor who continue to fish to ‘retain dignity’’ (Carvalho, 2008)

sectoral conflicts

Suez canal, Ferdinand de Lesseps, 1869

- River and agricultural engineers encountered growing opposition and were accused to be single-minded on:
  - Hydropower dams
  - Irrigation and drainage schemes
  - Navigation canals and sluices
  - Large, large, large, .. (too) large?
- But they felt ‘we are doing this like we did since the start of the enlightenment’ – what has changed? (my subjective story)

so, what to integrate actually?

- Here IWRM comes in
- different sectors compete, so needs should be weighed together, but:
  - Power distribution may be unequal
- The idea of IWRM arose in the 90ies* among engineers, and among WB, UN and FAO experts
  - who were confronted with serious stakeholder opposition
  - who were students in the 60ies and 70ies (and witnesed/had been part of democratic grass roots movements)

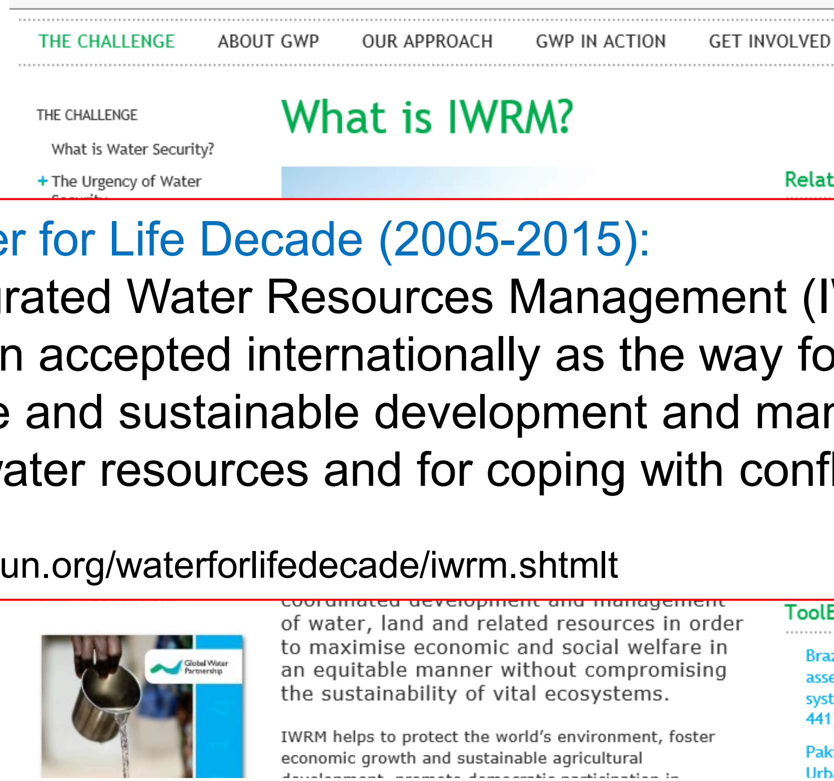
Let the river Alta live, hydropower vs local, and conservationist stakeholders, until 1981

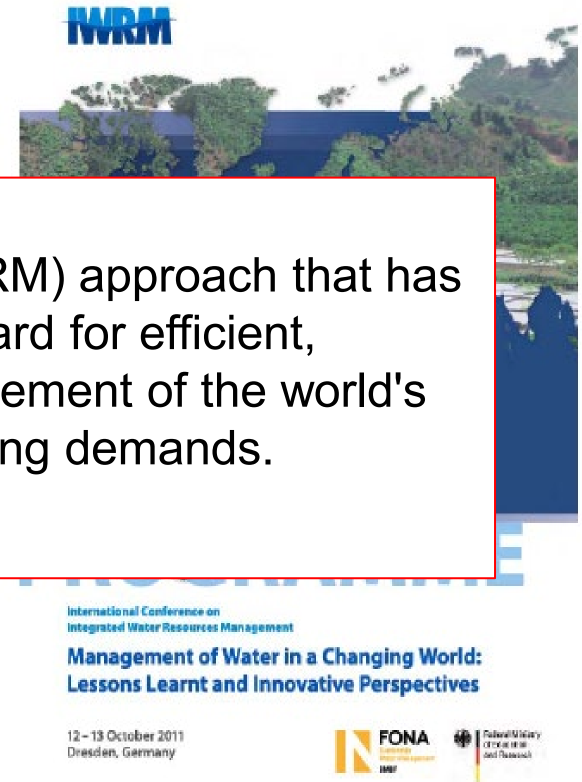
*1992, so called Dublin principles

notion: multisectoral is better

- Traditional supply management became ‘simple’, ‘old-fashioned’
- Sectoral fragmentation was recognized as a problem,
  - This was really HOT when I worked at UNESCO-IHE in Delft.
  - But still seen from the top, by those that train WRM managers, not necessarily in real cases
- New, more fashionable concepts emerged on conferences and in courses and text books:
  - Cross-sectoral, multifunctional integration
  - River basin as spatial unit for coordination
  - Institutional and capacity building
  - Indigenous communities and stakeholder consultation

including a definition





UN Water for Life Decade (2005-2015):
the Integrated Water Resources Management (IWRM) approach that has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands.

http://www.un.org/waterforlifedecade/iwrm.shtmlt

- Gwp.org: nice words, right to my heart!! UN: a bit simpler, but OK
- But the IWRM page has not been updated since 2010, Water for Life since 2014 ..

Dresden conference (2011)

> **IWRM** continues to be **amorphous**, and there is **no agreement on fundamental issues** like what aspect should be integrated, how, by whom, or even if such integration in a wider sense is possible. …**in the real world, the concept will be exceedingly difficult to be made operational.**“
>
> **Asit Biswas**
> (Stockholm Water Prize Laureate 2006; Third World Centre for Water Management)
>
> In Water International, Vol. 29, Issue 2, June 2004

- local cases of progress
- and cases of dead-lock or deterioration
- Not much new science or knowledge,
  - Neither at the side of the developers of models and DSS tools
  - nor at the side of the social scientists who are skilled in ‘dialogue’ and ‘consultation’
- this seems not so useful as a message in a lecture?

But let us look at these cases: maybe inspiration and lessons

Lesotho case: LHDA and Katse dam

1997 Rand Water, the end–user for LHWP water, reveals that Phase 1B could be postponed by as much as 20 years with water conservation measures. NGOs and US government officials press for review of demand–side management options and the economics of project postponement, but Department of Water Affairs urges World Bank to fund Phase 1B without delay.

1998 Water deliveries from Katse Dam began, as well as power production from Muela power plant (18 months later than planned).

1999 Widespread discovered on LHWP. Numerous multinational companies on the project found to have bribed the project's CEO.

2000 For the first time, dam–affected people hold a public demonstration to call attention to their plight. Research into the impacts of the dam project on downstream ecosystems reveals that, if the project delivers all the water it has promised, Lesotho's rivers will become akin to "wastewater drains."

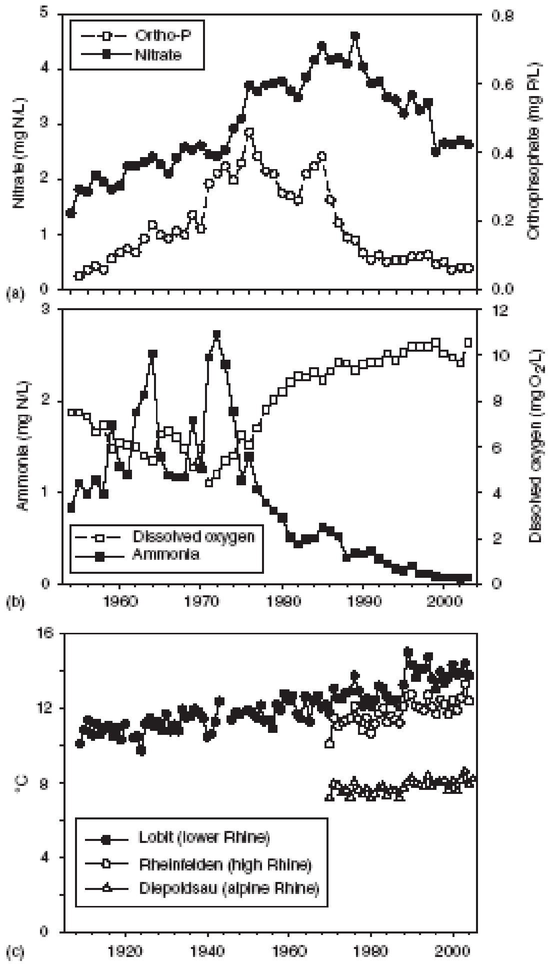
2002 First of bribe–giving firms found guilty in a Lesotho court.

2004 World Bank finally debars ACRES, one of the firms found guilty of bribery on LHWP.

More information:

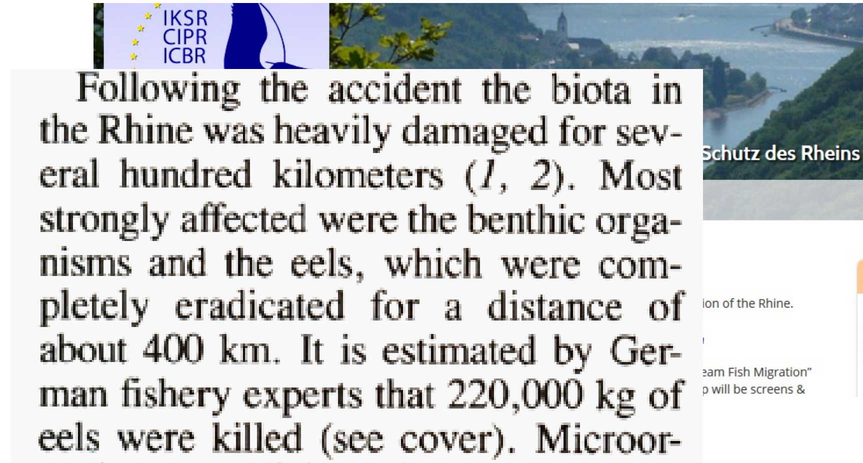
The Dam That Shook the Earth

IWRM case – maybe the Rhine is a success story



- This river is truely multisectorally used
- Water quality was really bad. Riparian states decided to improve this substantially in 1990 and it shows
- Climate change is projected to cause more serious floods and droughts with effects for many sectors. Riparian states jointly work on coping programmes

IWRM case – maybe the Rhine is a success story



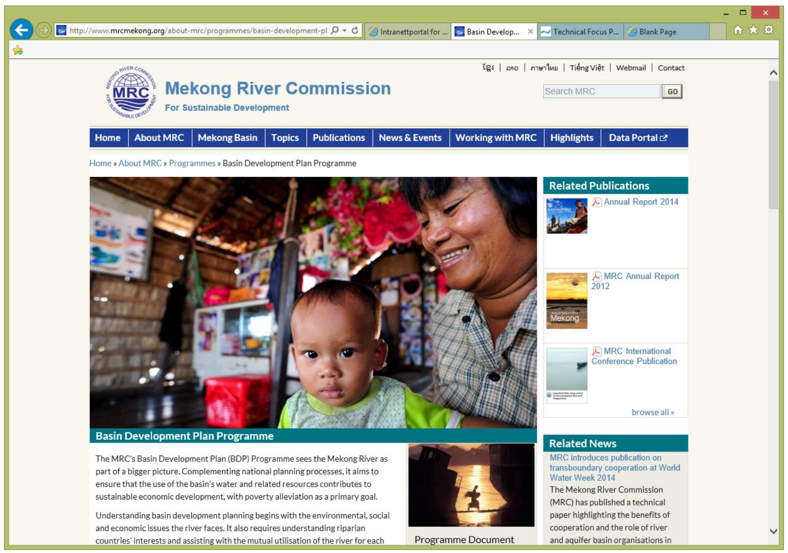
Following the accident the biota in the Rhine was heavily damaged for several hundred kilometers (*1*, 2). Most strongly affected were the benthic organisms and the eels, which were completely eradicated for a distance of about 400 km. It is estimated by German fishery experts that 220,000 kg of eels were killed (see cover). Microor-

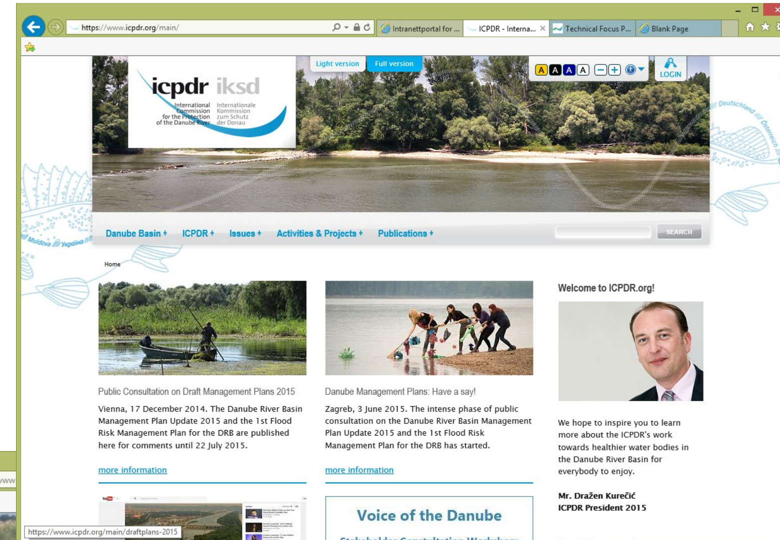
- What was the key? (Again my personal view)
- The Sandoz spill in 1986 was the trigger
- Massive public concern coincided with water ministers who really felt they had to, and could, show something (RAP, 1990, plus ICPR)
- Governments had money, institutional capacity and persistence
- European Commission was a silent but formidable partner, before WFD and flood directive became operational

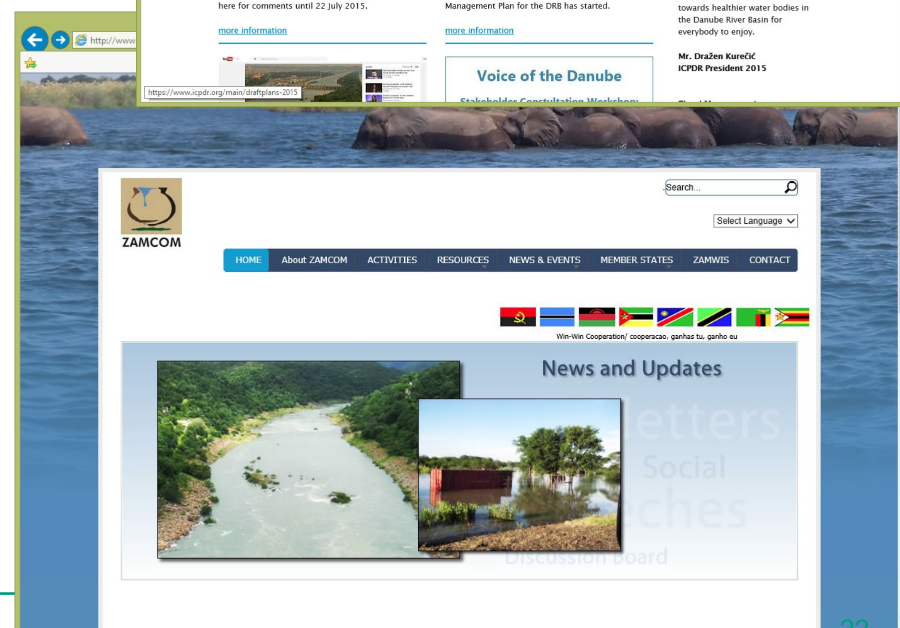
- But this was not orchestrated as IWRM, it developed into it, almost by stumbling and falling

progress: through establishment of river basin authorities

Danube, Mekong, Zambesi







What can we learn?

- Water is a limited AND a renewable resource

- Worldwide, water scarcity will increase, notably in poorer areas
- Meeting different, conflicting needs would increasingly necessitate multisectoral and Upstream-downstream integration and coordination
- So the word INTEGRATION in IWRM is necessary
- However, no clear convergence is apparent on IWRM as a practical vehicle for this purpose

- Local successes show that it does work!!
- with help of policy, law and their reliable and fair enforcement
- Which needs a long-term patience in transboundary rivers

water quality issues

integrated water resources management

water quality management

Jan Vermaat

content

1. Let me introduce myself
2. Water Quality issues
   - What is water quality?
   - History
   - From the mountains to the sea
3. Integrated Water Resources Management
   - Water is a special renewable resource
   - Shortage and overuse, now and in the future
   - Upstream-downstream, sectoral, national and international
   - What to integrate, actually?
   - Any progress? River basin organisations
4. Water Quality Management
   - Management for what purpose?: 'boatable, fishable, swimmable'
   - Indicators and their (mis-)use; tools for the manager
   - Any progress made?
5. Concluding remarks

water quality management

- From issues (many different!)
- Via IWRM (upstream-downstream and across sectors)
- To combine both quantity and quality in management

- first a class-room thought experiment: small groups

WQM: a cook book recipe

1. Define the purpose and use of the water (boatable, fishable, swimmable, drinkable), and get an idea of the 'issue at stake'
2. Translate this into a measurable and meaningful indicator and standard criteria
3. Observe (= design a monitoring programme: station network, sampling frequency, standardise lab and reporting procedures, ensure funds for all this)
4. Compare observations with standards: analyse and conclude (WQ=OK?)
5. Design economically effective, and societally acceptable measures if WQ not OK

quick-and-dirty typology WQ issues

Issue (pollutant type)	Consequence in water body (STATE CHANGE)	Consequence for human society (IMPACT)
Type 1: organic loading (faeces)	• Low oxygen • faecal bacteria	• Fish kills, • Human disease and mortality
Type 2: excessive nutrient loading	• Eutrophication = increased algal growth and changing species • Turbid water • toxic micro-algae (cyanobacteria) • Mass decay then low oxygen	• Direct human health (nitrate & nitrite) • Disappearance desired species • Drinking water • Again fish kills
Type 3: toxic metals, pesticides and micropollutants	• Disappearance sensitive species • Foodweb accumulation	• Indirect ecosystem effects • Human food and drinking water
Type 4: thermal pollution	• Low oxygen • Disappearance sensitive species	• Fish kills • Indirect ecosystem effects
Type 5: hydromorphological change	• Form changes: flow and ecossytem function changes	• Many direct and • Indirect ecosystem effects

WQM: applying the recipe

- Back to the main ‘issues’ from first lecture block
- Check and discuss the 5 steps
- Purpose, wq issue and indicator, monitoring programme, judgment quality, remedial measures
- Then apply them on the cases illustrated by each photograph
- Use your common sense and decide which WQ issue would be at stake in each case, do not ignore water quaNtity aspects
- Use 15 minutes with your immediate neighbour

WQM-EXERCISE: purpose, issue, indicator and take measure?

© Roger A. Clark/Photo Researchers

Punch, 1835

was the exercise far from reality? NO

Microcystis in Fredriksborgs Slotsoe; DK, 1985

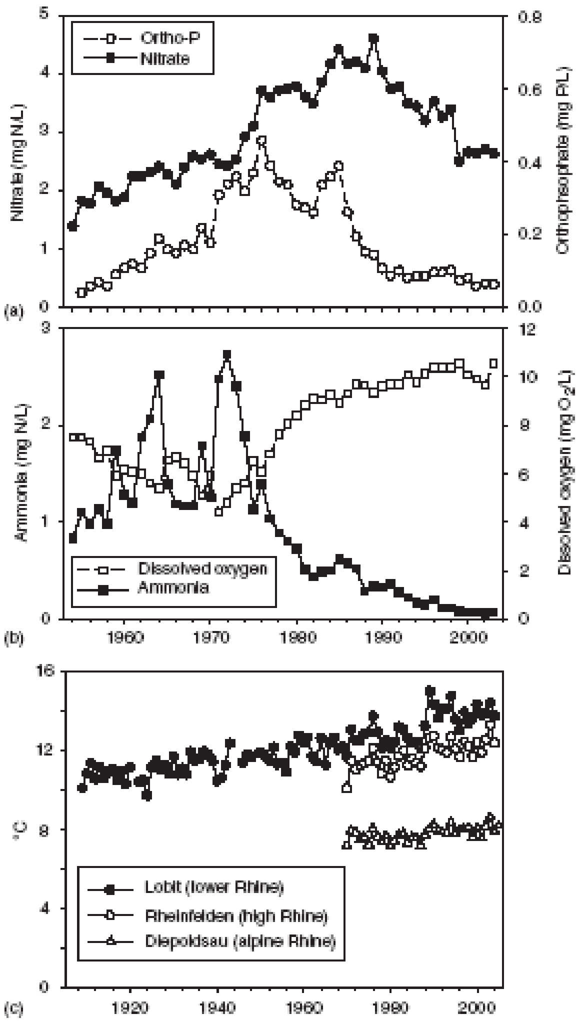
- in 1972, for example, the NL had the WVO, the law on the pollution of surface waters. This defined different water quality grades for different use, in a pragmatic way
- For example for carp and trout, based on oxygen (4 and 8 mg/L)
- And for swimming: 1 m water transparency
- Later came criteria for nutrients: 2 mg/L total N, 0.15 mg/L tot P
- And measures, with effects
- But across the EU, we have replaced this pragmatism for principle in the new millennium: the Water Framework Directive!

was the exercise far from reality? YES

- indicators and standards in reality have become a forest!!

Use	Drinking water					Fisheries and aquatic life		
Variable	WHO[1]	EU	Canada	USA	Russia[2]	EU	Canada[1]	Russia
Cadmium (mg l^{-1})	0.003	0.005	0.005	0.005	0.003		0.0002–0.0018[8]	0.005
Chromium (mg l^{-1})	0.05(P)	0.05	0.05	0.1	0.05		0.02–0.002	0.02–0.005
Cobalt (mg l^{-1})					0.1			0.01
Copper (mg l^{-1})	2(P)	0.1[1]–3.0[1]	1.0	1	2.0	0.005–0.112[8,9]	0.002–0.004[8]	0.001
Iron (mg l^{-1})	0.3	0.2	0.3	0.3	0.3		0.3	0.1
Lead (mg l^{-1})	0.01	0.05	0.05	0.015	0.01		0.001–0.007[8]	0.1
Manganese (mg l^{-1})	0.5(P)	0.05	0.05	0.05	0.5			0.01
Mercury (mg l^{-1})	0.001	0.001	0.001	0.002	0.001		0.0001	0.00001
Nickel (mg l^{-1})	0.02	0.05			0.02		0.025–0.15[8]	0.01
Selenium (mg l^{-1})	0.01	0.01	0.01	0.05	0.01		0.001	0.0016
Zinc (mg l^{-1})	3	0.1[1]–5.0[1]	5.0	5	5.0	0.03–2.0[8,10]	0.03	0.01
Organic contaminants[11]								
Oil and petroleum products (mg l^{-1})		0.01			0.1			0.05
Total pesticides (μg l^{-1})		0.5	100					
Aldrin & dieldrin (μg l^{-1})	0.03		0.7				4 ng l^{-1} dieldrin	
DDT (μg l^{-1})	2		30.0		2.0		1 ng l^{-1}	
Lindane (μg l^{-1})	2		4.0	0.2	2.0			
Methoxychlor (μg l^{-1})	20		100	40				
Benzene (μg l^{-1})	10			5			300	
Pentachlorophenol (μg l^{-1})	9(P)			10	10			
Phenols (μg l^{-1})		0.5	2		1.0		1.0	1.0
Detergents (mg l^{-1})		0.2		0.5[12]	0.5			0.1

measures and their effects 1



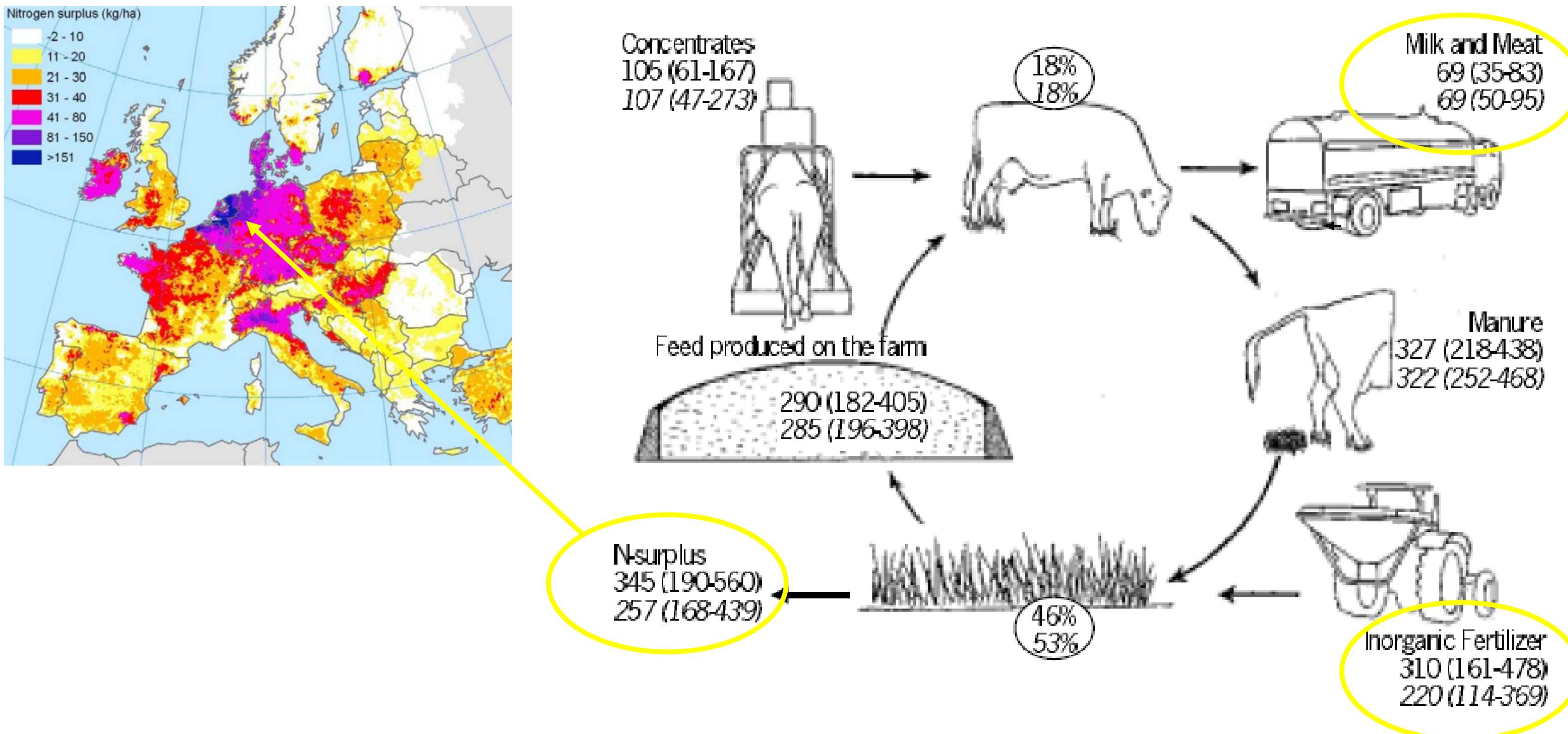
- Domestic sewage was an important point source, of BOD and nutrients. We built 1000s of sewage works, banned P in detergents and added P-removal as well as N-removal
- The Rhine, again, is an impressive example
- See also how climate change is apparent

- Unfortunately not all waters responded as expected* and we, the scientists, were sent back to do a better job.

- Food for thought and a good reason for modesty.

* Many Dutch lakes retained cyanobacteria, ditches turned more and more turbid

measures and their effects 2



Verhoeven et al 2003 NJAS; kg N/ha/yr
1995 and 1998

- Farming was identified as a major diffuse source of nutrients. Farmers were forced te become more economical in fertilizer use. In NL dairy productivity was constant as fertilizer use declined – paradoxically?

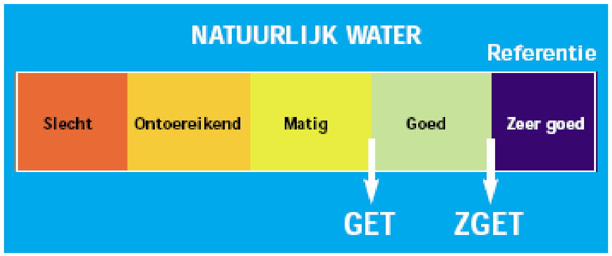
NB Levied max N surplus for 2003 was 180

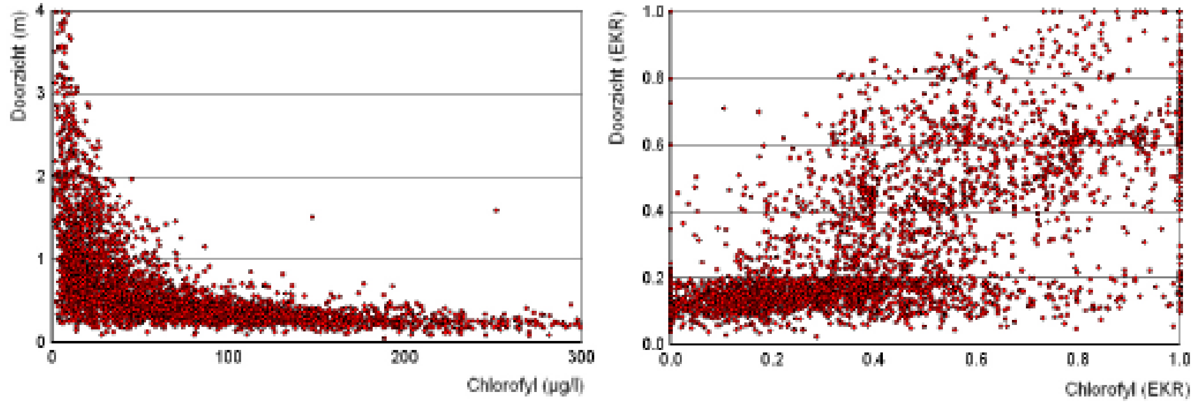
The WFD in the EU (and Norway)

The Water Framework Directive (WFD) expands the scope of water protection to all waters and sets clear objectives that a "good status" must be achieved for all European waters by 2015 and that water use be sustainable throughout Europe. This new overarching system is quite timely as Europe is water resources are facing increasing pressures. There is no time like the present to tackle the challenges and help secure our water resources for today and for future generations.

- Objective: a "good ecological condition" of all our surface- and ground-waters, to be filled in by member states
- Based on reference conditions, using ecology, physico-chemistry and morphology.
- combined clear, legalistic reporting conditions to Brussels

WFD





uur 45. Vergelijking tussen alle jaarwaarden chlorofyl en doorzicht: links met de oorspronkelijke eenheid, rechts met de beoordeling volgens de maatlat; extreem hoge waarden zijn in de linker grafiek weggelaten.

Element	Rivers	Lakes	Transitional waters	Coastal waters
Phytoplankton	X	X	X	X
Macroalgae			X	X
Angiosperms			X	X
Macrophytes Phytobenthos	X	X		
Macrozoobenthos	X	X	X	X
Fish fauna	X	X	X	

- All indicators standardised
- Different types of indicators for different water types,

. Unfortunately not all seem logical: political process

- unfortunately some are actually overlapping for the expert
- One out = all out, all indicators should be OK!

WFD: harmonising WQM in the EU

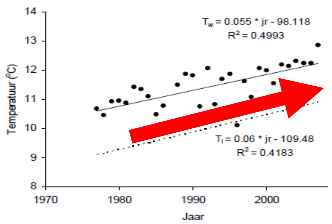
- It may have cost a bit
- But it brought harmonisation across the EU and made scientists and managers talk to each other at a large scale
- (already within the small NL, this was highly necessary. Every water board had its own WQ evaluation system in aaddition to the national system)
- it formed a solid enforcement mechanism (‘sorry, but we have to report this to Brussels’)
- Led to massive strategic behavior (‘do not include that station in the set we report to Brussels, you stupid!’)
- And it does include a cost-efficiency evaluation of measures (economics, ☺!!)

Tools for the manager

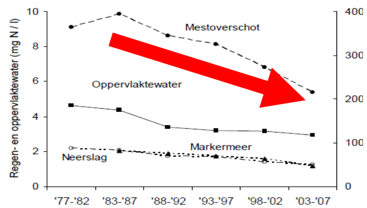
- Sound legal basis
- The means to enforce the law (Dutch water boards have the right to fine)
- Institutional capacity and network
- Skilled staff to understand monitoring results, explain them in simple words, be able to translate these creatively in measures (yes, very close to perfection), and interact with the public
- Filled tool box: catalogue of measures (exists for the WFD, also for river restoration measures)
- Some funds (Dutch water boards have the right to tax independently)

Any progress made?

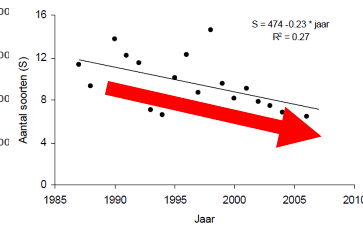
water and airtemp



Nitrogen load and conc



waterplant diversity



field course 1985 Terschelling

- Oh yes
- Water quality has greatly improved across Europe since 1972. And the same is true for many other parts of the world.
- WQM has become more integrated and -ing, more ecosystem-oriented, and more cost-aware
- Still, we need better understanding of underlying mechanisms
- New pollutants emerge
- Climate change worsens WQ, and some indicators go down anyway
- Science-management communication can be improved from both sides
- In Europe, the WFD of the EU has been a great stimulus

water quality management - conclusions

- Management for a practical purpose (‘boatable, fishable, swimmable - drinkable’) has been replaced in Europe by a *principal* purpose, the ‘good ecological condition’ of the WFD
- Still, a 5 step approach is needed (purpose-indicator-monitor-decide if OK-take measure), but integrated in an ecosystem perspective, also including water quantity aspects
- Worldwide*, and certainly in ‘western’ societies, considerable progress has been made

* See UNEP GEMS and GEF

overall conclusions

- Even if IWRM appears a bit out of fashion, do not drop the good ideas
- (we also had ICZM, integrated cosatal zone management)
- Please think cross-disciplinary and multi-sectoral
- When you are an engineer – better get interested in ecology and economics
- When you are a biologist – better …
- Engage and communicate with stakeholders, even though that appears a burden at first. Take them seriously, the way you would like to be. It generally pays off later
- Try to avoid my own favorite pitfall: you think you already know the story and stop listening

Thank you and good luck with the course!