# Retention of metals and metalloids in Atleverket treatment wetland 2003-2012

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# Landfill leachate is different from effluents discharged from STPs

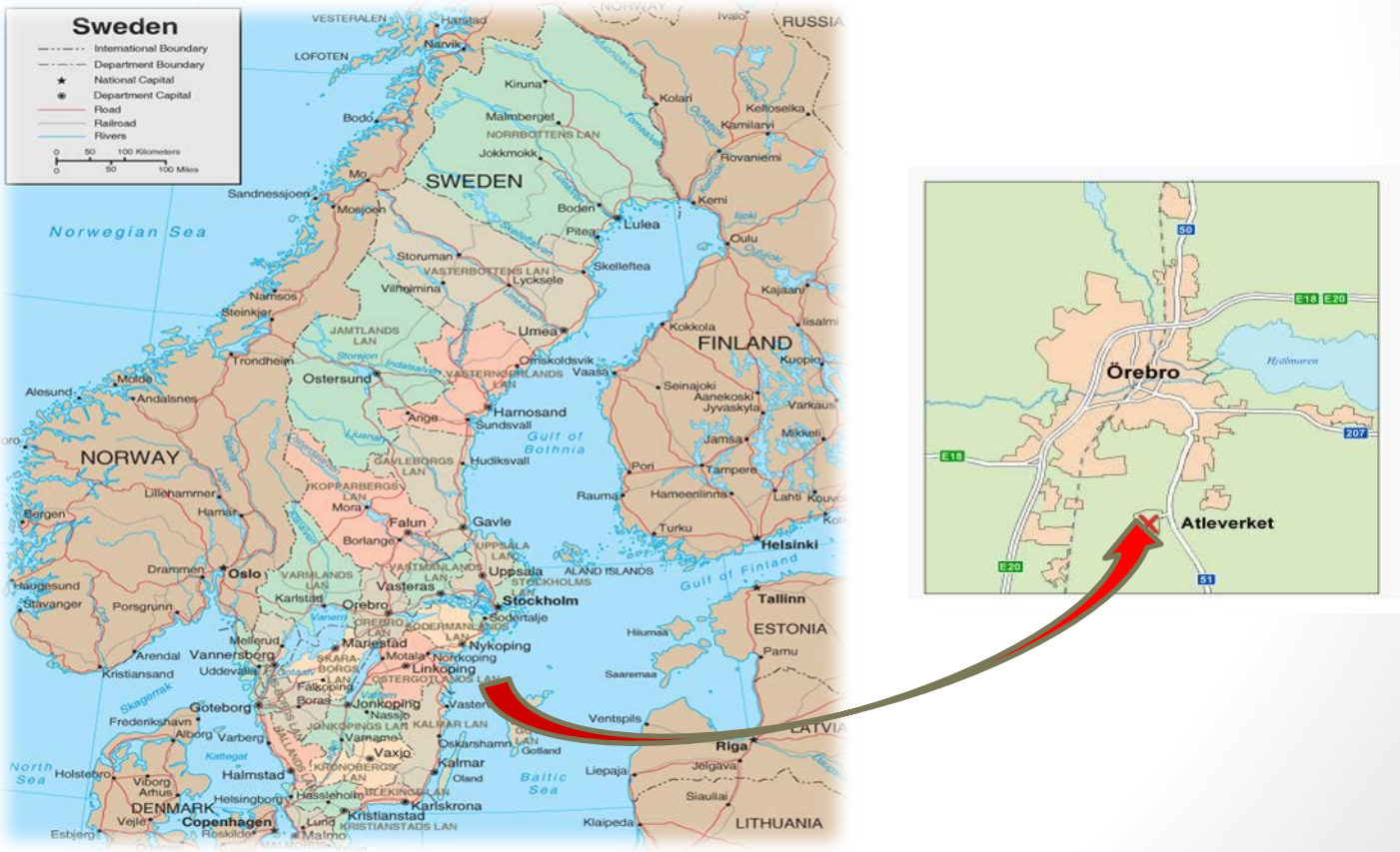
- In methanogenic stage
  - Very high in nitrogen (100-1000 mg/l in Sweden)
    - 95 % as ammoniacal nitrogen
  - High COD low BOD
    - COD/BOD ratio high can be more than 100
  - High concentration of suspended matter and sulfur
  - High concentration of major ions such as Ca, Mg, Na, Cl, $SO_4$

# Averages at Atleverket

| Parameter | Concentration in inflow mg/l | Concentration in outflow mg/l |
|---|---|---|
| Total nitrogen | 248 | 22 |
| $NH_4$-N | 66 | 3.6 |
| COD | 685 | 218 |
| BOD | 82 | 4 |
| Suspended matter | 258 | 8.5 |

# Atleverket landfill, Örebro

Source: Belinda Huerta Buitrago



# Atleverket, Örebro

Photo: Atleverket

# Aerial photo pf Atleverket wetland (Google Earth)

# Some characteristics of the wetland in operation since 2001

| Type of wetland: | Free Surface Flow (FSW) |
|---|---|
| Number of ponds: | 10 |
| Number of sediment traps: | 3 at the inlet |
| Area: | 8 ha |
| Total treatment volume: | 52. 000 $m^3$ |
| Retention time: | Very long and variable<br>1-2 wetland volumes treated/year |
| Dilution in system: | around 15 % |

# Overflow between pond 1 and pond 2

Photo: Susann Lillsjö Cronblad, 2005

# Aims

- **Determine the removal efficiency of metal and metalloids in Atleverket wetland during 2003-2012 and** determine how it is associated with other physical and chemical parameters measured
- **Determine if removal efficiency in the wetland varies with wetland age**
- **Compare removal efficiency with other treatment wetlands for landfill leachate**
- Determine if there is an hazard for the metals in the recipient by comparing concentrations out of the wetland with PNEC-based guidance values from Netherland and Canada.
- Give suggestions on how to improve design and operation of the wetland in order to improve retention ability

# Why perform this evaluation on Atleverket wetland?

- Atleverket wetland was not primarily designed for removal of metals and metalloids but for removal of nitrogen and organic material. However, it has an interesting design with sediment traps at the inlet and several ponds with overflows.

- There is a large amount of data available.

# Undersökta metaller

- Alkalimetaller
  - K
- Alkaliska jordartsmetaller
  - Mg, Ca, Ba
- Övergångsmetaller
  - V, Cr, Mn, Fe, Co, Ni, Cu, Zn
- Övriga metaller
  - Al, Pb
- Halvmetaller
  - Al, As, B

# Concentration and load data

- Concentration data has been used for;
  - Determining the removal efficiency
    - In different parts of the wetland as there is only flow measurement into and out of the wetland
    - Hazard assessment using PNEC based guideline values
- Load
  - Calculation of load for the whole wetland
    - Compare efficiency with other wetlands

| Metal | Load in | Load out | Removal % concentration | Removal load |
|---|---|---|---|---|
| Mn | 1100 | 131.6 | 90 | 88 |
| Ni | 20.9 | 11.5 | 51 | 45 |
| Pb | 4.1 | 0.2 | 96 | 95 |
| S | 21.3 | 12.7 | 48 | 40 |
| V | 7.6 | 0.5 | 94 | 93 |
| Zn | 96.9 | 7.7 | 93 | 92 |
| Total inflow in | | 486692 (43494 27507 48088 81235 24575 57283 29571 51724 68691 84095) | | |
| Total inflow out | | 557122 (59474 50445 52596 68577 36303 5987 54617 52570 73737 102816) | | |
| Dilution % | | 14 | | |

| Metal | Load in | Load out | Removal % concentration | Removal % load |
|---|---|---|---|---|
| Al | 670 | 87.8 | 89 | 87 |
| As | 6.7 | 1.0 | 86 | 85 |
| Ba | 103.8 | 17.0 | 85 | 84 |
| B | 838.8 | 490.6 | 49 | 42 |
| Ca | 83700 | 29400 | 69 | 65 |
| Co | 7.0 | 29.4 | 57 | 56 |
| Cr | 23.6 | 3.1 | 86 | 83 |
| Cu | 16.0 | 3.9 | 82 | 77 |
| Fe | 4.4 | 3.7 | 94 | 93 |
| K | 108.2 | 288.7 | 49 | 41 |
| Mg | 21.5 | 63.6 | 43 | 34 |

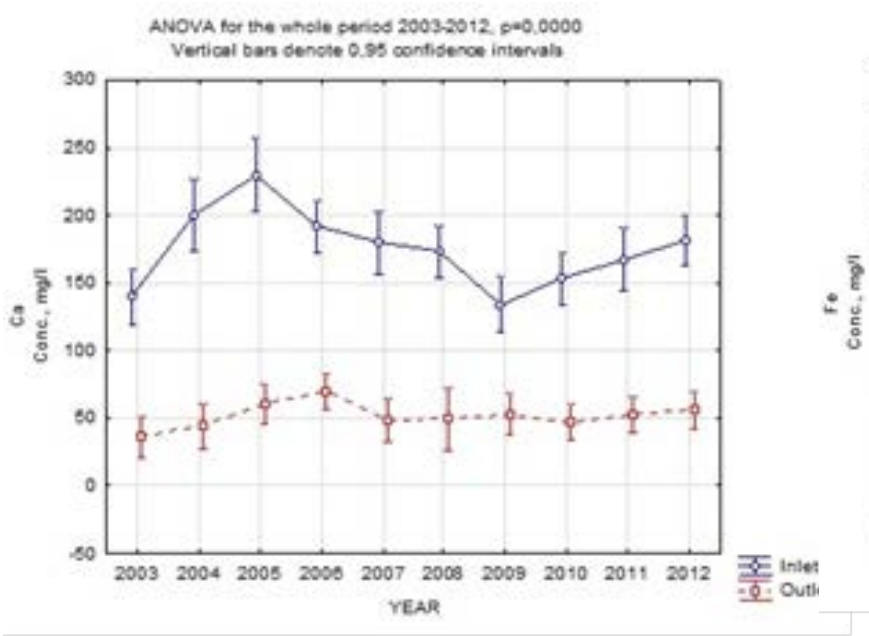
# Removal pattern 2003-2012

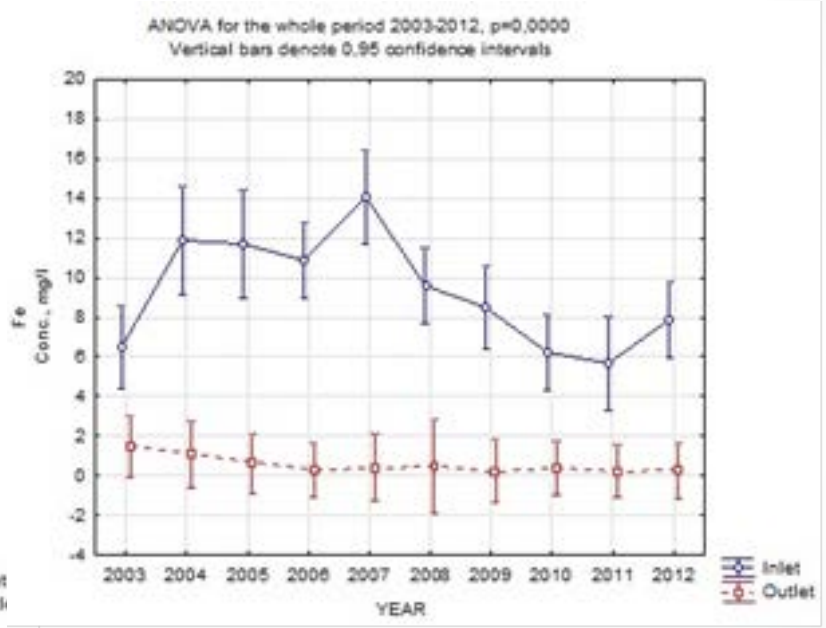
## 2 groups can be discerned

- Group 1: Metals and metalloids with a relative stable concentration out although concentration in may vary
  - Al, As, Ba, Ca, Cr, Cu, Fe, Mn, Pb, V, Zn
    - Removal efficiency 65-95 %, minimum for Ca

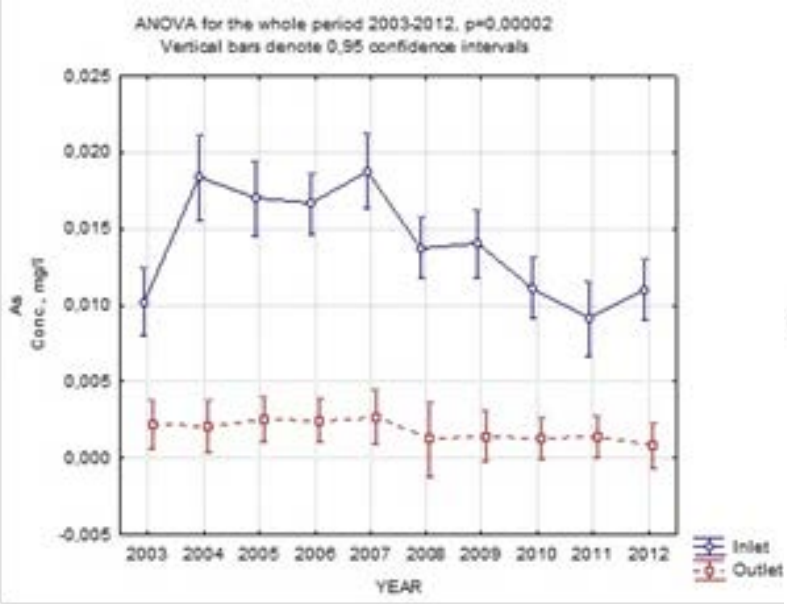
- Group 2: Metals and metalloids with variable concentration out. A peak outlet concentration may be observed 2006 and a low concentration may be seen 2008
  - B, Co, K, Mg, S, Ni
    - Removal efficiency 34-56 %, maximum for Co

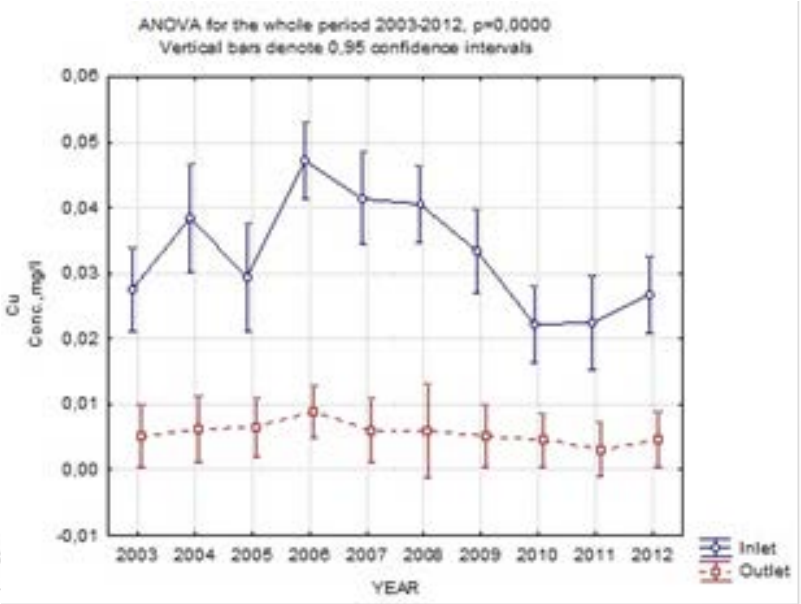
# Group 1 – examples with elements with high concentration into the wetland



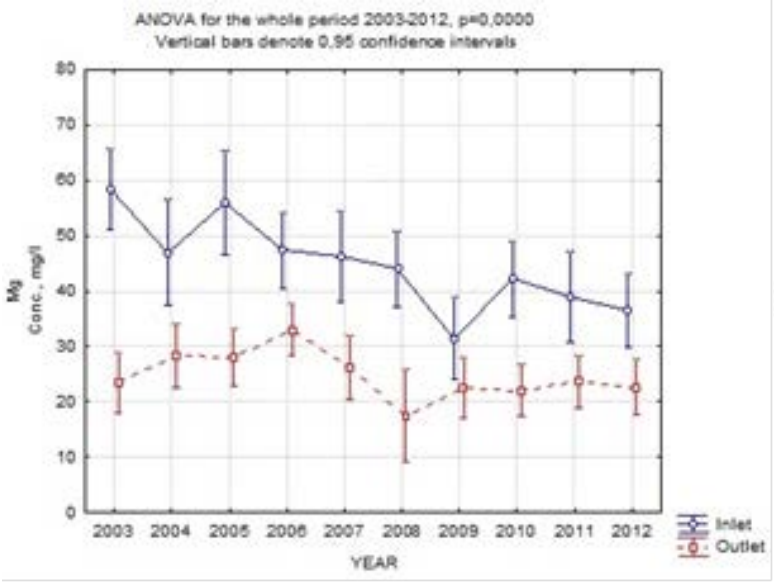



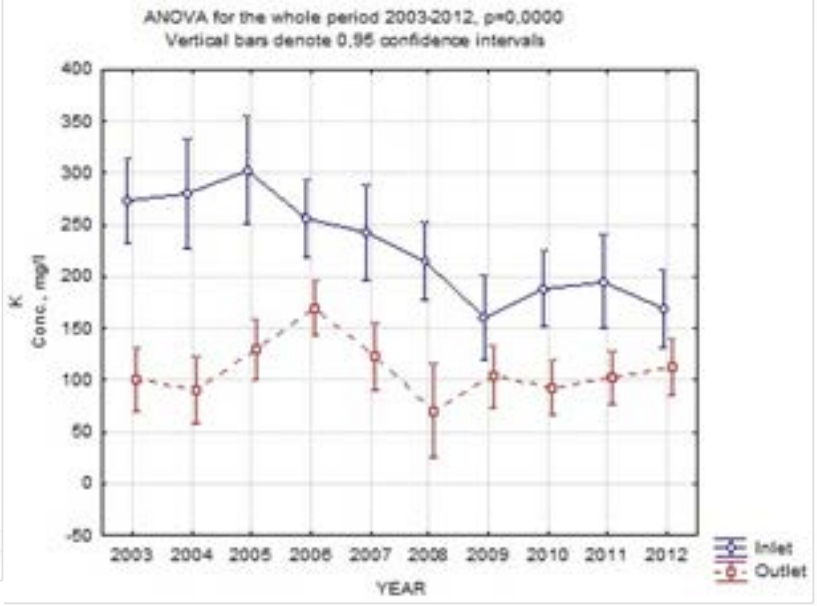
# Group 1 – examples of elements with low concentration into the wetland



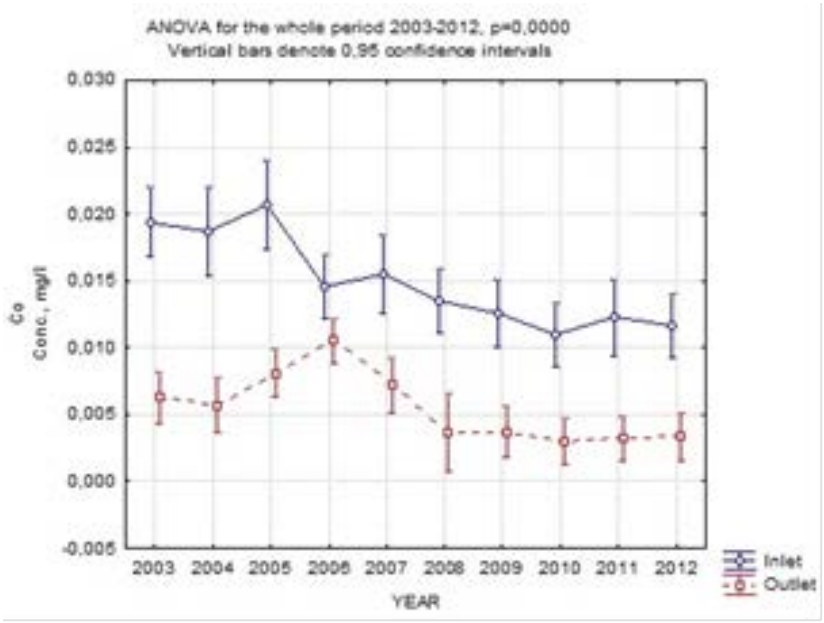



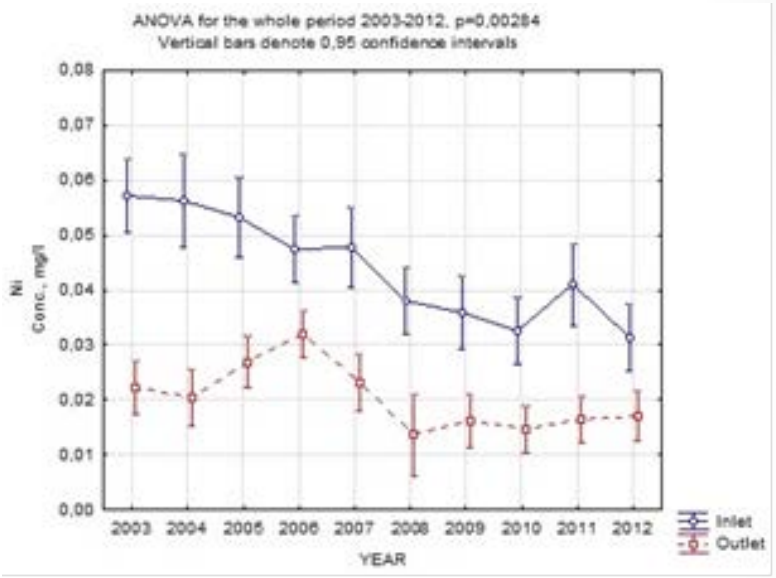
# Group 2 – examples with elements with high concentration in



# Group 2 – examples of elements with low concentration in



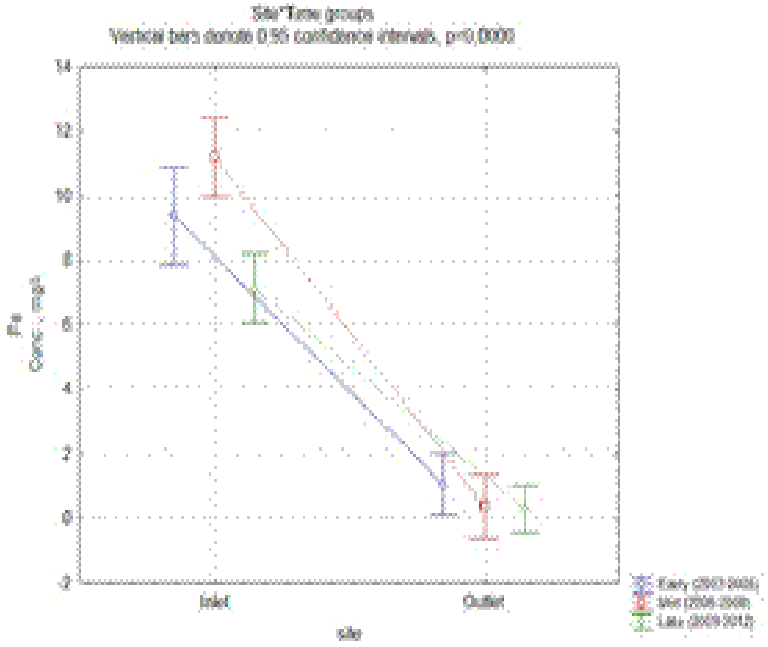
# Conclusion grouping

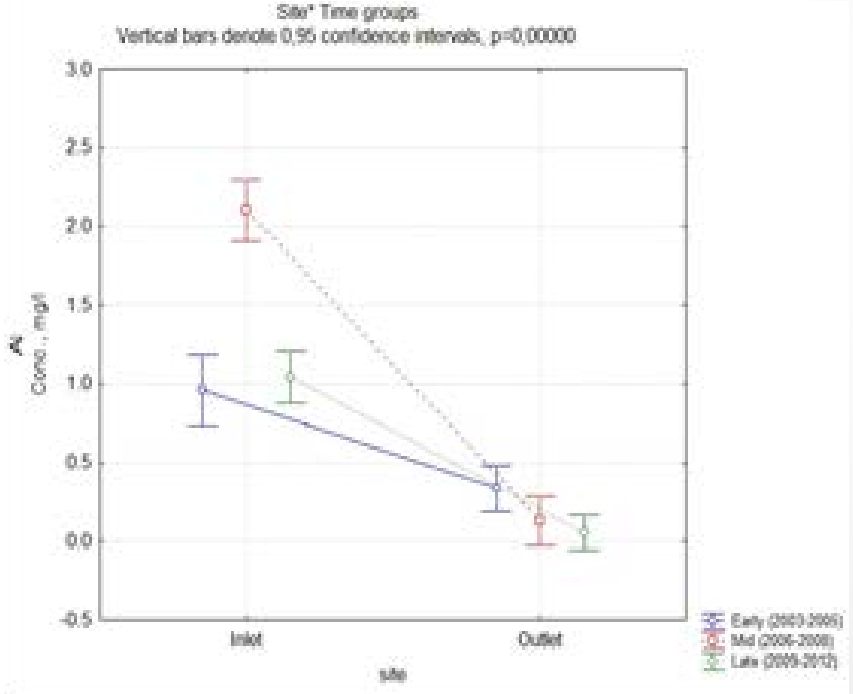
Removal efficiency for the whole period  is not related to concentration into the wetland

# Is the wetland age influencing the removal efficiency?

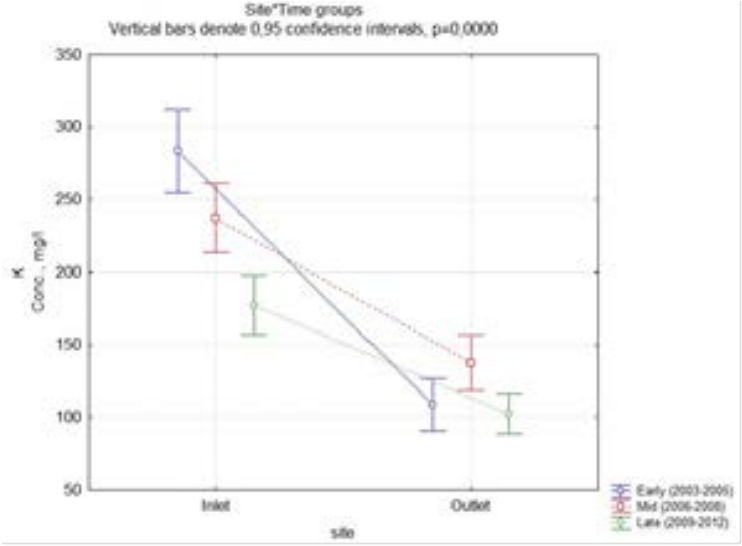
- Age
  - 2003-2005
  - 2006-2009
  - 2010-2012

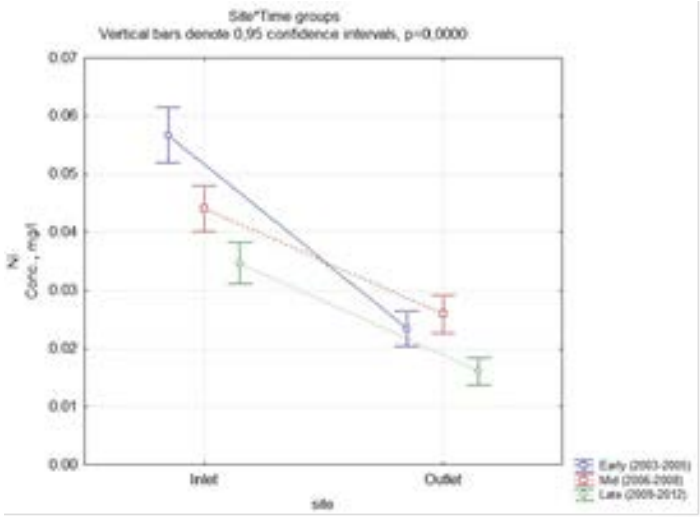
# Group 1
# Left: Element with high concentration into the wetland
# Right : Element with med high concentration into the wetland



# Grupp 2
till vänster: metall med hög koncentration in i våtmarken
till höger: metall med hög koncentration in i våtmarken



# Bakgrundskoncentration

# Förklaring till skillnader

- Metaller sk oxiderare som Fe, Mn bör bilda oxider och sedimentera/fälla ut om syrgaskoncentrationen är hög vilket är troligt i en våtmark med ytvattenflöde
  - Stämmer de visar en hög avskiljningsgrad men Ni borde också fälla ut samtidigt med Fe och Mn

# Undersökta metaller grupp 1 – fet stil

- Alkalimetaller
  - K
- Alkaliska jordartsmetaller
  - Mg, **Ca**, **Ba**
- Övergångsmetaller
  - **V**, **Cr**, **Mn**, **Fe**, Co, Ni, **Cu**, **Zn**
- Övriga metaller
  - **Al, Pb**
- Halvmetaller
  - **As**, B

Slutsats: Avskiljning beror inte på metalltyp

# Jämförelse med riktvärden

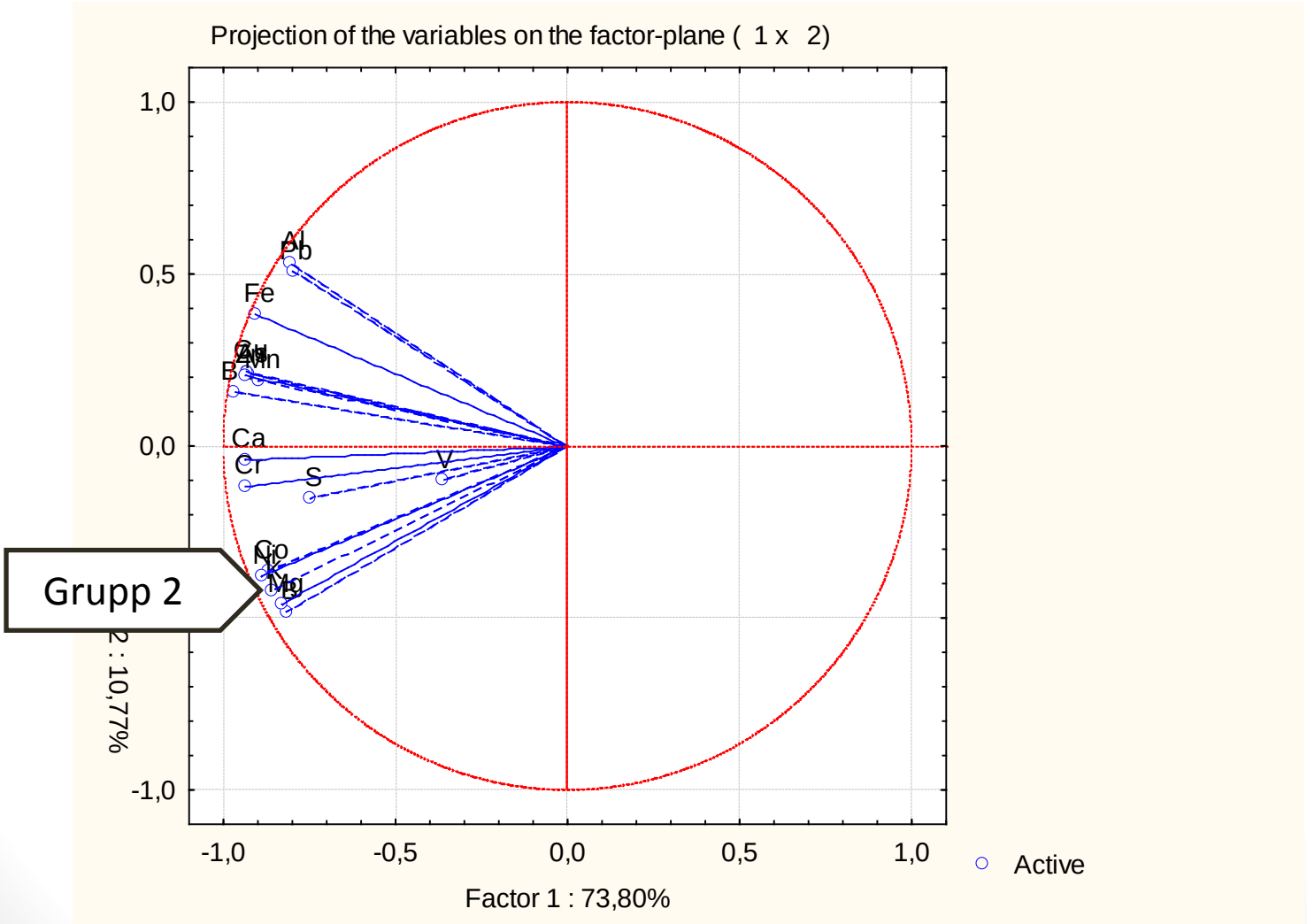
- MPC – Maximum Permissible Concentration för sötvattenekosystem, Nederländerna tar hänsyn till bakgrundskoncentration av metaller i Nederländerna
  - Tillåten koncentration för en kort tidsperiod
- WQG – Water Quality Guidelines – koncentration ska ge skydd för alla arter i sötvattenekosystem under lång tid i Kanada
  -

| Metal | Intervall in | Intervall out | MPC | WQG |
|---|---|---|---|---|
| Al | 220-3200 | 5-870 | ----- | 100 µg if pH 6.5≥ |
| As | 3,7-28 | 0,2-4 | 25 µg/l | 5 µg/l |
| Ba | 74-440 | 5-75 | 220 µg/l | ------- |
| B | 930-2900 | 150-1800 | ----- | 1500 µg/l |
| **Co** | **0,32**-26 | 1,4-18 | 2,8 µg/l | --------- |
| Cr | 15-120 | 1,9-20 | för Cr III+Cr VI | 8,7 µg/l |
| **Cu** | 13-80 | **0,05**-16 | 1,5 µg/l | H. reg<br>min 2 µg/l |
| Fe | 10-19000 | 71-3900 | -------- | 300 µg/l |
| **Ni** | 22-64 | 4,8-49 | 5,1 | H reg. min 25 µg/l |
| Pb | 1,5-19 | 0,25-2 | 11 | H reg min 1 µg/l |
| Zn | 60-360 | 0,25-150 | 9,4 | 30 µg/l |
| V | 1,9-34 | 0,025-3 | 4,3 | ------ |

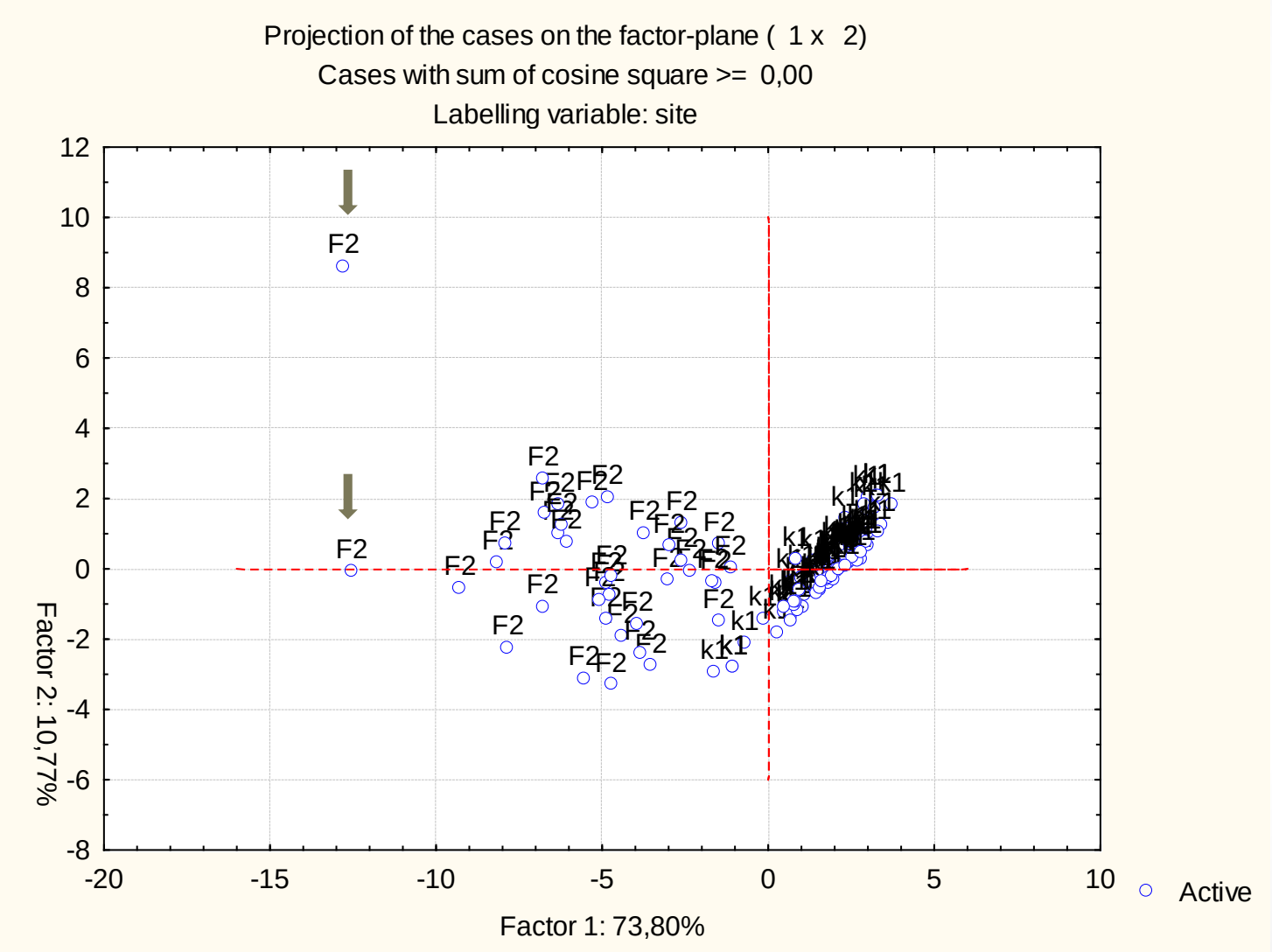
# Avskiljningsmönster PCA – Principal Component Analysis

- Alla metaller på en och samma gång, koncentration
- F2 och k1
- 2003-2012

# De två första komponenterna förklarar 85 % av variationen i datasetet



# Identifiering av outliers



# Avvikande mätvärden (outliers)

- Maj 2007: Osannolikt höga värden för Al, As, Ba, Cu, Fe och Zn
- Oktober 2011: Osannolikt höga värden för Al, As, Fe och Pb
- Anledning?

# Förklaring till PCA

- Faktor 1: I de flesta fall relaterad till storlek
  - Förklarar ca 84 % av variationen i data. Reduktion av alla metaller från F2 till k1
  - Varför V skiljer sig är oklart i dagsläget, det kan vara för att många värden ligger nära detektionsnivån
- Faktor 2: I de flesta fall relaterad till mönster
  - Förklarar hur metallerna avskiljs
  - Alla metaller som tillhör grupp 2 utom S finns placerade i en grupp (se pil i slide 22)

- Två prover har identifierats som klara outliers
  - F2 från oktober 2011
  - F2 från februari 2006

- PCA ska köras om utan dessa outliers

- Mer analyser ska utföras, återkommer.