Rapid degradation of pesticides at low concentrations - the possibility of using biodegradation to purify polluted groundwater during sand filtration

C.N. Albers*, S.R. Sørensen, O.S. Jacobsen, J. Aamand
Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350 Copenhagen, Denmark
* E-mail: cal@geus.dk

Introduction
In Denmark, herbicides like the phenoxy acids, phenoxyureas and especially the degradation product of dichlobenil; 2,6-dichlorobenzamide (BAM), have closed down numerous groundwater wells due to their presence above the 0.1 µg/L threshold limit. In recent years a number of microorganisms capable of degrading these classes of pesticides at relevant low concentrations have been isolated and described. We are currently investigating if these microorganisms can be used to purify groundwater either at remediation wells or during simple biological water treatment at waterworks.

Results – lab experiments
Over the years, bacteria have been isolated, which degrade low concentrations of a number of pesticides, including:
- Phenoxy acids (e.g. mecoprop, dichlorprop, MCPA, 2,4-D)
- Phenoxyureas (e.g. diuron, linuron, isoproturon)
- Dichlobenil and its degradation product BAM

Batch experiments showed that Aminobacter sp. MSH1 can degrade and mineralize BAM in concentrations from less than 1 µg/L to 50 mg/L at temperatures from 10–25 °C. E.g. the incubation of a moderate number of cells (6*10^10 cells/mL) resulted in the complete degradation of 1 µg/L BAM in less than 0.5 hours at 10 °C (Fig. 1).

Column experiments show that the MSH1 strain adheres well to common filter materials like sand, chalk and expanded clay and that the strain degrades BAM well in the first days after inoculation.

Field experiment – prel. results
The ambiguous lab-scale column experiments made a field experiment attractive to avoid laboratory biases. This is currently running. Initial results show good degradation in the days after inoculation, but also that this degradation is lost within 1 month. Various analyses are currently performed to explain the loss of degradation.

Discussions and future experiments
Future experiments will focus on:
- The tendency that degradation of BAM per cell at very low concentrations in sand filters is relatively slow, (mass transfer limitations?) which may make it difficult to reach the 0.1 µg/L threshold limit under field conditions.
- The fact that degradation capacity is lost relatively fast including the interaction and competition with indigenous microorganisms including bacteria and protozoa living in the biofilters, that is:
  - Can MSH1 compete with indigenous bacteria in this oligotrophic environment and form a stable population?
  - Will the added MSH1 be quickly grazed by protozoa?
  - Can other filter materials be used to better protect the bacteria?

Conclusions:
- Bacteria degrading various pesticides have been isolated and bio-filters may be used to purify polluted groundwater
- The MSH1 strain can degrade BAM to below threshold value in a number of small- and large-scale laboratory filters. At 20 °C and a residence time of 1 hour, 2.7 µg/L BAM was initially degraded to below the detection limit but during 25 days most of the degrading activity was lost (Fig. 3a), while at 10°C and shorter residence time, which are more realistic waterworks conditions, only 65% of 2 µg/L BAM was degraded (Fig. 3b). This degradation was however only slightly decreased over several weeks despite backwashing of the filters.
- Problems may exist regarding fast degradation at low conc. and competition with indigenous microorganisms
- A currently running field experiment will clarify the potential of this technology further

This study was financially supported by the BIOTREAT and the Miresowa projects.