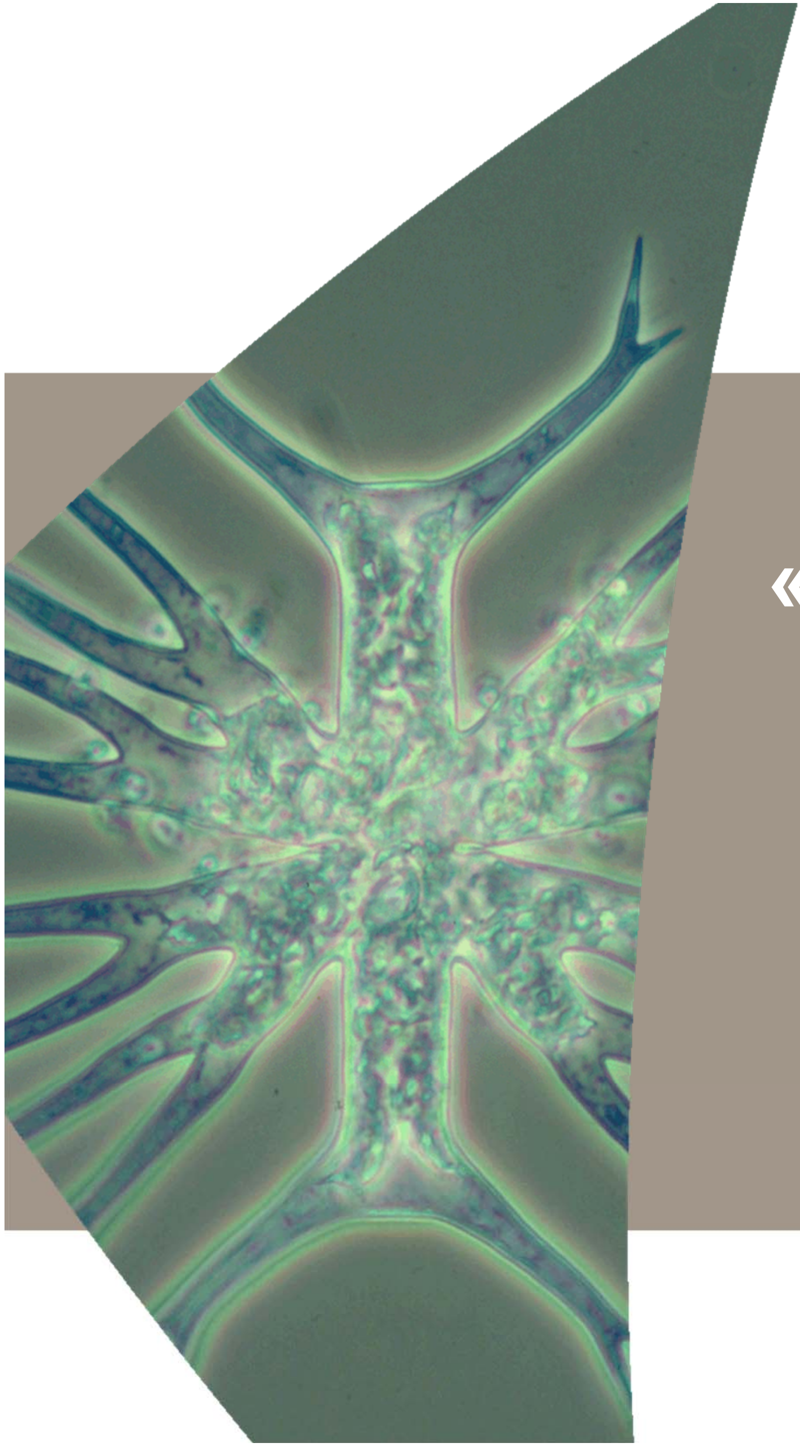

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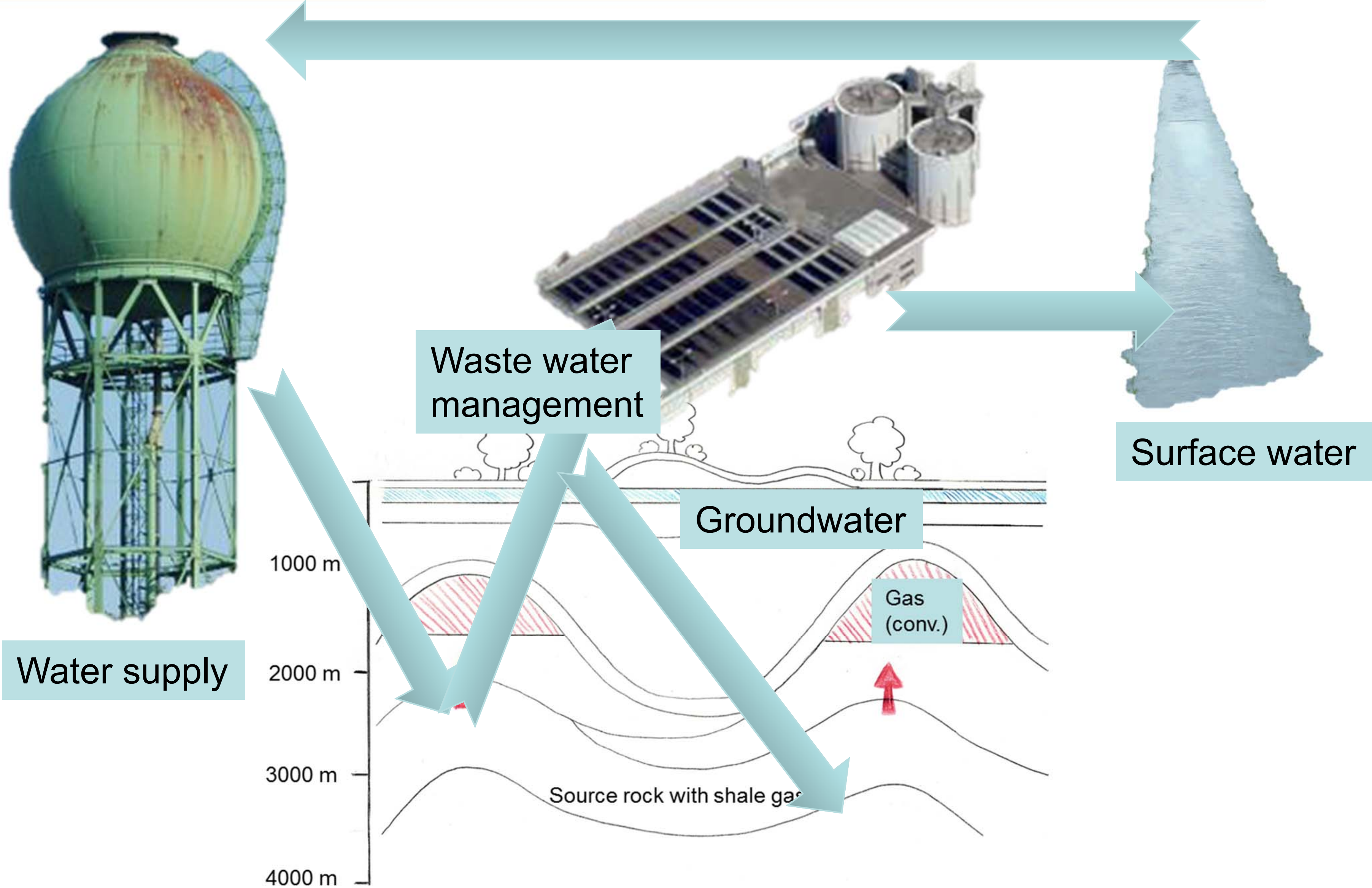
«Shale gas exploration: Water related issues»

Marion Junghans

ETHZ 02.04.2014

Affected water management areas



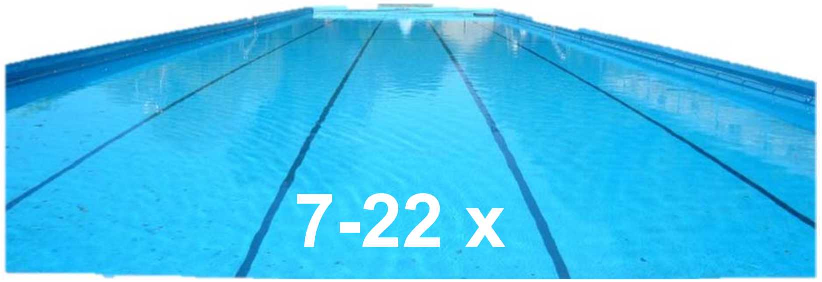
Water supply

Water consumption

- <u>Drilling</u>:
  - Maintaining downhole hydrostatic pressure
  - Cooling of the drillhead
  - Removal of drill cuttings
    - ➢ **400-4000 m3**

- <u>Hydr. fracturing</u>:
    - ➢ **7000-18000 m^3** per well

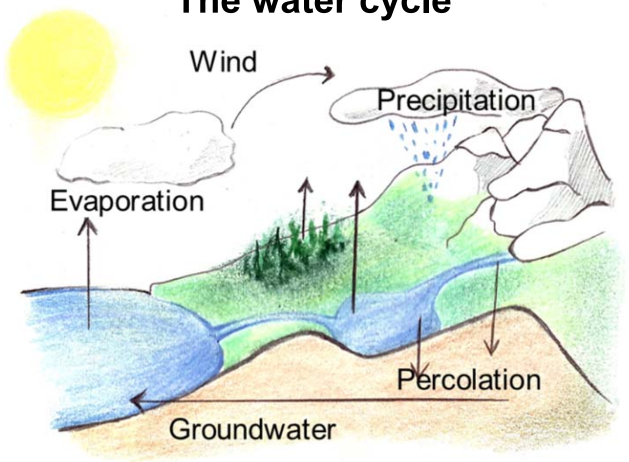
- <u>Total consumption</u>:
    - ➢ **7.4-22 million litres per well**



Water fate

- Water recovered as flowback:
  - 20-80%
  - 10-40%
    - ➢ depending on geology
  - ➢ Around half of the fracking fluid remains underground
- The majority of the flowback in the US disposed of by deep underground injection

The water cycle



➢ **The majority of the water is withdrawn from the water cycle**

Implications for water supply

- USA:
  - Permitting requests for water in Texas Barnett shale 2.5 billion liter water within 10 years
  - ➢ In the US the water use is becoming an important issue, since many drilling sites are in rather dry areas (e.g. Texas)

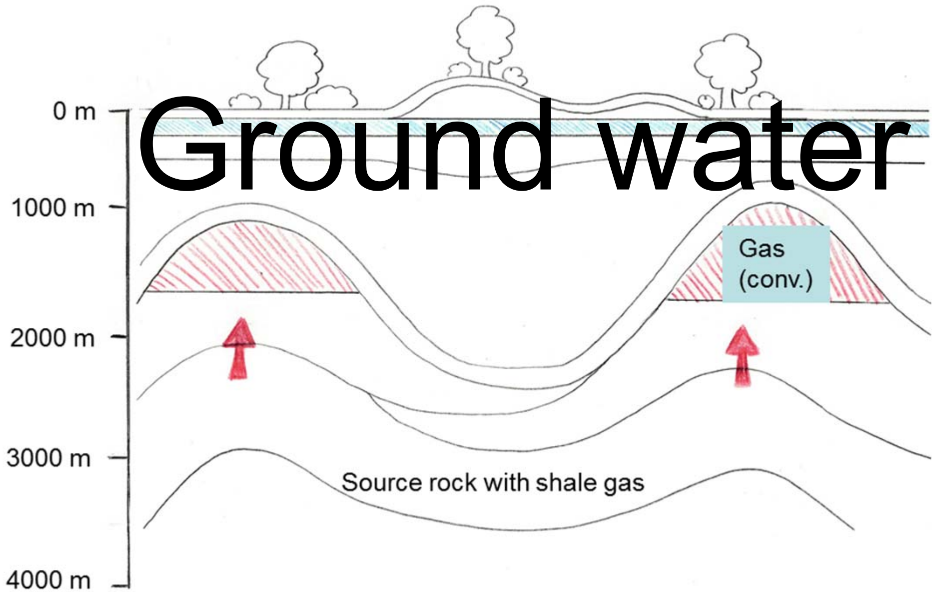
- Implications for Europe:
  - In periods of drought (hot summers, low precipitation) water need for shale gas exploration might conflict with:
    - Drinking water supply
    - Agricultural irrigation
    - Protection of surface water ecology

Implications for surface water ecology

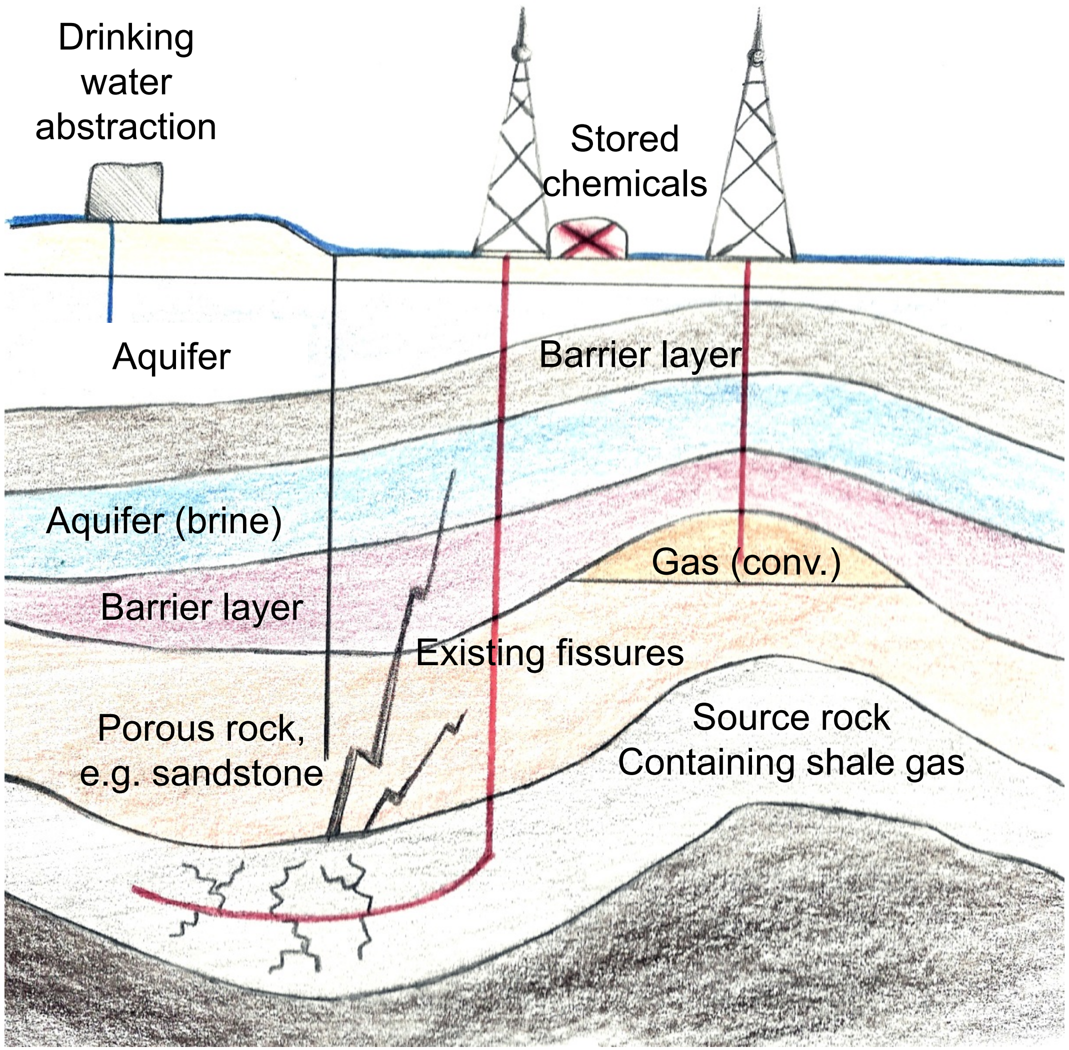
- Stressor for aquatic communities:
  - Regional water shortages in low order streams
  - Reduction of stream flow may alter community structure

➢ <u>Water use needs to be cut down for “sustainable” shale gas exploration</u>

- More on water demand in next presentation by Christian Bauer


Ground water
0 m
1000 m
2000 m
3000 m
4000 m
Gas
(conv.)
Source rock with shale gas

Risks of groundwater contamination



- Gas leaks:
  - Fissures
  - Old bore holes
  - Current bore hole
- Leaking flowback:
  - Lacking bore hole casing
  - Damage to bore hole casing during fracturing
- Hydraulic short circuit:
  - Brine to fw aquifer
- Spillage of
  - Stored chemicals
  - Stored flowback

Important safety measures

- Stable and and durable well-bore casings
- Durable cementing of casing
- Good knowledge of rock formation and previous drillings
- No shale gas exploration in drinking water protection areas
- Good management of chemical storage and use at surface
- Good waste water disposal scheme
  - Safe interim storage
  - Choice of caverns for deep underground injection
  - Efficient waste water treatment

Waste water management

Composition of flow back – fracking fluids

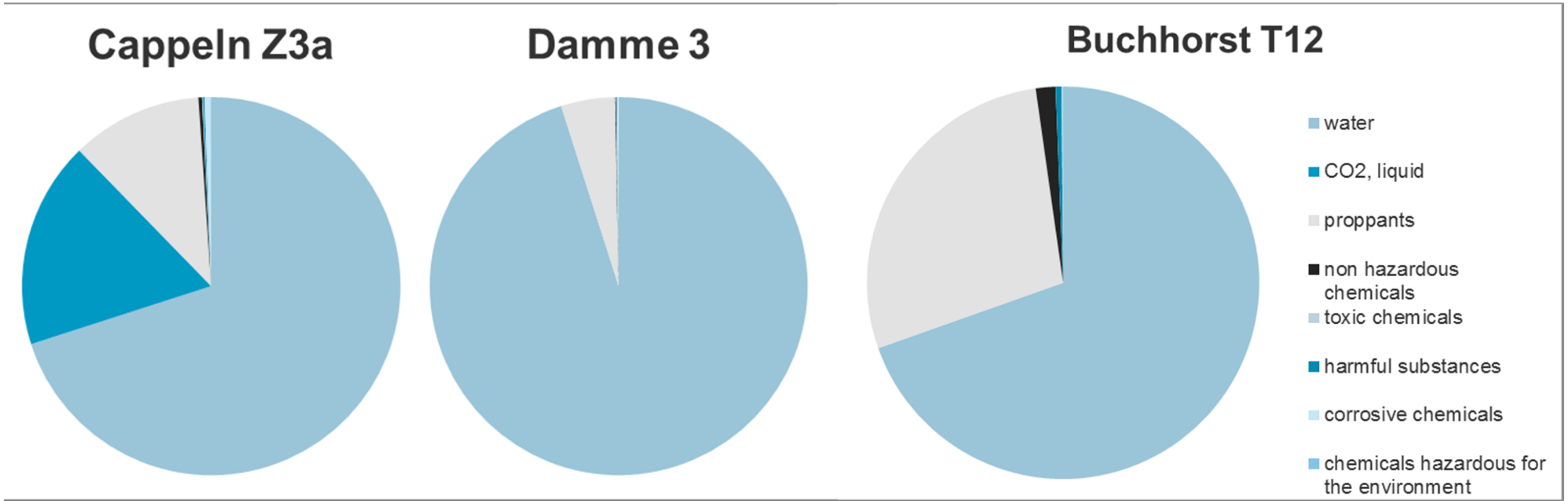
- Fracking fluids
  - Generally composed of some or all of the following categories

Category	Purpose (Gregory et al. 2011, Elements 7: 181-186)
Water and sand	«Proppant»: sand grains hold microfractures open
Acid	Dissolves minerals and initiates cracks in the rock
Friction reducer	Minimizes friction between the fluid and the pipe
Surfactant	Increases the viscosity of the fracturing fluid
Salt	Creates a brine carrier fluid
Scale inhibitor	Prevents scale deposits in pipes
pH-adjusting agent	Maintains effectiveness of chemical additives
Iron control	Prevents precipitation of metal oxides
Corrosion inhibitor	Prevents pipe corrosion
Biocide	Minimises growth of bacteria that produce corrosive and toxic by-products

(Gregory et al. 2011, Elements 7: 181-186)

Fracking fluids - no general composition

- Adjusted to site specific conditions
- Composition for three arbitrarily chosen sites in Germany:



➢ Mainly composed of water, CO_2, and sand (proppants)

http://www.erdgassuche-in-deutschland.de/technik/hydraulic_fracturing/fracmassnahmen.html

Mass of chemicals used in fracking fluids

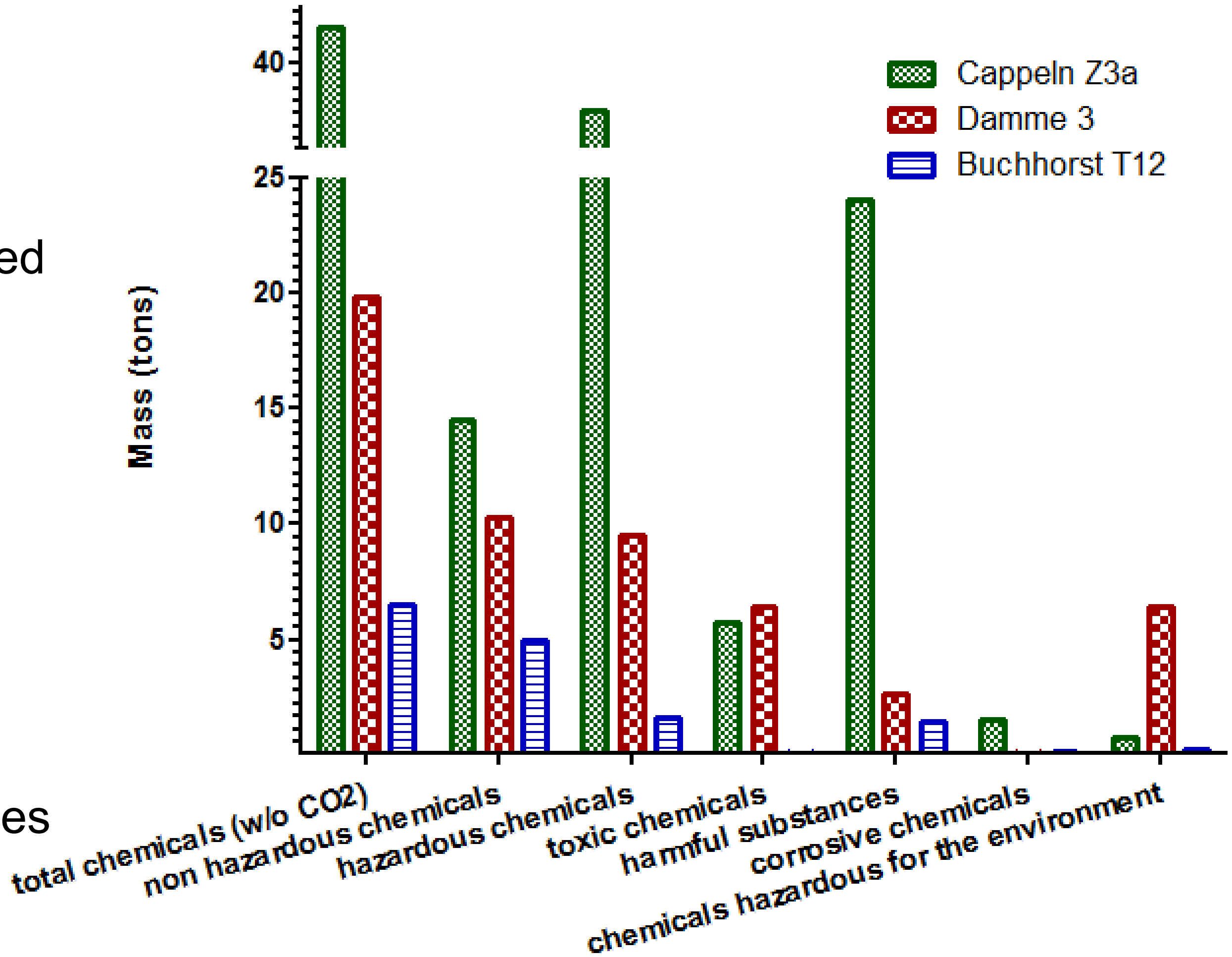
- Chemicals <3% of fracking fluids

BUT

- Total tonnage used per site is not negligible

HOWEVER

- Research on fracking fluids containing less harmful substances is going on

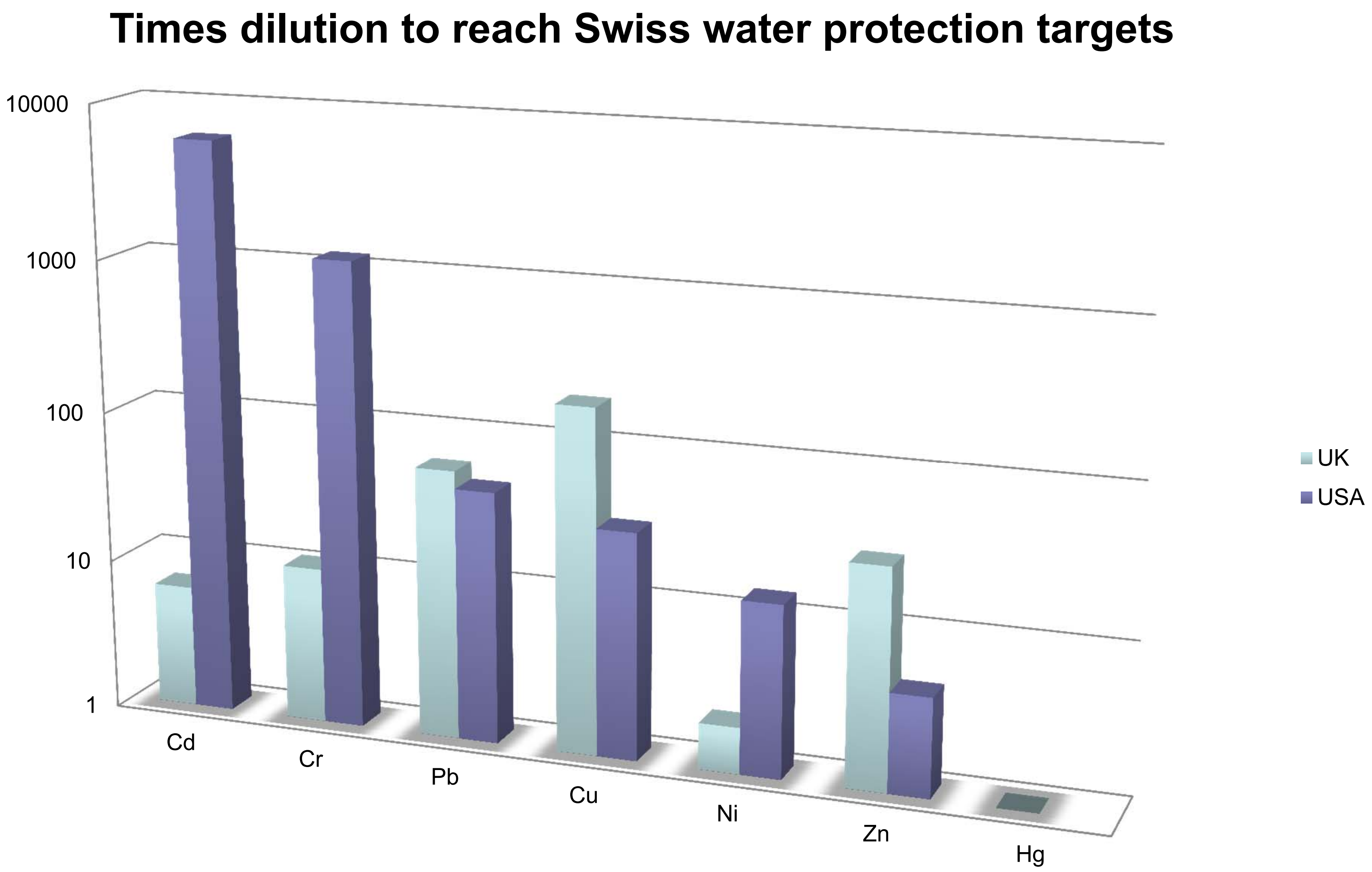


Composition of flow back – dissolved solids

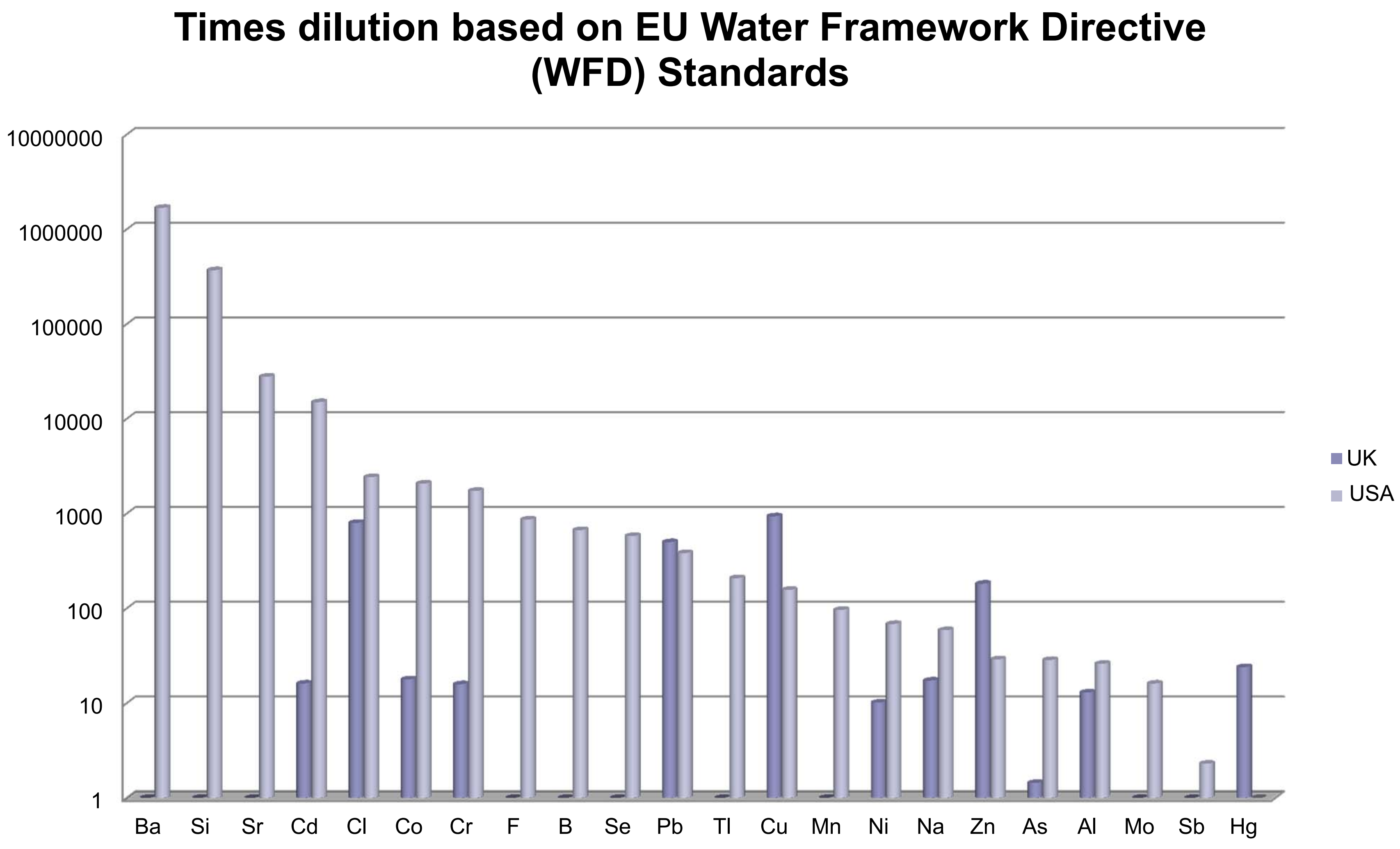
- Flow back is occurring over a few days to weeks after fracturing process
- Flow rate diminishes over time
- Especially the later flowback contains high concentrations of dissolved solids (minerals and organics present in the rock formation)
  - ➢ Highly concentrated brine solution

➢ Even if the fracking fluid contains no harmful substances, the brine in the flowback makes direct discharge of the flowback into surface water virtually impossible

Elements in flow back from hydraulic fracturing



Elements in flow back from hydraulic fracturing



Flowback management is of regulatory concern

- 2013 draft report by **Public Health England**:
  - "Clearly shale gas extraction and related activities have the ***potential to mobilise natural contaminants and minerals*** and these will vary accordingly to the geology of the area. There is a need to characterise these contaminants on a case by case basis. ***Agencies*** in the UK will ***need to agree criteria for correct disposal*** of waste water after treatment via regulation and permitting regimes."
  - "Currently, the reuse of flowback water is limited but as technology advances it is likely that the volume of flowback water that is treated and processed for re-use will increase. ***Developments in recycling*** flowback water can have great benefits in that it ***can reduce*** the ***burden on water sources*** where supplies are limited. ***Flowback*** waters in Europe are ***expected generally to have high salinity*** due to their predominant marine origin which ***may reduce the potential for reuse*** "

Current flow back management options - 1

- Around 15 million liter flow back water need to be managed per well
- Current management options :
  - **Underground injection**
    - Depending on geology
    - Most frequently used option in US
  - **Discharge to waste water treatment plants**
    - Briny character makes disposal via communal WWTP as standard management option impossible
    - To be in the limits of the operation conditions of WWTPs flow back needs to be discharged in small portions

Current flow back management options - 2

- **Reverse osmosis**
  - In trials volume reduction by 80%
  - Energy intensive
  - Considered to be economically infeasible for waters containing >40g/l total dissolved solids

- **Thermal distillation and crystallization**
  - Distillation may remove 99.5% of the dissolved solids (TDS)
    - Energy intensive
    - Low flow rates (ca.1/10th of flowback produced per site and day)
  - Crystallization can manage TDS concentrations up to 300 g/l
    - Energy intensive
    - High capital costs

Current flow back management options - 2

- **<u>Onsite Reuse for further fracturing operations</u>**
  - Attractive option
    - Less water need and lower waste volume
  - Achieving good operating conditions with re-used fracking fluid is a challenge, because stable carbonate and sulfate precipitates may be formed that may reduce the gas production
  - Pre-treatment to reduce divalent cation concentration may be necessary

Conclusions

Conclusions

- From a water perspective there are still major unresolved issues:

  1. Flow back management
  2. Pressure(s) on water resources

- Prior to shale gas exploration in Switzerland/Europe these need to be solved

- Studies on viability should also take into account the energy needed for flow back treatment

Thanks to

- Henning Clausen (Danish EPA) for comparison of flow back elements with EQS
- Eawag co-authors of fact sheet on fracking
- Lisa Wiesner (Ecotoxcentre) for drawings
- ETH for inviting me
- You, for your attention

Further reading

- Broderick J, Anderson K, Wood R, Gilbert P, Sharmina M, Footitt A, Glynn S, Nicholls F, 2011. Shale gas: an updated assessment of environmental and climate change impacts. A report by researchers at the Tyndall Centre University of Manchester. Report commissioned by The co-operative. http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_update_v3.10.pdf
- Entrekin S, Evans-White M, Johnson B, Hagenbuch E, 2011: Rapid expansion of natural gas development poses threat to surface waters. Front Ecol. Environ 9(9): 503-511.
- Ferrar KJ, Michanowicz DR, Christen CL, Mulcahy N, Malone SL, Sharma RK (2013): Assessment of effluent contaminants from three facilities discharging Marcellus Shale wastewater to surface waters in Pennsylvania. Environmental Science and Technology 47: 3472-3481
- Gregory KB, Vidic RD, Dzombak DA, 2011: Water management challenges associated with the production of shale gas by hydraulic fracturing. Elements 7: 181-186.
- Eawag fact sheet on hydraulic fracturing: http://www.eawag.ch/medien/publ/fb/doc/fb_fracking_e.pdf
- Review of the Potential Public Health Impacts of Exposures to Chemical and Radioactive Pollutants as a Result of Shale Gas Extraction: Draft for Comment. Public Health England: http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317140158707

Derivation of EU WFD standards for Water

Protection of the most sensitive link in the food chain

$$\frac{\textit{Toxicity to most sensitive organism group}}{\textit{safety factor}}$$