Possibilities to control nitrogen discharge in extractive industry

WaterPro seminar

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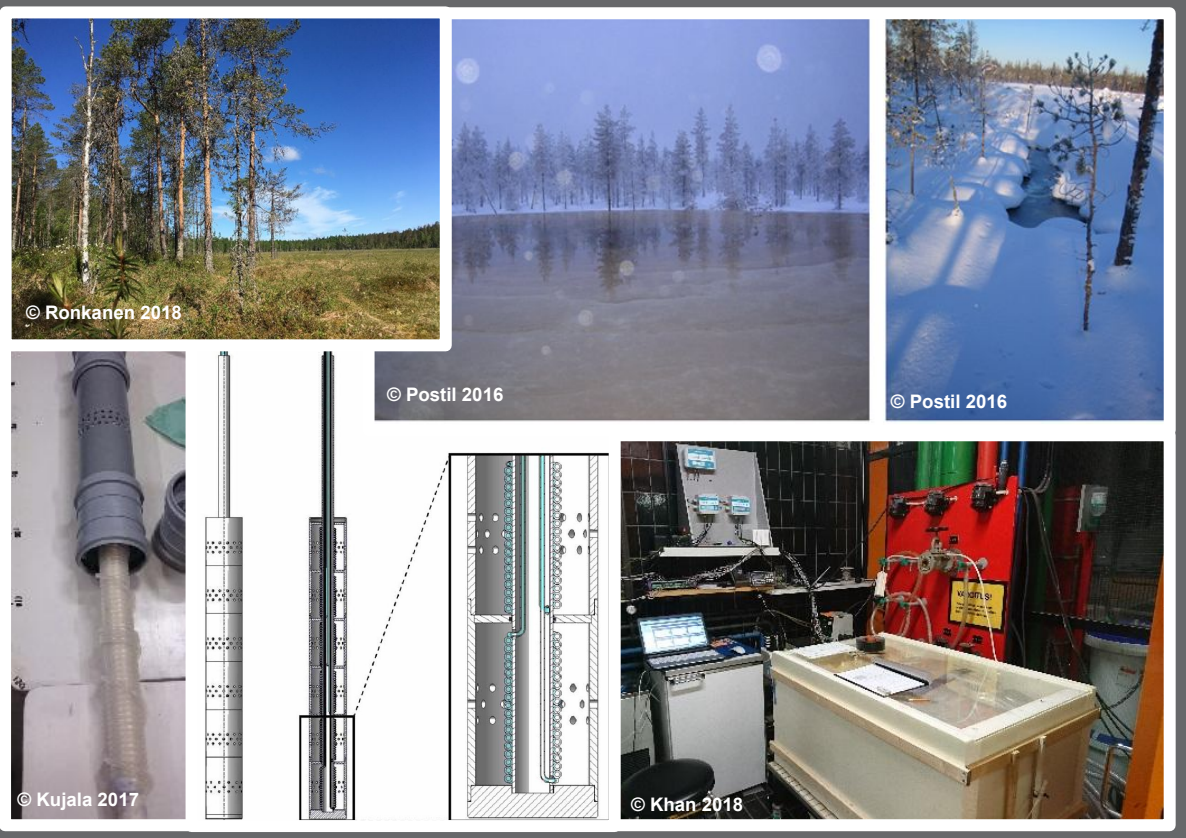
– Water, Energy and Environmental Engineering Research Unit



CONTENT

Background

- Nitrogen load from extractive industry
- Removal methods mostly used in mines in Finland and in EU

Challenges to remove nitrogen

Opportunities for nitrogen removal at mines

Conclusion

In Finland….

Before the year 2010

Nitrogen load from extraction activities did not get nearly any attention

In Finland….

Before the year 2010

Aluehallintovirasto

Länsi- ja Sisä-Suomi

YMPÄRISTÖLUPAPÄÄTÖS

Nro 212/2015/1

Dnro LSSAVI/295/04.08/2010

Annettu julkipanon jälkeen

9.12.2015

Ympäristönsuojelulain mukainen hakemus, joka koskee Dragon Mining Oy:n Oriveden kaivoksen toimintaa, Orivesi

About 5 years ago

In Finland….

Before the year 2010

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Länsi- ja Sisä-Suomi

YMPÄRISTÖLUPAPÄÄTÖS

Nro 212/2015/1

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jen EQS-arvojen mahdollinen ylittyminen Ala-Jalkajärvessä. Kaivoksen vesienkäsittelyä on tehostettava. Vesienkäsittelymenetelmän valintaa varten on tehtävä tarkempia selvityksiä mm. typpi-, alumiini-, sulfaatti ja sinkkilähteistä ja näiden aineiden fysikaalis-kemiallisesta käyttäytymisestä vesiympäristössä. Pirkanmaan ELY-keskus tulee edellyttämään näitä tarkempia tutkimuksia myös valvonta-asiana. Tarkempien selvitysten perusteella on myös selvitettä-

Oriveden kaivoksen toimintaa, Orivesi

About 5 years ago

In Finland….

Before the year 2010

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Länsi- ja Sisä-Suomi

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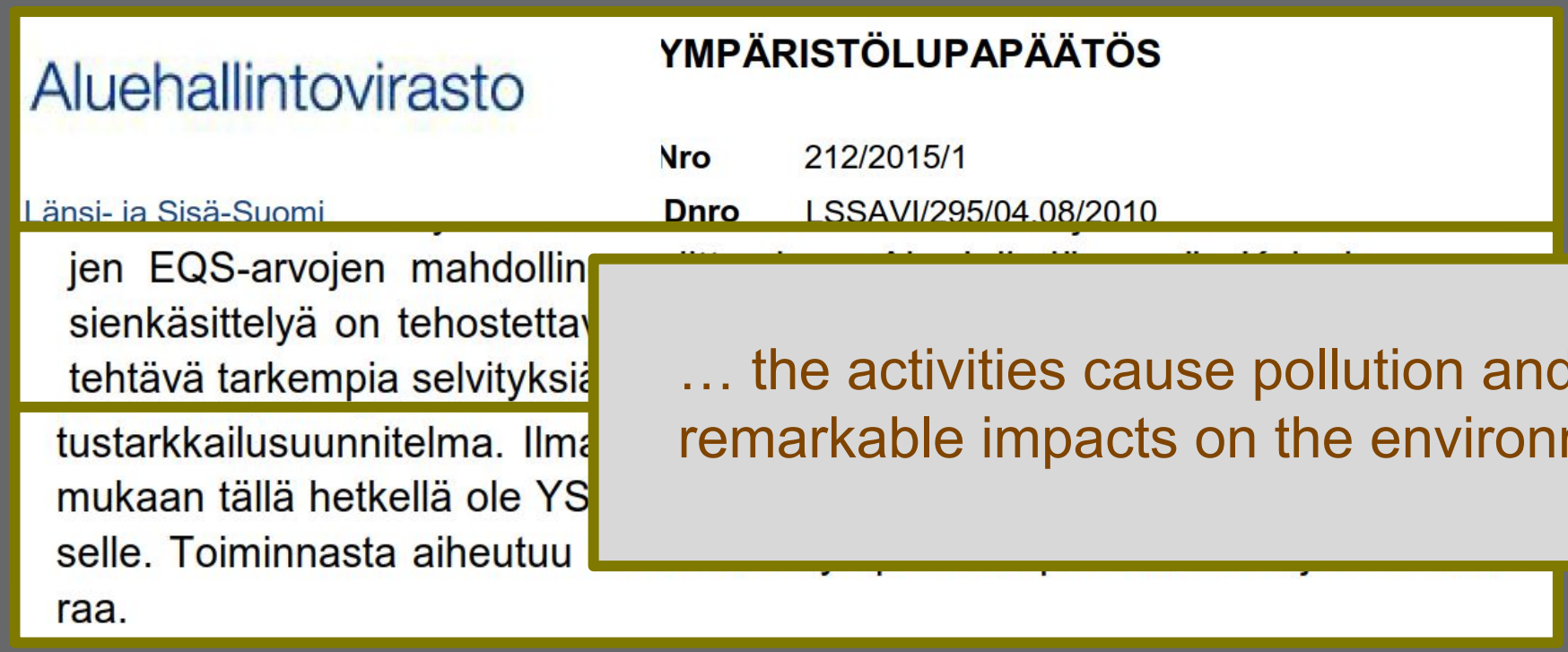
tustarkkailusuunnitelma. Ilman edellä mainittuja selvityksiä ei ELY-keskuksen mukaan tällä hetkellä ole YSL:n 42 §:n mukaisia edellytyksiä luvan myöntämiselle. Toiminnasta aiheutuu merkittävää ympäristön pilaantumista ja sen vaaraa.

About 5 years ago

In Finland….

Before the year 2010



Aluehallintovirasto

Länsi- ja Sisä-Suomi

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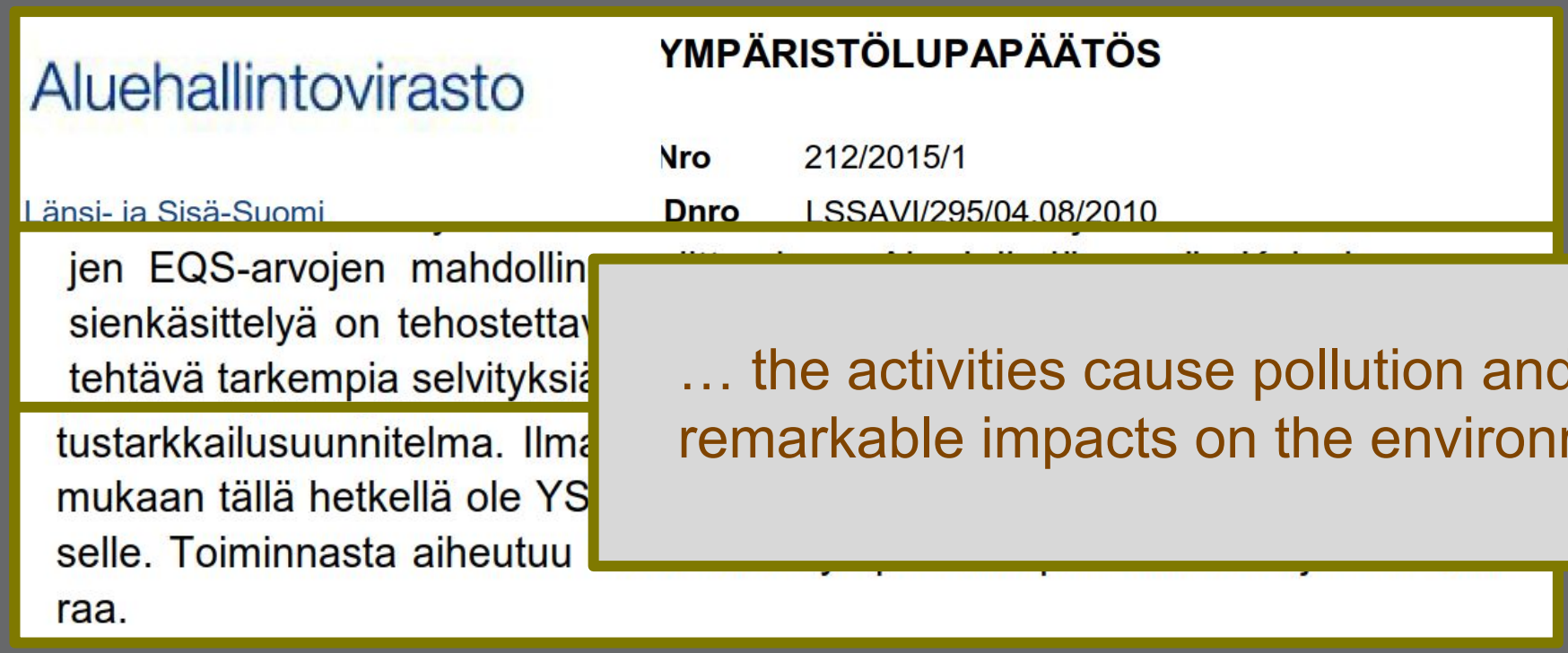
tustarkkailusuunnitelma. Ilma
mukaan tällä hetkellä ole YS
selle. Toiminnasta aiheutuu
raa.

… the activities cause pollution and it has remarkable impacts on the environment…

About 5 years ago

In Finland….

Before the year 2010


Aluehallintovirasto

Länsi- ja Sisä-Suomi

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… the activities cause pollution and it has remarkable impacts on the environment…

About 5 years ago

Nowadays

Finland is one of the leader in number of extraction sites in EU

In Finland….

Before the year 2010

Pohjois-Suomi
Aluehallintovirasto
Ympäristöluvat

PÄÄTÖS
Nro 59/2018/1
Dnro PSAVI/82/04.08/2013
Annettu julkipanon jälkeen
18.6.2018

ASIA Soklin kaivoksen ympäristö- ja vesitalouslupa, Savukoski

LUVAN HAKIJA Yara Suomi Oy
Bertel Jungin aukio 9
02600 Espoo

About 5 years ago

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PÄÄTÖS
Nro 59/2018/1
Dnro PSAVI/82/04.08/2013
Annettu julkipanon jälkeen
18.6.2018

About 5 years ago

… N has been mentioned in the list of key elements to be removed

…. No any limit values have been set… OR value is high (50 mg/l in Hannukainen case)

…. No any specific removal unit have been required

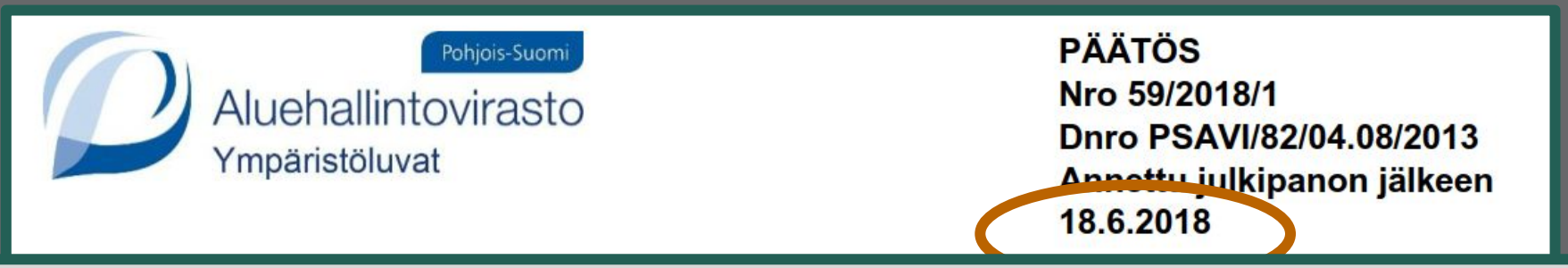
…. N load is required to monitor…

Nowadays

Finland is one of the leader in number of extraction sites in EU

In Finland….

Before the year 2010


Pohjois-Suomi
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18.6.2018

About 5 years ago

SOLUTIONS used

1) Explosive selection: emulsion based
2) Optimization of explosive usage: only used when needed
3) Dilution of process waters
4) Recycling of waters (especially process waters) in tailing ponds
5) Selection of effluent point in recipient water bodies: to use river where N is not limiting nutrient
6) Passive treatment methods: Constructed wetlands or treatment peatlands

Nowadays

Finland is one of the leader in number of extraction sites in EU

Nitrogen of extractive industry

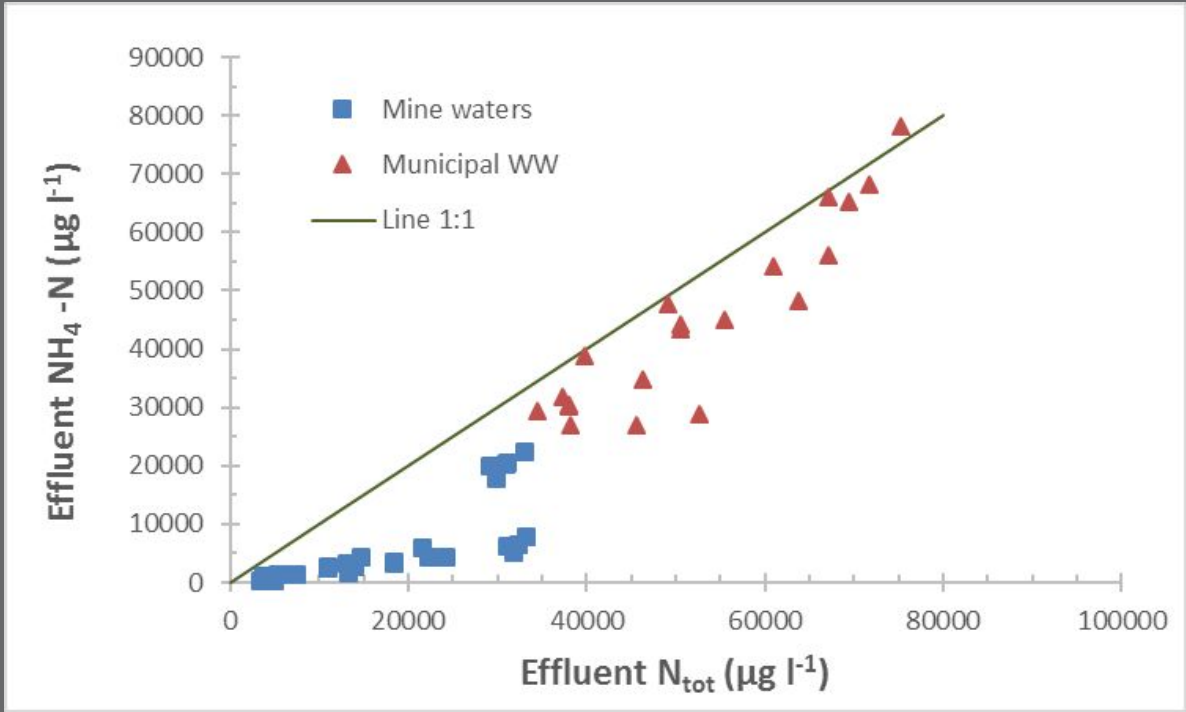


Figure: Data from 6 mines and 3 municipal wastewater treatment plants. All waters have been treated and represent effluent to the recipient water bodies before constructed wetlands applied.

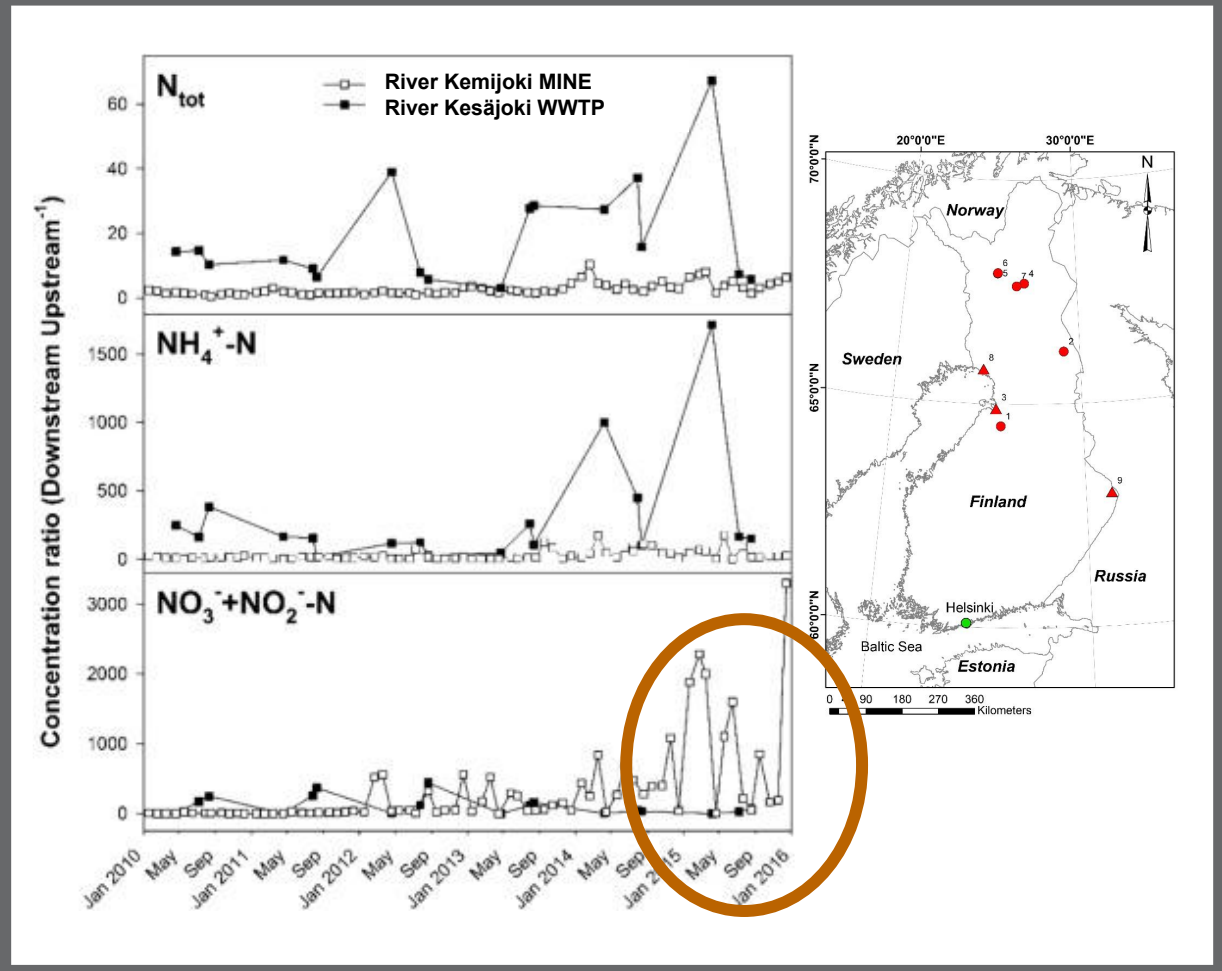
Lower N concentration than in treated municipal wastewaters

- Varies typically from 3 to 33 mg l^{-1} in mine waters in Finland
- Due to high water amount, N load similar or even higher than N load from municipal WW TPs
- No seasonal variation in the load

N is mainly as NO_3^-/NO_2^- form in mine influenced waters

- Typically more than 70% of N_{tot}
- Mainly explosive originating but also chemicals used in beneficiation processes
- NO_3^- does not adsorb to the soil particles but is transported with water

Nitrogen of extractive industry



High N load from mine can be seen in recipient water body

- 2 to 4 times higher N_{tot} in the river after mine
- NO_3^-/NO_2^- dominating fractions and cause high impact
- In municipal WW TP, the impact varies depending on treatment processes in the plant
- In national level, contribution of mines is not remarkable but locally mine activity can be important N source to the surface waters

Kujala K., Karlsson T., Nieminen S., Ronkanen A-K. 2019. Design parameters for nitrogen removal by constructed wetlands treating mine waters and municipal wastewater under Nordic conditions. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2019.01.124

- **Too little attention have been paid to N load from mines**
- **There are very few N removal options because**
    1) Water amount is huge
    2) Year-round purification efficiency is needed
    3) Winter condition cause limitations

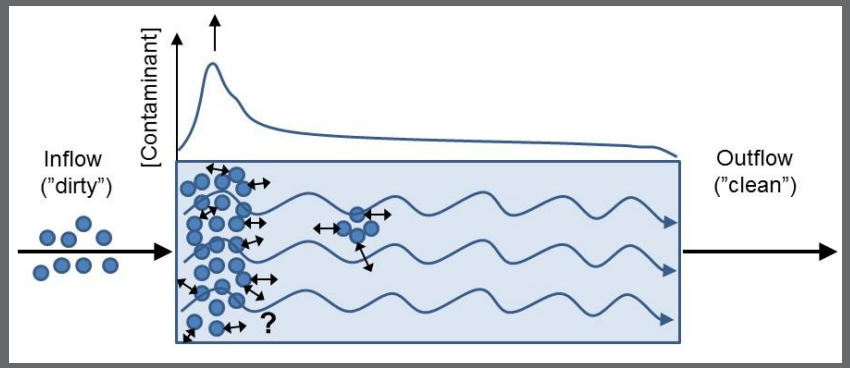
N can be removed by

1. BIOLOGICAL/MICROBIOLOGICAL PROCESSES
   - The most often used
   - Difficult to control

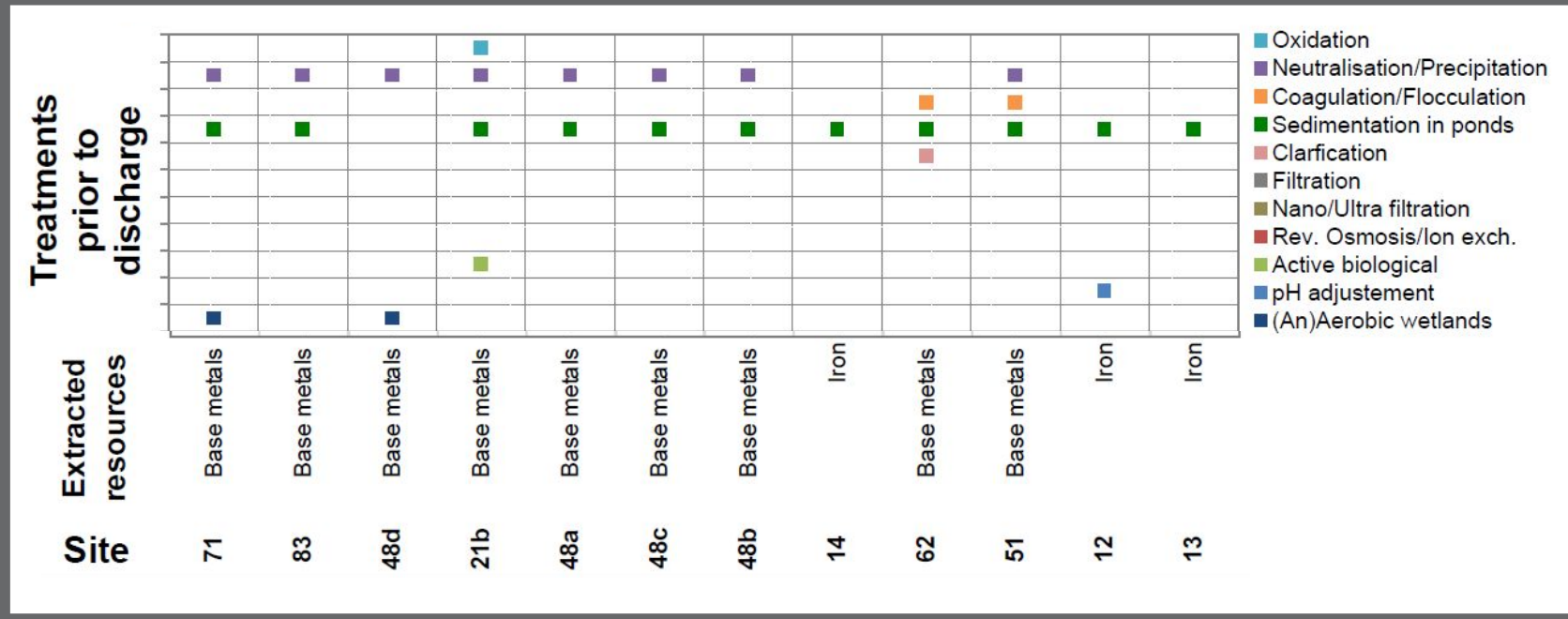
2. PHYSICAL FILTRATION AND SEDIMENTATION TOGETHER WITH SUSPENDED SOLIDS
   - Typically side processes

3. CHEMICAL ADSORPTION or ION EXHANGE
   - High maintenance cost
   - Short life-time
   - Not to all N compounds

4. PLANT UP-TAKE
   - Harvesting is needed
   - Low purification effect during winter



In EU…

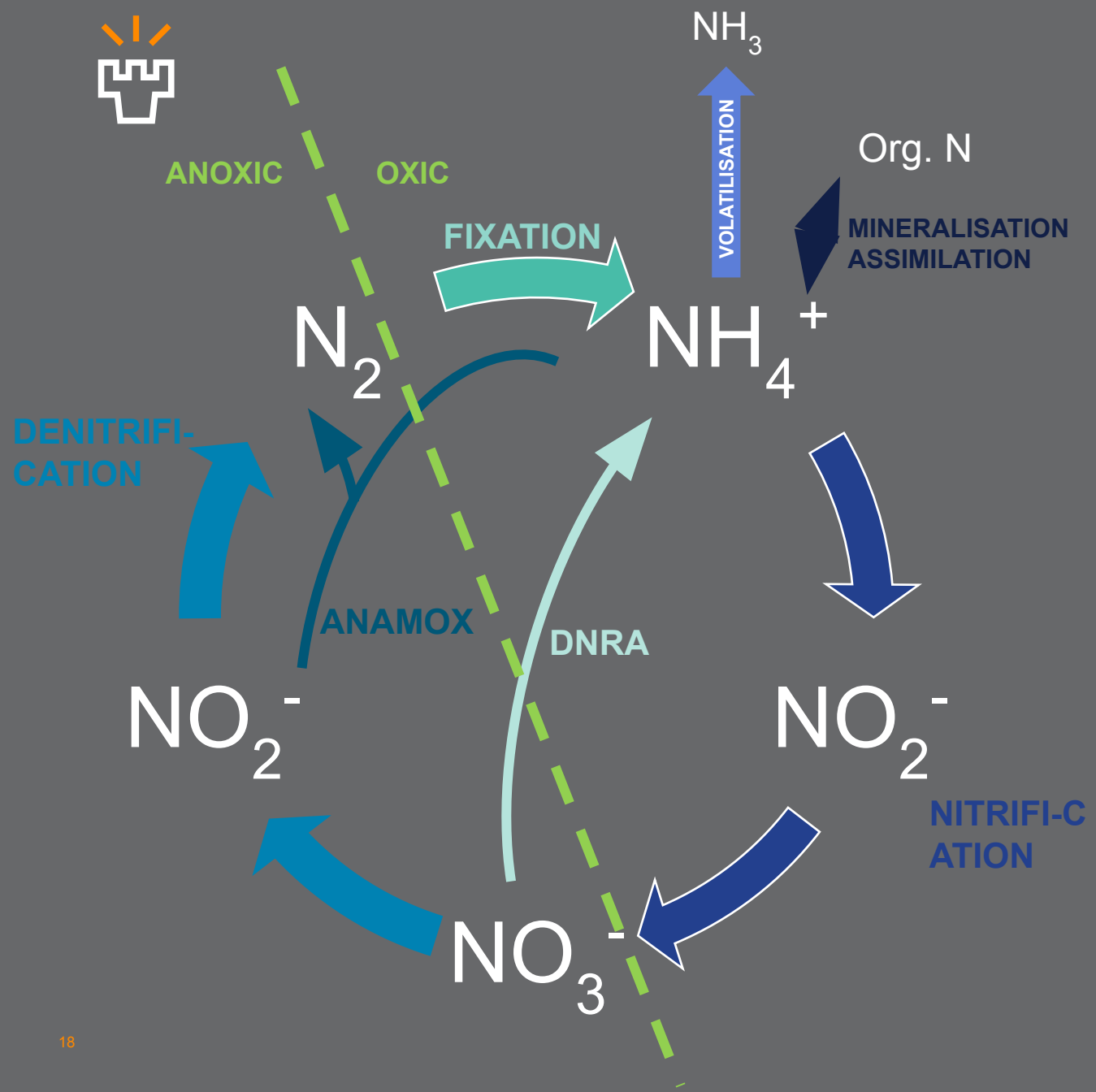


Applied methods

- Passive treatment in ponds or wetlands
- Biological active treatment
- Ion exchange technologies
- Bioreactors
- Membrane technologies: ultrafiltration

NO_3^- levels achieved by biological treatment

- 2-9 mg/l (0.2-6 mg/l for NH4+)
- 90% removal efficiency using wetland
- 95% removal efficiency using Moving Bed Biological Reactor (MBBR)
- Typical range is 60-90% removal (70-90% for NH4+)



CHALLENGES TO APPLY NATURAL N PROCESSES

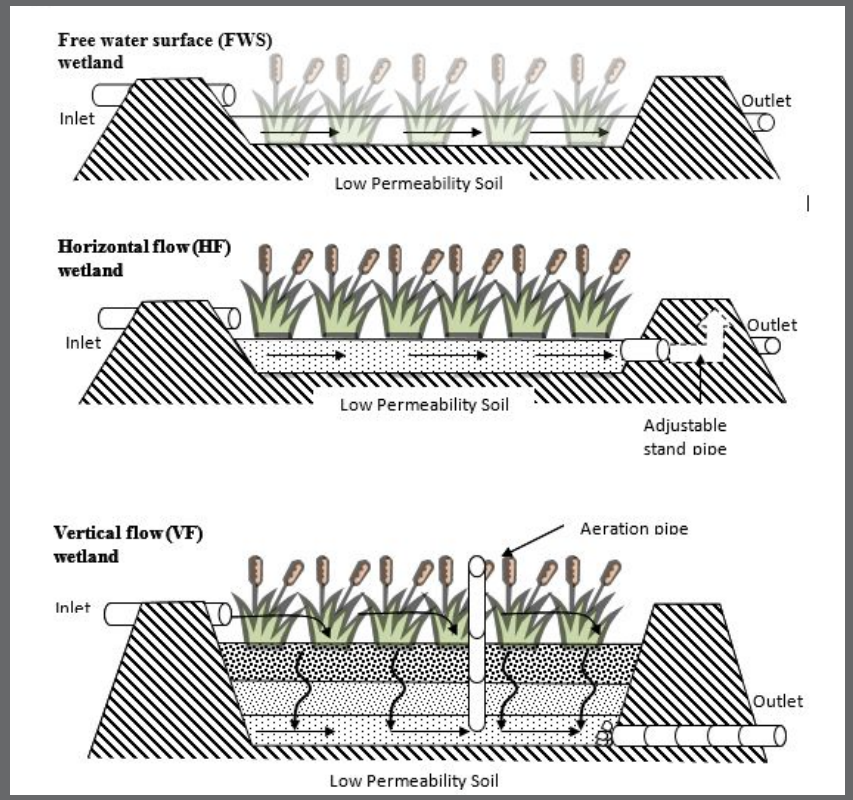
- Temperature limitation
- pH requirement
- Redox sensitivity
- Residence time of water long enough

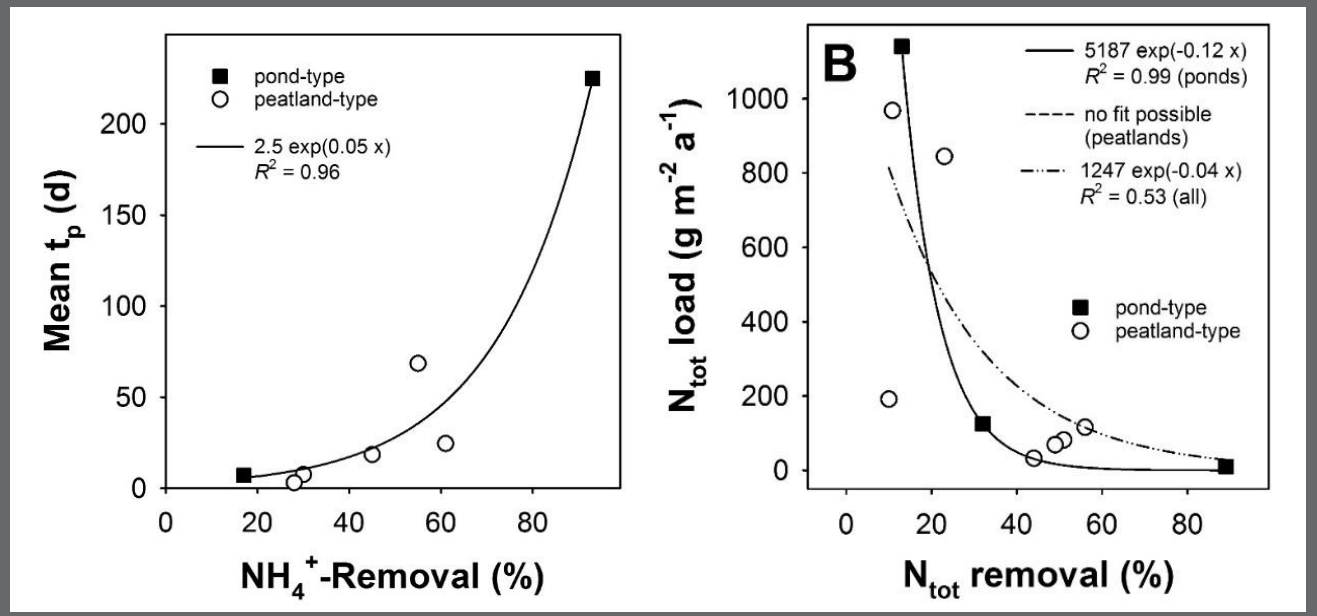
- Snow and ice lower temperature but also influence on water flow paths and oxic condition

What could be possibilities to improve N removal?

CONSTRUCTED WETLANDS

- Good removal capacity
- Peatlands are not BAT for mine waters
- Lower efficiency during winter
- Area requirement is high
- Removal rate generally 0.003 - 1.02 g N m^{-2} d^{-1}



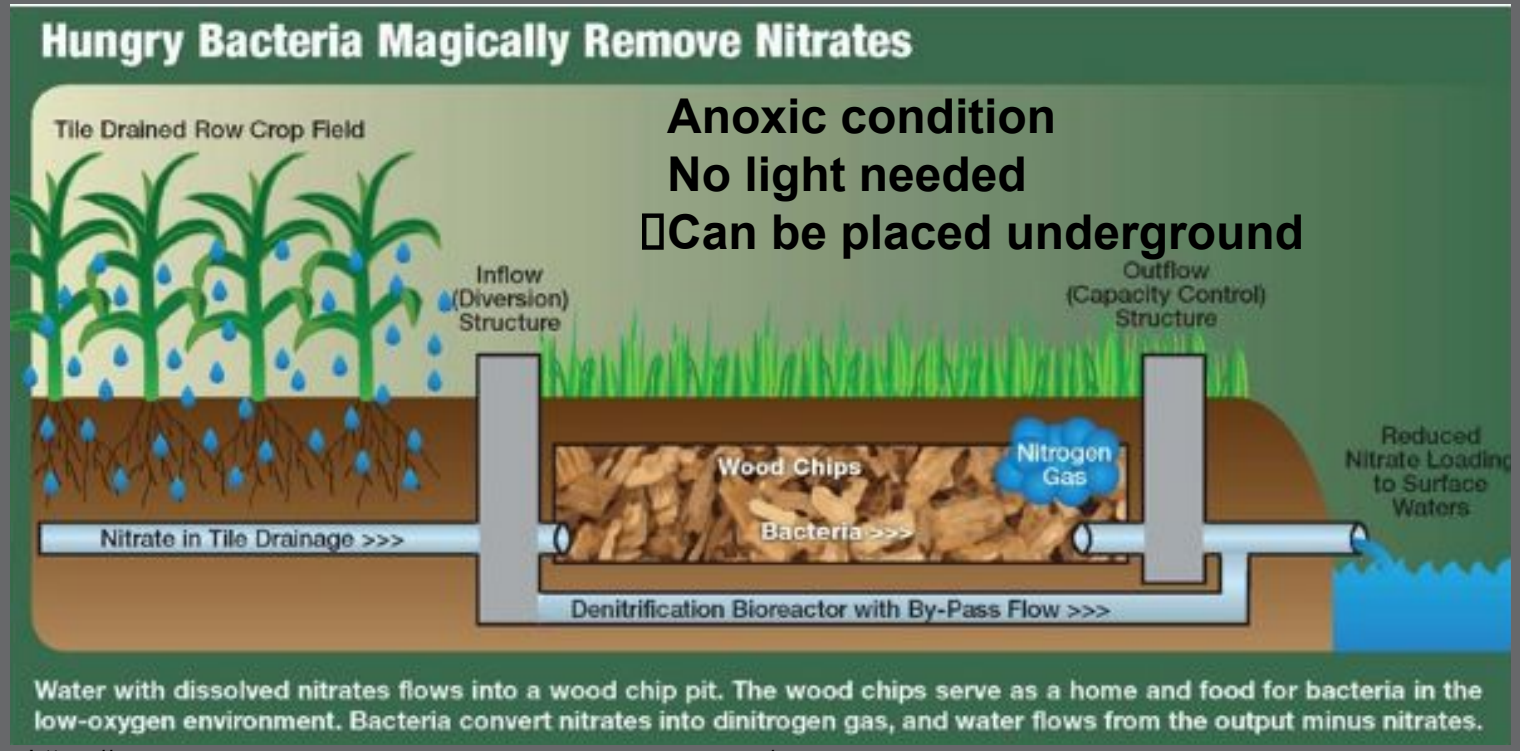


What could be possibilities to improve N removal?

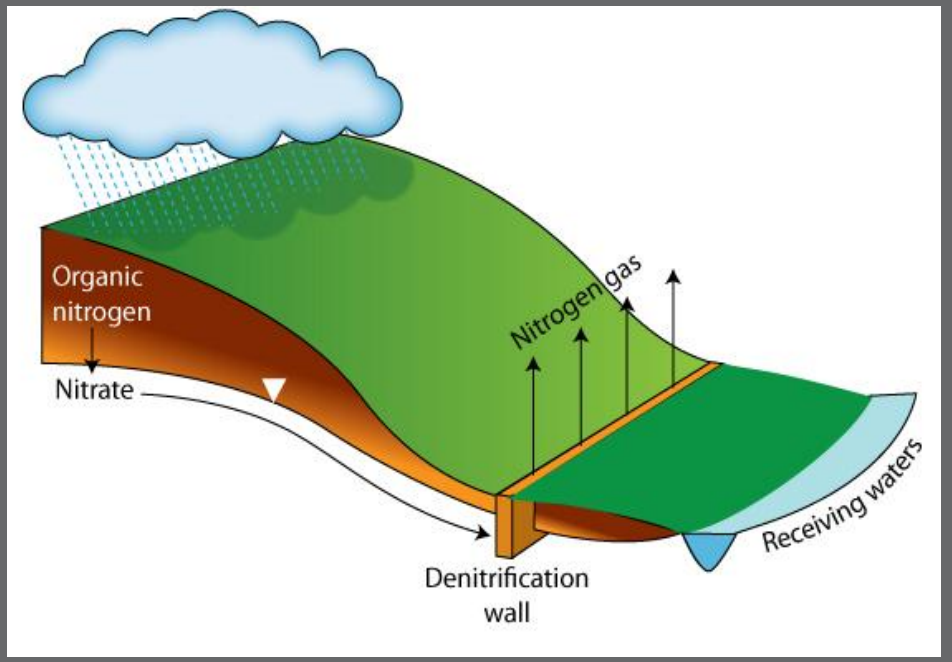
To nitrate

- Denitrification walls
- Denitrifying beds
- Denitrifying layers

For more information: e.g. Schipper, L.A., Robertson, W.D., Gold, A.J., Jaynes, D.B. and Cameron, S.C., 2010. Denitrifying bioreactors—an approach for reducing nitrate loads to receiving waters. Ecological engineering, 36(11), pp.1532-1543.

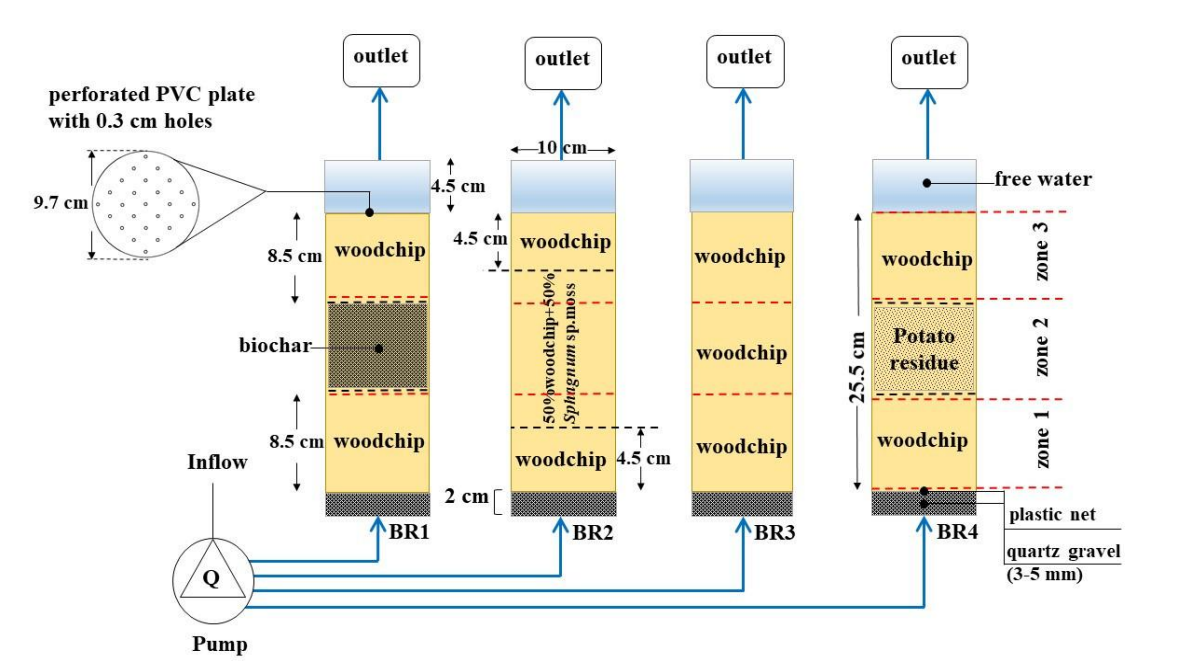


https://www.agweb.com/article/bioreactors_take_on_the_dead_zone/



https://www.sciencelearn.org.nz/resources/799-professor-louis-schipper

Denitrifying bioreactor



- **Microbiological process**
- **Good removal efficiency**
  - 70-90% removal efficiency
  - Carbon type and availability
  - Nutrient
- **Even more than 15 years life-time for woodchip bioreactors**
- **Commonly used for agricultural runoff**
- **Good for water with high N concentration**
- **More pilot scale studies are needed in cold climatic region**

Denitrifying bioreactor

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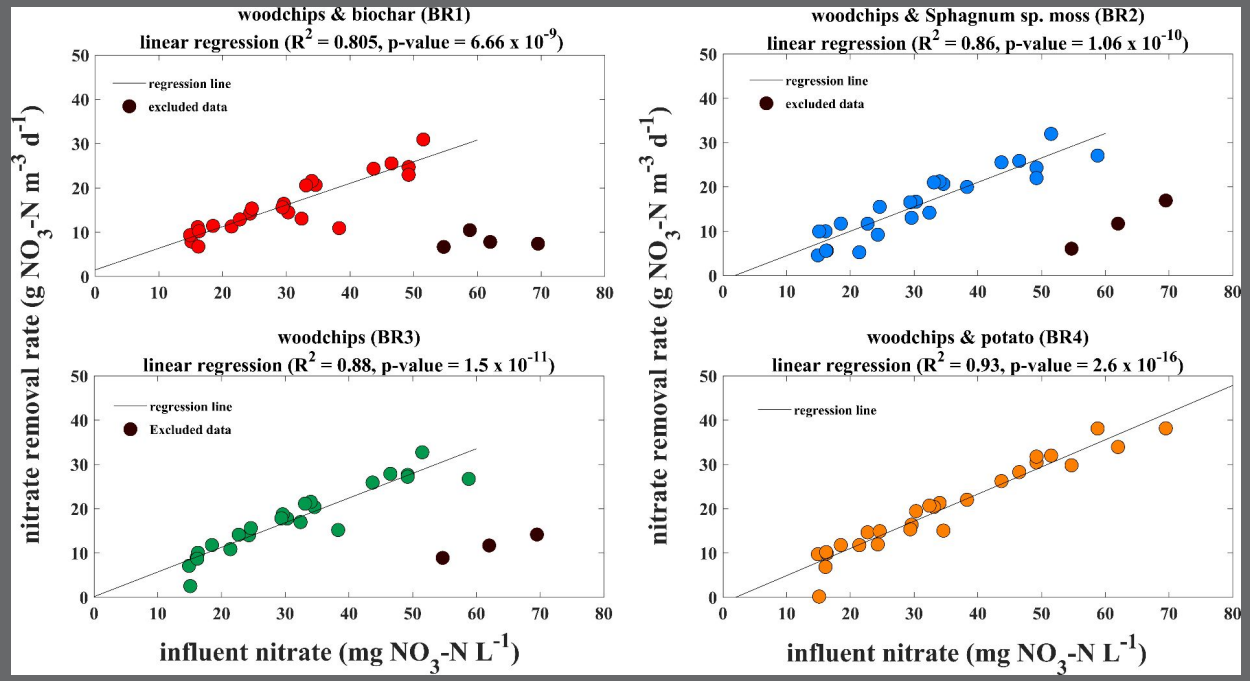

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- Commonly used for agricultural runoff
- Good for water with high N concentration
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HybArkt

Passive hybrid treatment solutions to remove nitrogen and heavy metals from different types of waters in arctic region

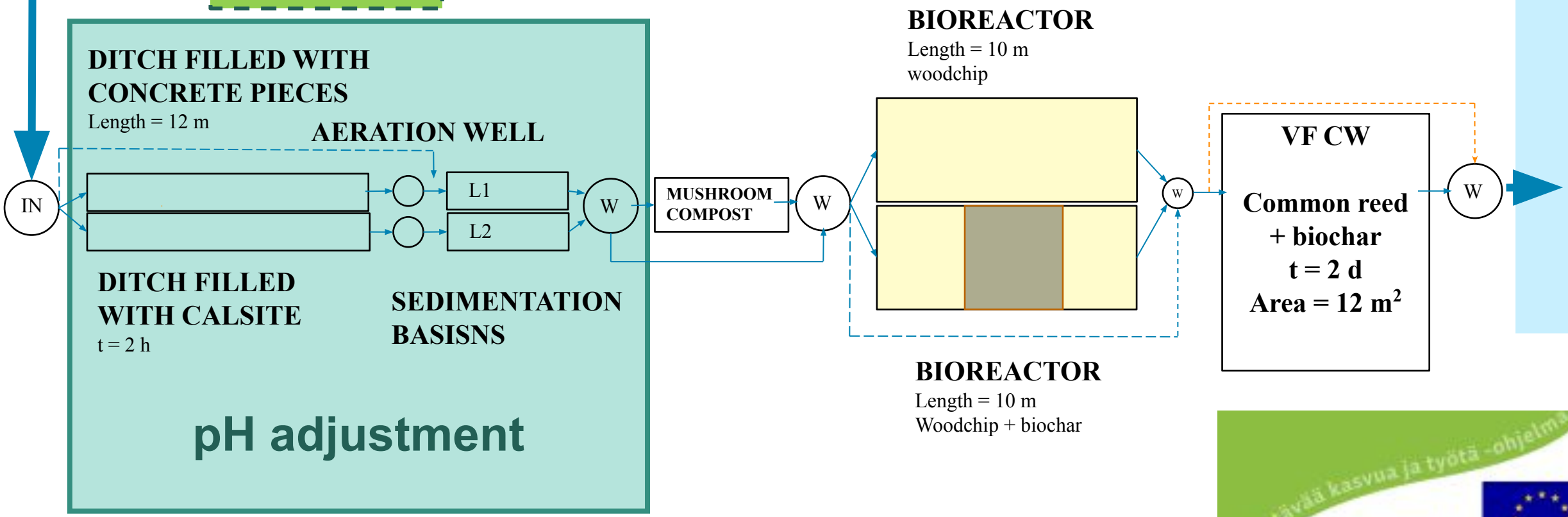
Aim to design, test and construct pilot scale passive treatment solutions for N and metal removal in cold climatic region

- 3 pilots using hybrid solution methods have been build in the years 2018-2019
- 2 of those includes also woodchip bioreactors
- Also aqua moss units and mushroom compost filter has been applied

Q = 0.07 l/s
= 6 m^3/d

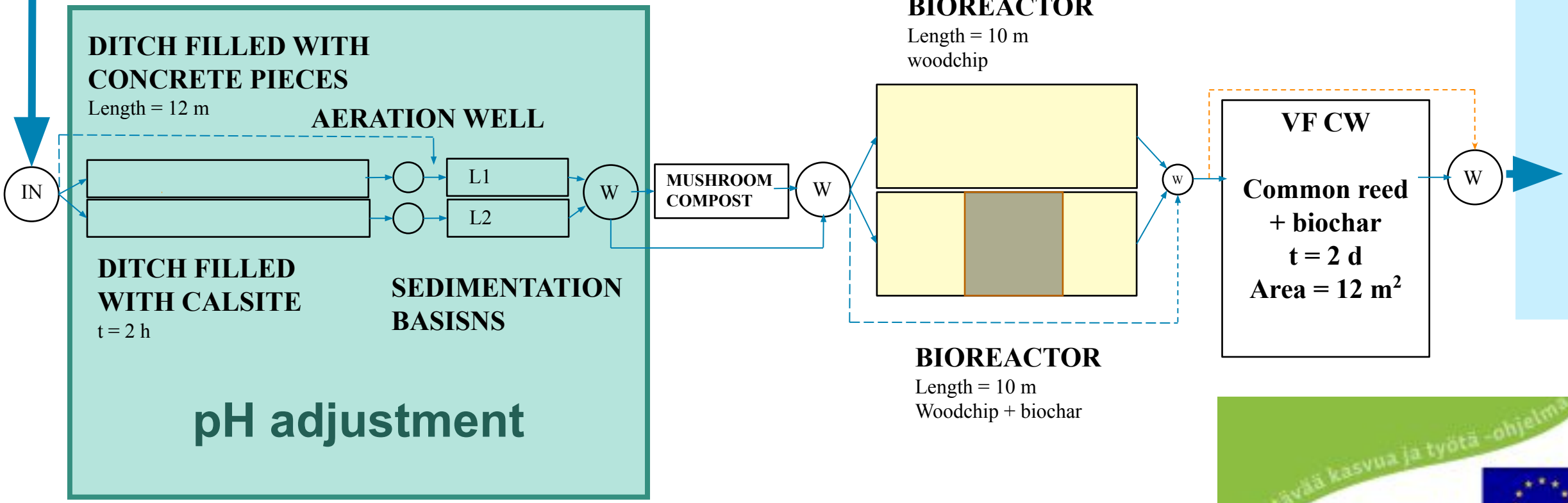
AQUA MOSS FILTER

OPEN DISCH RECEIVING MINE INFLUENCED WATER



After first winter (n is now)	N_{TOT}	Zn	Cu	Al	Cd
Purification efficiency	56%	95%	95%	95%	95%
Concentration after bioreactors	0.7 mg/l	15 µg/l	0.34 µg/l	10 µg/l	0.028 µg/l

Q = 0.07 l/s
= 6 m^3/d



To be taken to home…

1. N load from mines can be high
2. We could do more to decrease N load from extraction activities to recipient water bodies in Finland
3. Treatment peatlands remove N but due to other contaminant in treated mine waters those are not BAT anymore
4. Denitrifying bioreactors combined with other passive methods (such as constructed wetlands) have a high potential also for mine waters
5. We should accept some limitation in year-round purification levels due to winter condition but not use this as excuse not to remove N at all.

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Any questions?