NGU Report 96.128

The 6th Seminar on Hydrogeology and
Environmental Geochemistry 1996

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

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REPORT

Report no.: 96.128 | ISSN 0800-3416 | Grading: Open

Title:
The 6th Seminar on Hydrogeology and Environmental Geochemistry 1996

Authors:
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Client:
NGU

County:

Commune:

Map-sheet name (M=1:250.000)

Map-sheet no. and -name (M=1:50.000)

Deposit name and grid-reference:

Number of pages: 62 Price (NOK): 80,-

Map enclosures:

Fieldwork carried out:

Date of report:
07.11.96

Project no.:
2718.00

Person responsible:

Summary:
The 6th seminar on Hydrogeology and Environmental geochemistry was arranged on nov. 11. and 12. 1996 at the Knut S. Heier Conference Centre, NGU, Trondheim. The first day was primarily used for discussions of hydrogeological topics, and the presentations was mostly made in Norwegian. The second day was set aside for topics in ecochemistry with the presentations made in English. This year the theme of the seminar was "Geochemistry, Toxicology and Risk Assessment". The seminar concluded with a debate on the motion that "*Norms and action levels should be decided on the basis of natural background concentrations rather than toxicological criteria.*"

Abstracts of lectures are sorted chronologically according to the programme. Abstracts of posters are to be found in the second part of the report.

11. og 12. november 1996 ble det 6. seminar om Hydrogeologi og Miljøgeokjemi arrangert på Knut S. Heiers konferansesenter ved NGU i Trondheim. Første dag var vesentlig forbeholdt hydrogeologiske problemstillinger med innleggene hovedsakelig på norsk. Andre dag var avsatt til miljøgeokjemi med innleggene på engelsk. I år var fokus satt på emner knyttet opp mot **"Geokjemi, toksisitet og risikovurdering".** Seminaret ble avsluttet med en debatt over utsagnet: *"Tiltaksgrenser bør heller fastsettes på grunnlag av naturlige bakgrunnskonsentrasjoner av uønskede parametre enn på toksikologiske kriterier"*

Sammendrag av foredragene er systematisert kronologisk i henhold til programmet. Sammendrag av plakatpresentasjoner er samlet i del 2 av rapporten.

Keywords: Geokjemi	Grunnvann	Regional kartlegging
Hydrogeologi	Miljøgeologi	
	Geokjemiske undersøkelser	Fagrapport

MANDAG 11. NOVEMBER

09.30 - 10.00 Registrering.

Sesjon Hydrogeologi

Ordstyrer: *Gleny Foslie, Sør Trøndelag fylkeskommune.*

10.00
Åpning av seminaret v/adm. dir.
Arne Bjørlykke, NGU

10.05
Grunnvann som medisin for vannforsyningen 1996.
Knut Ellingsen, NGU

10.25
Lavt grunnvann og mye tele. Hva lærte vi i år?
Øystein Aars, Tor Simon Pedersen, NVE

10.45
Brønnboringsdatabasen - status og utfordringer.
Geir Morland, NGU

11.05 Kaffe og te pause.

Sesjon Hydrogeologi fortsetter

Ordstyrer: *Kari Sand, Hordaland fylkeskommune.*

11.20
Sprekkesystemer og bergspenningers betydning for vanngiverevnen i borebrønner i Sunnfjord.
Helge Henriksen, HSF, A. Braathen, NGU, E. Midtbø, NTNU, M. Fejerskov, NTNU, A. Myrvang, NTNU, E. Rohr-Torp, NGU.

11.40
Statistisk bestemmelse av hydrogeologiske parametre.
Henning Omre, Kjell Øivind Oulie, NTNU, Tom Bostrøm, SINTEF.

12.00
Modellering av koplet grunnvannsstrømning og biokjemiske reaksjoner.
Tom Bostrøm, SINTEF.

12.20
Karakterisering av grunnvann nedstrøms en kommunal fylling ved bruk av uorganisk species som indikator på grunnvanns-forurensning og fortynning.
Leif Basberg, NTNU.

12.40
Grunnvannsforurensning fra kisgruver. Beskrivelse av prosjektet.
Erik Rohr-Torp, NGU.

13.00 - 14.00 Lunsj

Plakatpresentasjoner

Ordstyrer: *Nina Hongseth, Høgskolen i Telemark*

14.00
Effekter av veisalting på grunnvann (foredrag)
Ole Åstebøl og Oddmund Soldal, Geofuturum.

14.20
Bergspenninger på Nordvestlandet
Elisabeth Midtbø, NTNU.

14.25
Groundwater Modelling at Oslo Main Airport Gardermoen
T. Bostrøm, T Furuberg, A. Watn, G.J. Westerlund, SINTEF.

14.30
A 2D Model of the Trandum Delta.
N.-O. Kitterød, NVE, W. K. Wong, NVE/UiO, T. S. Pedersen, NVE

14.35
Nasjonalt markvannsprogram, markvannsdata i "real time".
Tor Simon Pedersen, NVE.

14.40
Estimation of Hydrostratigraphical Architecture by Indicator Kriging.
Nils-Otto Kitterød, NVE and Elin Langsholt, UiO

14.45
A Tracer Study in the Unsaturated Zone of a Heterogeneous Formation
Helen French, NLH, Elin Langsholt, UiO and Nils-Otto Kitterød, NVE.

14.50
Chemical Modelling of Early Karstification in Limestone.
Johan B. Knudsen, Ingeniørstaben/FKN

14.55
Oksygenets skjebne i grunnvannssonen.
Atle Dagestad, NTNU.

15.00
A Geochemical Atlas of the Central Parts of the Barents Region
Clemens Reimann, NGU.

15.05
Hva finnes av publisert miljølitteratur fra Barentsregionen?
Demo av Jo Halvard Halleraker m.fl., NGU.

15.10
Major and Trace Element Chemistry in Groundwater from the Skjellbekken Catchment, North-East Norway.
Gaute Storrø, NGU.

15.15
Remobilization and Toxicity of Heavy Metals from Lead-Zinc Mine Tailings Deposited under Water in a Natural Lake System
Karl Jan Aanes, NIVA.

15.20
Heavy Metal Uptake in Natural Vegetation - An Outlining of Different Sources.
Bjørn Ove Berthelsen and Eiliv Steinnes, NTNU.

15.30 Te og kaffepause

Sesjon Hydrogeologi fortsetter

Ordstyrer: *Aase K. Midtgård, NGU*

16.10
Hydrogeoturisme, del 13. Tomsk, Sibir - Verdens største akvifer, verdens største grunnvannsuttak og verdens største deponering av radioaktivt avfall
David Banks, NGU.

16.30
Pollution and State of the Ecosystem in the Central Barents Region.
Galina Kashulina, NGU, C. Reimann, T.E. Finne, J. H. Halleraker, P. de Caritat, Ø. Jæger, T. Volden, NGU, M. Äyräs, GTK, V. A. Chekushin, CKE.

16.50
Sesongvariasjoner i fluoridinnhold i grunnvann.
Asgeir Bråten, UiB, Kjell Bjorvatn, UiB og Kari Sand, Hordaland fylkeskommune.

17.10
Lateritt, et mulig medium for vannbehandling i høy-fluorid områder i utviklingsland.
Kjell Bjorvatn, Asgeir Bårdsen og Marian Kjellevold, UiB.

Slutt 17.30

20.00 Seminarmiddag på Hotel Residence

TUESDAY 12th. NOVEMBER

Session Environmental geochemistry

Chair person: *Marianne Langedal, Trondheim kommune.*

09.00 Introduction
Bjørn Frengstad, the Organising Committee

09.05
Use of Risk Assessment in Contaminated Land Investigation and Remediation.
Keynote speaker Mike Quint, Dames and Moore.

09.35
Assessing Soil and Groundwater Contamination at Former Soviet Military Bases in Lithuania.
Bernardas Pauksys, GROTA.

09.55
Evaluation of Water Protection in Complex Karst Source Structures on the Basis of their Vulnerability and Pollution Risk.
Jadranka Milina, SINTEF.

10.15
An Authority Based Risk Assessment System for Contaminated Sites. Presentation of SFT's Work on Revising the Norwegian System Including Harmonization with the EU.
Eilen Arctander Vik, Aquateam og Harald Solberg, SFT.

10.45 Coffee and tea break

Environmental geochemistry cont.

Chair Person: *Eilen Arctander Vik, Aquateam*

11.00
Investigations and Decisions Concerning Polluted Soils: Current Shortcomings.
Randi Skirstad Grini, Kummenje, M. Langedal, R. T. Ottesen, Trondheim kommune.

11.20
Heavy Metals in the Soils at Industry-contaminated Sites: Selective Examples from Sweden.
Prosun Bhattacharya, KTH.

11.40
Assessing Metal Mobility: Is it Important?
Sjur Andersen, Jordforsk.

12.00
Importance of Chemical Speciation in Risk Evaluation of Heavy Metal Toxicity.
Eiliv Steinnes, NTNU.

12.20
Bioavailability of Soil Contaminants as a Determinant of Toxicity
Keynote speaker Lennart Dock, Karolinska Institutet.

12.40
Ni and Pb Exposure from Trondheim Soils: Health Effects?
Marianne Langedal og Rolf Tore Ottesen, Trondheim kommune.

13.00 - 14.00 Lunch

Environmental geochemistry cont.

Chair person: *Randi Skirstad Grini, Kummeneje AS.*

14.00
Bio-markers for Environmental Contamination - What Can They Tell Us?
Keynote speaker Karl Erik Zachariassen, NTNU.

14.20
Assessment of Bioremediation Results Using Toxicity Tests.
Marianne Ness, Hege Jonassen and Gijs Breedveld, NGI.

14.40
A Comparative Study of Geochemical and Medical Data in Norway.
Bjørn Bølviken, NGU.

15.00 **Debate:**
Should norms and action levels be decided on the basis of natural geological background concentrations or on toxicological criteria?
Introduction by *Bjørn Bølviken, Mike Quint, Karl Erik Zachariassen and Rolf Tore Ottesen.*
Leader: *Tor Erik Finne*

15.25-15.45 Coffee and tea break

16.45 Closure of the seminar

Poster contributions

Liming of Wetlands in the Røynelandsvatn catchment. Hydrological and Hydrochemical Response on a Runoff Event in a Limed Fen.
Jens Kværner, Per Kraft and Sjur Andersen, Jordforsk.

Nasjonalt markvannsprogram, markvannsdata i "real time".
Tor Simon Pedersen, NVE.

A 2D Model of the Trandum Delta.
N.-O. Kitterød, NVE, W. K. Wong, NVE/UiO and T. S. Pedersen, NVE

Estimation of Hydrostratigraphical Architecture by Indicator Kriging.
Nils-Otto Kitterød, NVE and Elin Langsholt, UiO.

A Tracer Study in the Unsaturated Zone of a Heterogeneous Formation
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Effekter av veisalting på grunnvann.
Ole Åstebøl og Oddmund Soldal, Geofuturum.

Oksygenets skjebne i grunnvannssonen.
Atle Dagestad, NTNU.

The State of Ecosystems in the Central Barents region: The database of the Published Litterature
J.H. Halleraker, C. Reimann, E. Berge, NGU M.V. Kozlov, E. Zvereva, Univ. of Turku

Major and Trace Element Chemistry in Groundwater from the Skjellbekken Catchment, North-East Norway.
Gaute Storrø, NGU.

A Geochemical Atlas of the Central Parts of the Barents Region
Clemens Reimann, NGU.

Gravity Minewater Discharges from Abandoned UK Coalmines: Prioritisation for Remediation.
Sheila Banks, NGU.

Bergspenninger på Nordvestlandet.
Elisabeth Midtbø, NTNU.

Remobilization and Toxicity of Heavy Metals from Lead-Zinc Mine Tailings Deposited under Water in a Natural Lake System
Karl Jan Aanes, NIVA.

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T. Bostrøm, T Furuberg, A. Watn, G.J. Westerlund, SINTEF.

Heavy Metal Uptake in Natural Vegetation - An Outlining of Different Sources.
Bjørn Ove Berthelsen and Eiliv Steinnes, NTNU.

Chemical Modelling of Early Karstification in Limestone
Johan B. Knudsen, Ingeniørstaben/FKN

INNHOLDSFORTEGNELSE

Grunnvann som medisin for vannforsyningen 1996

Knut Ellingsen

Norges geologiske undersøkelse, Postboks 3006, Lade, 7002 Trondheim

Norges vannforsyning er de seneste årene blitt tildelt sykdomsstatus som har påkalt behov for medisin. Den sterkeste medisinen har vært mobiliseringen av ansvarlige aktører til innsats; vannverkseiere, fagfolk og regjeringens Program for vannforsyning PROVA som de viktigste. Men grunnvann er oftest spesielt god medisin for vannforsyningen slik det ofte har vært påpekt, nemlig både på kostnad og på vannkvalitet.

Tradisjonelle løsninger basert på overflatevann som vannkilde har et stort momentum både blant kommunenes tekniske etater og blant de store konsulentfirmaene. Grunnvannet må derfor synliggjøres gjennom grunnundersøkelser før det kan ha håp om å anses for å være et reellt alternativ som vannkilde. For at grunnvann skal kunne bli vurdert på like fot med overflatevann, tilsier erfaringen fremdeles at forundersøkelsene bør gjennomføres med svært små kostnader for kommunene.

NGU har de seneste årene gått tungt inn for å bidra til å få grunnvannet vurdert i flest mulig tilfelle der ny kilde kan være aktuell. Muliggjort av NOEs bevilgning til NGU via PROVA har NGU i 1996 gått inn med 60% egenandel i undersøkelser fram til produksjonsbrønn kan etableres. Fylket har oftest gått inn med 25%, kommunen 15%. Inneværende år har NGU gjennomført slike undersøkelser på ca 50 steder i ca 25 kommuner hovedsakelig i seks fylker, Rogaland, Sogn og Fjordane, Møre og Romsdal, Oppland, Sør-Trøndelag og Nordland. Alle resultatene er ennå ikke klare, men det tegner til at nesten alle stedene har oppnådd positivt resultat, altså ligger det an til å bli mye god medisin!

På de fleste steder med løsmasser omfatter undersøkelsene befaring, geofysikk (oftest georadar, undertiden seismikk, geoelektriske undersøkelser), boringer og nedsetting av rør for prøvetaking av masse og vann, undertiden også for peiling av vannstand. Eventuelle undersøkelser ut over dette gjøres til full pris under vanlige konkurransevilkår mot øvrige aktører. Grensen for ekstra ytelse fra NGU settes her, før nedsetting av brønn, fordi vannverkseieren ved dette stadium i tilstrekkelig grad har fått klargjort grunnvannet som mulig alternativ ny kilde. Da kan vannverkseieren gjøre et reelt valg av løsning mest mulig likeverdig mellom eventuelle overflatevanns- og grunnvannskilder, og kan gjennomføre planlegging og prosjektering på et bedre grunnlag. Der fjellbrønn har vært aktuell, har NGU i noen få tilfelle etter befaring og overflateundersøkelser boret brønner med 60% egenandel. Men for det meste har eksterne brønnborefirma gjennomført boringene på ordinære betingelser.

Lavt grunnvann og mye tele. Hva lærte vi i år?

Øystein Aars og Tor Simon Pedersen

NVE, Postboks 5091, Majorstua, 0301 Oslo

Vinteren 1995-96 var unormal i store deler av Sør-Norge, med vedvarende kulde, lite nedbør og lite snø, og derfor problemer med tele og vannforsyning i mange områder. En henvendelse fra Justisdepartementet på vegne av fylkesmannen i Oppland førte til at en rapport ble utarbeidet av en arbeidsgruppe ved Hydrologisk avdeling, NVE, i februar, der mulige scenarier for utviklingen fram mot sommeren av grunnvannsforhold og tele skisseres. Scenariene for tele omfatter et "beste fall" og et "verste fall", mens grunnvannsutviklingen skisseres under gunstige værforhold, under normale værforhold og i det "verste" scenariet med lite nedbør og fortsatt lave temperaturer.

Data fra LGN (NGU/NVEs landsomfattende grunnvannsnett) og fra reguleringsforeninger viste at det det verste scenariet ble virkelighet, med rekordlave grunnvannstander i mange observasjonsrør. Dette medførte ikke så lite medieoppmerksomhet, samt økt erfaring i hvorledes informasjoner gjengis av journalister

Vi synes selv vi "traff" forbausende bra med vårt scenario, også når det gjaldt teleutviklingen. Men vi hadde nok i noen grad undervurdert størrelsen på oppfyllingen, når den først kom.

1996 har gitt oss verdifulle erfaringer. Behovet for observasjoner i sann tid ble gjort smertelig klart. Våre teleobservasjoner må kvalitetssikres, det er behov for teledata.
Når det gjelder media: Journalister kan være gode medarbeidere, men noen trenger mer hjelp enn andre!

Brønnboringsdatabasen - bakgrunn, status og utfordringer

Geir Morland

Norges geologiske undersøkelse, Postboks 3006, Lade, 7002 Trondheim

Etablering av oppgaveplikt for boring etter vann ble aktualisert av en utredning av førstelektor Bjørn Stordrange ved UiO i 1988 med tittel «Nye rettsregler om grunnvannet?». Utredningen var initiert av det daværende Vannressursutvalget. Dette resulterte til slutt i at vassdragsloven ble en paragraf rikere i og med at § 11 a om oppgaveplikt for boring etter vann ble føyd til. I denne paragrafen er det nedfelt at den som utfører boring etter vann skal sende melding til Norges geologiske undersøkelse om hvor det er foretatt boring og om hvordan boringen er utført.

For å sikre en enhetlig og standardisert innrapportering av opplysninger fra brønnborere og andre som kommer inn under oppgaveplikten, har NGU i samarbeid med brønnborerne utarbeidet et skjema til bruk i oppgaveplikten. Skjemaet kan virke komplisert, men ut fra de tilbakemeldingene vi har fått fra brønnborere som bruker skjemaet, ser det ut til å fungere veldig greit i praksis. Skjemaet er laget slik at de enkelt kan forandres i takt med generelle endringer i f.eks. terminologi og ønske om endringer basert på erfaringer fra praktisk bruk.

I loven er det presisert at det skal gis opplysninger om hvor boringen er utført. Det er derfor en forutsetning at det enkelte borepunkt koordinatfestes. Uten at NGU kjenner koordinatene til et borepunkt, har det i praksis ingen betydning hvor gode opplysninger som ellers gis om boringen. NGU har derfor gått ut med et tilbud om at de som ønsker det gratis kan låne en GPS-mottaker (GPS= Global Positioning System) av NGU for å koordinatfeste borepunktene. Dette gir en posisjoneringsnøyaktighet som generelt er bedre enn 100 m. Alternativet ville f.eks. vært å bruke M711-kart i målestokk 1:50 000, med fare for enda større usikkerhet i posisjoneringen.

Dagens gjeldende lovtekst (§ 11 a i vassdragsloven) hjemler også at departementet kan gi forskrifter for å gjøre innrapporteringen av opplysninger enhetlig. Denne forskriften vil sannsynligvis tre i kraft fra 1. januar 1997.

I 1994 kom det en NOU som inneholdt forslag til en ny lov som bl.a. skulle erstatte den gamle vassdragsloven. Den nye "Lov om vassdrag og grunnvann" omhandler i hovedsak problemstillinger tilknyttet overflatevann, men det er også tre viktige paragrafer som omhandler grunnvann. I forslag til § 49 omhandles temaet rådighet over grunnvannet, i forslag til § 50 hjemles konsesjonsplikt ved grunnvannsuttak og i forslag til § 51 videreføres § 11 a i dagens vassdragslov.

I NGUs brønnboringsdatabase er det siden starten i 1951 registrert ca. 20 000 borebrønner i fjell. Brønnboringsdatabasen har eksistert på ulike tekniske plattformer helt siden hullkortets dager. I dag har vi i tråd med NGUs databasestrategi utviklet en relasjonsdatabase som nå skal videreutvikles for å tilfredsstille de behov ulike brukere av våre data har. I tillegg til å tilrettelegge brønnboringsdatabasen for våre kunder ser vi en stor utfordring i å gjøre ulike typer informasjon om grunnvann spesielt tilgjengelig. Dette gjelder f.eks. sammenstillinger om forventet vanngiverevne i ulike bergarter, hvilken vannkvalitet som kan forventes i ulike områder, om det er lokalisert brønner i nærheten av nye brønnlokaliseringer osv.

Sprekkesystemers og bergspenningers betydning for vanngiverevnen i borebrønner i Sunnfjord, Sogn og Fjordane.

H. Henriksen[1], A. Braathen[2], M. Fejerskov[3], E. Midtbø[3], A. Myrvang[3] og E. Rohr-Torp[2].

[1]*Høgskolen i Sogn- og Fjordane, Postboks 39, 5801 Sogndal*
[2]*Norges geologiske undersøkelse, Postboks 3006, Lade, 7002 Trondheim*
[3]*Institutt for geologi og bergteknikk, NTNU, 7034 Trondheim*

NGU, i samarbeid med NTH/NTNU og HSF, startet i 1996 et større forskningsprosjekt om grunnvann i fjell. Prosjektarbeidet er rettet mot Sunnfjord, hvor det foreligger gode kunnskaper om berggrunnen og dens geologiske historie. Prosjektet har som hovedmålsetting å framskaffe forståelse av hvilken betydning deformasjonen langs regionale bruddsoner har for oppsprekningen i den nærliggende berggrunnen med tanke på å oppnå mer kunnskap om grunnvannspotensialet i tilknytning til de forskjellige bruddsonene i regionen.

I krystallin berggrunn med lav/ingen porøsitet er grunnvannsstrømningen styrt av et sprekkenettverk av sprekker med forskjellig alder og hydrauliske egenskaper. Et viktig spørsmål er om fordeling og intensitet av sprekker i berggrunnen er skala-avhengig og systematisk. En slik systematikk vil, satt i sammenheng med vannføringen i eksisterende og nye borebrønner, kunne benyttes i evaluering av brønnposisjon langs større sprekkesoner. Denne vurderingen omfatter også betydningen av dagens spenningsfelt, som antakelig spiller en vesentlig rolle for vannstrømmen langs sprekker i berggrunnen.

Metodene som vil bli benyttet i prosjektet omfatter:

- Lineamentsanalyse og GIS-baserte korrelasjonsstudier av lineament- og borebrønndata.
- Strukturgeologisk feltarbeid og utvikling av en tektonisk-kinematisk modell for området.
- Bergstress-studier og in-situ bergspenningsmålinger.
- Akviferkarakterisering av utvalgte testområder: Strukturgeologisk kartlegging, geofysiske bakkemålinger, hydrogeologisk og geofysisk borehullslogging av undersøkelsesbrønner, prøvepumping.

Resultater fra innledningsfasen vil bli presentert.

Statistisk bestemmelse av hydrogeologiske parametre

Henning Omre, Kjell Øivind Oulie og Tom Bostrøm

Henning Omre, Inst. for matematiske fag, NTNU, 7034 Trondheim
Kjell Øivind Oulie, Inst. for matematiske fag, NTNU, 7034 Trondheim
Tom Bostrøm; Bygg og miljøteknikk/Avd. Geoteknikk; SINTEF, 7034 Trondheim

Beregningsmodeller for strømning i porøse media er i utstraktbruk i hydrogeologiske undersøkelser. Modellene for strømninger er vanligvis basert på fysisk forståelse via Darcy's lov. Egenskapene til det porøse media, dvs. reservoaret, har en imidlertid mindre kunnskap om. Vanligvis må en basere seg på generell reservoarinformasjon og reservoarspesifikke observasjoner når reservoarets egenskaper skal modelleres.Førstnevnte består av geologisk erfaring samt målinger i analoger. Sistnevnte består av observasjoner av reservoaret i brønner samt pumpetester. I denne studien er fokus på hydraulisk konduktivitet, eller permeabilitet, for vann. Studien har to siktemål: Prediksjon av permeabiliteten i en brønn i reservoaret samt å forbedre modellen for estimering av permeabilitet ut fra kornfordelingskurver i reservoaret som evalueres. Sistnevnte er basert på Gustafson formel, se Gustafson (1986).

Problemet er formulert i et bayesiansk rammeverk, se Casella og Berger (1990). En prior modell basert på generell reservoarinformasjon er definert. Dette innebærer at parametrene i Gustafsons formel er gitt en stokastisk tolkning og at prior sannsynlighetsfordelinger er tilegnet dem basert på erfaring fra andre reservoarer. Deretter er reservoarspesifikke observasjoner, i dette tilfellet pumpetest data fra en gitt brønn, brukt til å tilpasse disse parametrene i Gustafsons formel til det reservoar som studeres. En bestemmer posteriori sannsynlighetsfordelingen for parametrene. Basert på dette kan prediksjoner av permeabiliteten i den brønnen som studeres utføres.

Fremgangsmåten som er skissert over er demonstrert på data fra Øvre Romerike akviferen på Gardermoen.

Foredraget er basert på et prosjektarbeid på NTNU, se Oulie (1996). Arbeid langs de samme linjer er utført på petroleumsreservoarer, se Omre og Tjelmeland (1996) og Lia et al (1997).

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Modellering av koplet grunnvannsstrømning og biokjemiske reaksjoner

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Jord og grunnvannsforurensinger på grunn av utslipp av olje og oljeprodukter er et økende problem. Typiske områder for slik forurensing er bensinstasjoner, flyplasser og tankanlegg. I tillegg kommer områder som forurenses av lekkasje fra nedgravde tanker og akutte utslipp fra industri og landtransport. En lovende teknikk for å renske opp grunnvann forurenset med nedbrytbare organiske forurensinger er in-situ mikrobiologisk opprensking.

Numeriske strømnings og reaktive transport modeller kan være verdifulle verktøy for design og overvåkning av in-situ biologiske opprenskingstiltak. Dataprogrammet TBC (**T**ransport, **B**iochemistry and **C**hemistry) utviklet ved Universitetet i Heidelberg (Schäfer, Schäfer og Kinzelbach) presenteres i foredraget. TBC løser likningene for tre-dimensjonal mettet grunnvannsstrømning, advektiv og dispersiv transport ved bruk av endelig differansemetoden. Transport av oppløste stoffer er koplet til mikrobiologisk nedbrytning av organiske stoffer. Mikrobiologisk vekst blir simulert med bruk av Monod type kinetikk. Substrat forbruk og frigivelse av metabolske produkter er koplet til mikrobiologisk vekst via utbyttekoeffisienter og støkiometriske sammenhenger. Effekter av mikrobiologisk aktivitet på den uorganiske sammensetningen av grunnvannet blir ivaretatt. I motsetning til tidligere publiserte modeller av mikrobiologisk aktivitet, som er skreddersydd til et gitt sett av reaksjoner, tillater TBC at brukeren selv spesifiserer biologiske og kjemiske reaksjoner utover det som er inkludert. Dette gjør at TBC er et kraftig og fleksibelt verktøy.

Anvendelse av TBC er vist på in-situ biologisk opprensking av hypotetisk akvifer forurenset med hydrokarboner.

Characterization of groundwater downgradient from a municipal landfill using inorganic species as an indicator of groundwater contamination and attenuation.

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Mapping of groundwater contamination plume downgradient from The Trandum municipal landfill has been carried out in the summer 1996. The focus of the study has been inorganic species in the groundwater, in particular redox sensitive species. Previous investigations by NGU in 1991 and ASPLAN-VIAK in 1994/95 constitute the bases for this study and provided valuable information with regards to changes in the contaminate plume over time.
The groundwatertable is located between 10 and 26 meters below the surface. Filters are placed at various depths from the watertable and down 15 meters. Spatially the wells cover an area 400 meters parallel to the groundwater flow and 200 meters transverse to the flow direction. Boarders of the contaminate plume seem to be confined within this area, with the furthest detectable influence 250 meters downstream. A total of 32 water samples have been collected from 18 different sampling points for analysis of inorganic species both in the field and the laboratory. Unstable parameters were analyzed in the field together with physical parameters, major anions and cations. The laboratory analysis are more comprehensive than the field analyses, but include the same species that were determined in the field.
The contaminant plume appears to be stable both in extent and composition from 1991 to 1996 with some seasonal fluctuations. Attenuation of the contamination seem to be controlled by the redox-environment that have developed in the plume due to entrance of the reduced landfill leachate into the groundwater.

Grunnvannsforurensning fra kisgruver, beskrivelse av prosjektet

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Statens forurensningstilsyn (SFT) har bevilget 500 000 til prosjektet som ledes av NGU i samarbeid med Norsk institutt for vannforskning (NIVA) og Statens bergvesen. Prosjektets varighet er ett år (1996).

NIVA har tidligere sammen med Bergvesenet og SFT utført en rekke undersøkelser av kisgruvers påvirkning av overflatevann.

Basert på disse resultatene har de utarbeidet en oversikt over de ca. 130 mest forurensende kisgruvene, og oversendt den til NGU, som har vurdert hvorvidt mulige større grunnvannsforekomster vil kunne bli påvirket.

NGUs vurderinger er basert på tilgjengelig bakgrunnsmateriale, det vil i første rekke si:

- Geologiske kart og publikasjoner (grunnvann, løsmasser, berggrunn, malm og grusregister)
- NGU s brønnboringsarkiv
- Topografiske kart
- NGU s registreringskart for malmforkomster
- Personlig kjennskap til ulike områder

Etter denne gjennomgangen satt vi igjen med ca. 20 grunnvannsforekomster som ville kunne bli påvirket av kisgruveavrenning.

En stor del av disse ble så befart med deltakere både fra NGU og NIVA. Samtidig ble vannanalyser fra tilgrensende vassdrag gjennomgått. Konklusjonene etter befaringen var klare:

Ganske overraskende viste nemlig NIVAs vannanalyser fra vassdragene nedstrøms for store kisgruver, og som grenser til kjente og antatte større grunnvannsforekomster, at vannkvaliteten mht. tungmetaller tilfredsstilte helsemyndighetenes krav til drikkevann (Drikkevannsnormene). Forurensning av større grunnvannsforekomster fra kisgruver antas derfor knapt å forekomme i Norge.

Effekter av veisalting på grunnvann

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I perioden 1992-95 ble effekten av veisalting på grunnvann undersøkt under ulike naturgitte forhold. Undersøkelsene av grunnvann ble utført ved fire målestasjoner beliggende i Akershus, Hedmark og Rogaland.

Veisalt spres til omgivelsene ved sprut, avdrift og avrenning av overvann. Den videre spredningen i naturmiljøet er avhengig av de naturgitte forholdene på stedet og utformingen av veianlegget. I områder med finkornige masser vil en stor del av saltavrenningen skje med overvannet via åpne grøfter eller lukkede avløp til vassdrag. Saltholdig vann som siger ned i grunnen vil enten fanges opp av veiens drenssystem eller spres med grunnvannet. I områder med grovkornige løsmasser (sand og grus), vil mesteparten av det saltholdige overvannet fra veien infiltrere i grunnen og sige ned til grunnvannet.

Ved målestasjonene for grunnvann varierte saltforbruket fra 7,9 - 14,6 tonn/km pr år i prosjektperioden (tofeltsvei).

Undersøkelser i et lite grunnvannsmagasin nær vei viste en midlere forhøyning i saltkonsentrasjonen som følge av veisalting på 77 mg Cl/l og 42 mg Na/l. I et stort magasin ble forhøyningen i saltkonsentrasjonen målt til 14 mg Cl/l og 8 mg Na/l. Mengden grunnvann som strømmer forbi veien er den faktoren som påvirker forhøyningen i saltkonsentrasjonen mest. Saltpåvirkningen avtar med økende vanngjennomstrømning. I små grunnvannsmagasin ble det registrert store variasjoner i saltkonsentrasjon gjennom året, mens variasjonen i store og dype magasiner var betydelig avdempet. Små magasiner med liten vanngjennomstrømning er således mest sårbare for saltforurensning.

Foruten økt konsentrasjon av natrium og klorid i grunnvannet, var virkningen av veisalting på øvrig ionesammensetning liten i disse magasinene.

I et grunnvannsmagasin under dyp umettet sone (12 m) var natriumkonsentrasjonen lav sammenlignet med kloridkonsentrasjonen i det overflatenære grunnvannet. Binding (adsorpsjon) av natrium i sedimentene var sannsynlig årsak. Grunnvannet hadde forhøyede konsentrasjoner av andre kationer. Over tid må man forvente en økende natriumkonsentrasjon i dette grunnvannet. I grunnvannsmagasin med umettet sone på 3-5 m var adsorpsjonen av natrium i sedimentene generelt liten.

En sammenligning av beregnede saltkonsentrasjoner med målte verdier, viser at saltkonsentrasjonen kan beregnes relativt sikkert når de hydrogeologiske forholdene er enkle.

Ved utnyttelse av grunnvann til vannforsyning, vil graden av saltpåvirkning generelt være større ved små vannuttak (selvmatende magasin) enn ved store vannuttak (infiltrasjons-magasin). Ved uttak fra selvmatende magasin vil saltkonsentrasjonen i utpumpet grunnvann være avhengig av saltforbruk, vanngjennomstrømning i magasinet og avstand mellom vei og brønn. Ved uttak fra infiltrasjonsmagasin vil saltpåvirkningen i utpumpet grunnvann være avhengig av saltforbruk, avstand mellom brønn og vassdrag og utpumpet vannmengde. For begge magasintypene vil veiens beliggenhet i forhold til grunnvannets strømningsretning også ha betydning for saltpåvirkningen i utpumpet grunnvann. Metoder for beregning av forventet saltkonsentrasjon i utpumpet grunnvann, er utredet.

Tomsk, Siberia - the world's largest aquifer, the world's largest groundwater abstraction and the world's largest disposal of radioactive waste ?

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The city of Tomsk lies at the south-eastern corner of what is probably the World's largest aquifer basin - the Western Siberian artesian basin. The basin consists of a series of largely undeformed Mesozoic and Cenozoic sediments with a number of discrete sandy aquifer horizons. Tomsk lies on the River Tom', a major tributary of the Ob'. It is a city of some 500,000 people and, like most Russian cities, tends to rely on a rather complex but essentially highly centralised water supply, with separate distribution systems for hot and cold water. The drinking water supply consists of two lines of water wells (184 in total) stretching for a length of 55 km along the inner side of the «V» formed by the confluence of the Tom' and Ob'. The wells draw their water from aquifer horizon IVa (I is the deepest and VI the shallowest of seven horizons beneath Tomsk), at depths varying from 80-170 m (Lgotin & Makushin 1997). The current rate of abstraction is some 240,000 m^3/d or ca. 2800 l/s. The water supplied by the Tomsk waterworks is generally of high quality, although treatment by aeration is necessary to remove elevated iron concentrations.

The well-field is relatively close to the closed city of Seversk (Tomsk-7), one of three major centres of reprocessing of nuclear materials (the others being at Mayak, near Chelyabinsk, and near Krasnoyarsk). Seversk was the site of a significant release of nuclides to the atmosphere during an accident in 1993 (Tomsk Oblast' State Committee for Ecology 1994). According to Bradley and Jenquin (1995), Seversk is the largest disposer of radioactive wastes in western Siberia, and conceivably, in the world, with over 1,000,000,000 Ci (40 Ebq = 40 x 10^{18} Bq) of wastes hitherto. Wastes have formerly been disposed of both to surficial lagoons and, to some extent, to surface waters draining into the Tom'. Since 1967, however, the wastes have been injected into the deep aquifer horizons II and III below Tomsk, of Cretaceous age, at depths of some 280-400 m (Lgotin & Makushin 1997, Solodov 1997).

Local civilian environmental authorities and the environmental authorities of the closed city of Seversk have established a comprehensive network of monitoring wells around the Seversk injection site. The Russian Academy of Sciences are collaborating closely with these authorities to investigate the controls on migration of radionuclides (Solodov 1997). The current consensus appears to be that there is little danger of contamination of the Tomsk well-field or of surface water features in the near future, partly due to the chemical attenuation and sorption of wastes in the geological strata in the vicinity of the injection wells. Some minor indications of migration of contaminants to adjacent aquifer horizons have been detected (Lgotin & Makushin 1997), and it has been suggested that this may be due to migration via poorly sealed observation wells. Whether the disposal option is viable in the long-term appears to depend on (i) whether the conceptual model of the deep aquifer horizons being effectively isolated by intervening clayey layers is correct and (ii) the possibility for eventual remobilisation of sorbed or precipitated nuclides in the zone of geochemical attenuation.

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Pollution and state of the ecosystem in the Central Barents Region.

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The Geological Surveys of Finland (GTK) and Norway (NGU) and the Central Kola Expedition in Russia (CKE) are carrying out a large scale environmental geochemical mapping of an area of 188,000 km^2 located north of the Arctic Circle and including most of Finnish Lapland, Finnmark county in Norway, and the western part of the Kola Peninsula in Russia (http://www.ngu.no/Kola). For the more than 650 localities, distributed evenly throughout the area investigated, a qualitative, visual estimation of the state of the ecosystem and its major components was made simultaneously with geochemical sampling during the summer 1995.

The territory investigated includes several large industrial centres in Russia, with some of the world's largest SO2 and heavy metal emission sources. Long term air pollution has brought about severe ecological damage in the vicinity of the major pollution sources (the Severonikel and Pechenganikel smelter complexes).

Present investigation shows that the local damage zones near the individual emission sources have joined and the ecological damage on the Kola Peninsula has actually become regional in character. 9% of sites in Russia have high level of pollution and strong or complete ecosystem disturbance. About 50% of the area has moderate pollution level and essential, visual signs of the ecosystem disturbance. The rest of the Russian area has low level of pollution with possible hidden damage.

In spite of very high variation of the major pollutants content in the moss and humus samples (as a measure of pollution load) within one class of damage, there is a quite well pronounced gradient between different classes of the ecosystem damage in Russia. The first visual signs of the moss cover damage (the most sensitive component) appears at sites where Ni concentration (major metal component of emission) in the humus equals 35 ppm (median value). The beginning stage of soil erosion coincides with 70 ppm Ni in humus and complete ecosystem disturbance with 1400 ppm.

The other major (Cu, Co) and minor (As, Cd, Pb) pollutants show similar pattern to Ni with low values according to their emission rate. Terrestrial mosses better indicate beginning stage of ecosystem disturbance, especially for elements with the low rate of emission, compared with humus, which is protected by upper moss layer.

In Finland and Norway pollution impact is much less important than in Russia. In these countries the reindeer grazing pressure appears to be the major factor in the degradation of the ecosystem. Due to extra sensitivity of the widespread tundra ecosystem and extremely high reindeer population, the damage in Norway is even more extensive than in Russia.

Seasonal variations of fluoride content of water in groundwater wells

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The fluoride content of groundwater is affected by factors such as availability and solubility of fluoride containing minerals, porosity of the rocks or soil through which the water passes, temperature, pH and also the presence or absence of other elements with which the fluoride may complex. Some variation in the concentration of fluoride in the individual water sources is, consequently, expected. In practice, however, most surveys on the fluoride content of drinking water are based on single-sample measurements. As relatively small variations in the fluoride content of drinking water may critically influence the mineralisation of human teeth; knowledge of the «fluoride-profiles» of relevant sources is therefore needed. The aim of the present study was to investigate seasonal variations in the concentration of fluoride in water samples from groundwater wells in the county of Hordaland, Norway, and assess possible causative factors which might be helpful in predicting these variations.

Clusters of wells were chosen from areas in Hordaland where the groundwater were known to contain high- and low fluoride levels. Water samples from 42 deep wells were obtained once a month for a period of one year (1995). The samples were taken directly from the wells or from the cold water taps after letting the water run for at least 5 minutes. Samples were analyzed for fluoride and pH by the use of a fluoride specific electrode and, respectively, a pH electrode. Technical information, meteorological- and geological data concerning each well were obtained. The data were coded, computerized and analyzed. Analysis of variance was used when comparing the nominal variable groups. Correlation analysis was carried out between interval scale variables using the Spearman correlation coefficient. Error analysis was performed on 150 duplicate measurements. The paired *t*-test did not reveal any bias between these two series ($p = 0.36$). The method error was evaluated by Dalberg's statistics, and showed acceptable reproducibility ($S_e = 0.034$).

Water from wells drilled in granite and amphibolitic greenstone with pegmatite dikes was found to contain significantly more fluoride than water samples from wells in other groups of bedrock (gneiss, granitic gneiss, foliated gneiss, quartzite and undifferentiated rock types). As compared to low-F water, samples from high-F wells showed significantly higher seasonal variations in the fluoride content. A positive correlation was found between the dergree of seasonal variations in water fluoride and 1) number of major fractures, 2) lithological boundaries. Negative correlations were found between F-variation and 1) size of precipitation area, 2) age of well. The data showed that the fluoride concentration in the wells was diluted after precipitation, with a delay up to 3 months. It seems to be a relation between the number of main fractures in the bedrock and the time lag.

The results show great seasonal variations in the fluoride content of groundwater wells. Predictors for these variations may be bedrock, number of major fractures, lithological boundaries, age of well and size of precipitation area. Information about seasonal changes is of importance for health workers. Individual counseling concerning supplementation- or reduction of daily fluoride intake should be based on solid knowledge on the fluoride content of the drinking water. In areas where groundwater is used, more than one analysis should be performed.

Laterite, a possible medium for water treatment in high-fluoride areas in developing countries.

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Fluoride has revolutionised oral health care in the industrialised world. Excessive intake of F, however, may create health problems such as dental and skeletal fluorosis. Dental fluorosis (DF) is indicative of too high fluoride intake during the period of enamel mineralisation (first decade of life), while skeletal fluorosis (SF), which is found especially in elderly persons, is due to high fluoride intake over a prolonged period of time. DF and SF are endemic in areas such as the East African Rift Valley. Harmful effects of fluoride intake in humans are normally linked to elevated F-content of drinking water. As high-F groundwater may be the only available water source, in these arid and semi-arid areas; simple, low-cost and low-tech methods for defluoridation of drinking water are urgently needed. Various methods have been suggested. The present study was made to assess the fluoride binding effect of lateric clay.

Material and methods. Laterite, which is a red, ferruginous soil formed in tropical regions, was collected in Adamoua, Northern Cameroon. The chemical composition of the laterite was assessed by electron spectroscopy (EDAX). Soil samples of 50 grams were prepared after, resp., bench drying, «sterilising» at 100°C, or firing at 250, 500 or 1.000°C for three hours. To each soil sample was added 500 ml water, prepared by mixing NaF into de-ionised water to a final concentration of 8.7 ppm F, or taken directly from a high-F natural groundwater well (7.7 ppm F). Water/soil samples were kept in closely lidded plastic containers. Double set of samples were prepared. One set was agitated (100/min.), the other was left without agitation. To challenge the laterite's *capacity* for fluoride removal, a special NaF solution - with 120 ppm F - was prepared. From each container 5 ml water samples were taken at 1h, 2h, 4h, 8h, 24 h, 5 d and 3w. $|F^-|$ was assessed by the use of a fluoride selective electrode (Orion 9609 BN) connected to an ion analysing unit (Orion model 920A).

Findings. The laterite contained fairly equal amounts of Si, Al and Fe, with minor contents of Ti, K, Ca, Mn etc.. Untreated laterite tended to soil the water, but the turbidity decreased with increasing firing temperatures. Rapid reduction in the F^-concentration was seen in all the solutions. At best $|F^-|$ was reduced by 70% in 2 h. Agitation significantly speeded up the fluoride removal during the first few hours. Combined with agitation, «firing» of clays up to 500°C *increased* the F-binding, while firing at 1.000°C significantly *reduced* the F-binding effect of laterite. After 24 h the average fluoride reduction in groundwater samples was 83% (range 63-95%). In the NaF solutions, the F removal was slightly better, with an average of 87% (range 69-98.6%). Excluding the samples fired at 1000°C, 50 g laterite in 500 ml solutions in all cases reduced the fluoride content from 7.7 (or 8.6) ppm F to less than 0.25 ppm F in one week. In the high-F solution, fluoride reduction was from 120 ppm to less than 10 ppm during the same period of time, which indicates a F-binding capacity > 1g F/kg laterite.

Drinking water in the East African Rift area rarely contains more than 10 ppm F. According to our findings, exposure to laterite (w/v 1/10) may reduce the fluoride content of these waters from *toxic* to *acceptable* levels (≈ 0.5 ppm F) in less than 24 h. The chemical reaction behind the fluoride removal is not known in detail. The taste of the water remains good after exposure to the laterite; total analysis of laterite-treated drinking water should, however, be performed before the method is recommended for practical use.

The use of Risk Assessment in Contaminated Land Investigation and Remediation.

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Practical approaches to dealing with contaminated land are becoming increasingly important as this issue moves further up the environmental agenda. Such approaches are desireable for both regulators and industry, the former having (in many countries) undertaken comprehensive land contamination surveys, while the latter are faced with uncertain, and potentially large, liabilities.

The aim of this talk is to describe a practical approach to dealing with contaminated land - namely risk assessment - which is gaining widespread use and support in Europe and around the world. The talk will describe the principles of risk assessment as they apply to contaminated land along with the broader concepts associated with Risk-Based Corrective Action (RBCA).

Risk assessment in relation to contaminated land can best be described as:

> "A scientific evaluation of the potential for adverse effects to occur, based on factual information about a site, scientific theories concerning the environmental behaviour and toxicity of the contaminants and assumptions made in the absence of knowledge or data".

Risk assessment forms a framework within which the full weight of scientific and site-specific knowledge can be brought to bear on the question of whether or not to clean-up a site and, if so, how best this should be achieved.

Fundamental to the process of risk assessment is the identification and understanding of source-pathway-target relationships. These relationships link detected chemical levels to the entities they may harm.Their existence at a site is dependant on the nature of contamination, the site's characteristics (land-use, hydrogeology, soil type, etc.) and the local environmental setting. All three components must exist for there to be an environmental or human health risk.

While the potential existence of source-pathway-target relationships can be identified qualitatively, their significance can only be established using quantitative risk assessment. Such an assessment makes use of chemical data and migration models and "tolerable dose" or other criteria that relate to the possibility of harm occurring. Human carcinogenic and non-carcinogenic effects may be treated differently, the former with a "stochastic" approach and the latter by a simple pass/fail approach. Targets can be human beings, ecological species, water courses or even buildings.

Models for quantifying source-pathway-target relationships are widely available in the form of computer software, and cover a range of complexity, user-friendliness and data requirements.

Within a risk assessment it is standard practice to make "worst case" assumptions in the absence of data/knowledge, in line with the "precautionary principle". Where a risk is identified as significant, the options for control can include, via the assessment framework, removal of the source, pathway or receptor. This can give rise to innovative, cost-effective solutions which go beyond the simple excavation and removal of soil or groundwater.

A recent development in the use of risk assessment for contaminated land is the RBCA approach outlined by the American Society for Testing and Materials (ASTM) and CONCAWE (the oil companies European organisation for environment, health and safety). This approach links risk assessment with data collection and remediation and recognises that different levels of complexity are often required to make an appropriate risk-based decision. For example, simple, worst-case assemptions and models may be suitable for concluding when there isn't a problem but, should be used with caution for saying that there is. Similarly, generic criteria based on worst-case assemptions (such as Dutch Intervention Values) are often set to be protective of the most sensitive sites such that few, if any, real sites need to be so clean.

The use of site-specific risk assessment as a practical framework for addressing contaminated land is necessary and desirable in preference to the adoption of background levels or generic criteria as the basis for clean-up decissions. It fits with the goals of "sustainable development" and incorporates the "precautionary principle", where appropriate. It also allows money to be spent on the issues that really matter, providing the most cost-effective protection of human health and the environment.

Assessing Soil and Groundwater Contamination at Former Soviet Military Bases in Lithuania

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421 military units were installed at 275 sites in Lithuania during the 50 years of Soviet occupation. They had an important influence on the environment of the country, as many of the sites were contaminated by oil products, organic materials and chemicals. After the withdrawal of Russian army it was necessary to evaluate urgently the degree of military pollution in order to assess a possibility to use the sites for defence and civil purposes. An appropriate methodology was necessary for the assessment of regional military contamination.

The international team consisting of scientists from the Geological Survey of Lithuania, Geological Survey of Norway, Canadian Department of National Defence and Norwegian Defence Research Establishment were awarded the NATO Scientific Affairs Division Grant for the development of methodology for investigations of soil/groundwater contamination at former military sites in Lithuania.

As an initial assessment, data from all previous studies carried out by private consultancies and government institutions were collated and summarized. Existing geological and hydrogeological information was also examined. A database "Waste" was created by the Lithuanian and Norwegian scientists as a result of this project. Further data collection on military and civil contamination is continued by the Geological Survey of Lithuania and some consultancy companies (e.g. Hydrogeological Company "Grota").

A wide set of field methods has been used for investiagtions of military pollution. It can be concluded that no universal methodology for assessment of environmental contamination can be recommended but that a combination of methods has to be applied. Drilling, soil/groundwater sampling and sample analyses are internationaly recognized and therefore recommended field investigation technologies. Geophysical and VOC detection equipment provide important additional data.

Regional assessment of soil/groundwater contamination was not an easy task as no similar references exist and environmental data was not sufficient. Therefore a lot of extrapolation was used. The figures showing contaminant migration might be not very accurate. They evident however the level of military pollution and that much wider environmental assessment is needed for the precise calculations of damage done by military activity. With appearance of more detailed information these figures will be corrected. But some tentative figures obtained and methodology used for the evaluation of military pollution could be used in other NATO and Cooperative countries.

The collaboration project between Lithuania, Canada and Norway has been very useful for all involved. Friendly contacts were established between the scientists from the two NATO and one Cooperation partner country. These links are not only intercontinental but also interinstitutional as geophysisists and hydrogeologists were working together with the scientists from Defence Departments and Universities. Cooperation enlarged scientific and social knowledge about the countries involved.

Evaluation of Water Protection in Complex Karst Source Structures on the Basis of their Vulnerability and Pollution Risk

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Research into the sensitiveness and into the risk of pollution of an aquifer structure provides a firm basis on which a consistent protection policy can be built up. In laws treating water economy which lack respective developed instruments for an integrated management of land and water resources, such an approach is considered very effective for solving the problem of the protection of fissured aquifers where the use of earth and water potentials is usually less complex than with groundwater in the river alluvions.

The concept is illustrated by an example related to the problem of protection of the karst source Sanica, located in Inner Dinaric Karst, in the Bosnian Karst zone. The source is captured for water-supply of Bosanski Petrovac Commune.

The catchment area of the Sanica source (320 km^2) was the subject of detailed and complex hydrogeological and hydrological investigations which provided the basic data of the system morphology and hydrodynamical characteristics of the preferential pathways. During 1991 there was carried out a new project where the main goal was to acquire the basic data of the risk of contamination, so that, in the next step, the pollution attenuation might be defined and simulated. The type of information generated by these research projects, presented as a matrix of aquifer vulnerability and risk of contamination, provided sound support for the Regional Water Protection Plan.

An Authority Based Risk Assessment System for Contaminated Sites

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Background

SFT prepared, with assistance from JORDFORSK, Østlandskonsult (Interkonsult) and NIVA, a preliminary manual for handling contaminated sites (SFT,1995). This manual is presently under revision and is to be completed by the end of 1998.

Aquateam and NGI submitted a proposal to The Norwegian Research Council's GRUF program in 1995 to develop an "Environmental Risk Analysis for Contaminated Sites, Especially Adapted to Norwegian Needs." The idea behind the initiation of this project was to use the experiences gained through similar work performed for offshore chemicals to evaluate the possibilities to develop a risk assessment system for contaminated sites. The project was funded under the premisses that it be coordinated with SFT.

Several meetings were conducted early in 1996, and the programme was significantly altered to include SFT's needs to revise the existing manual (SFT, 1995). In parallel with the Norwegian initiative, SFT received an invitation to represent Norway and participate in the newly established EU programme, CARACAS (Concerted Action Risk Assessment for Contaminated Sites). Harald Solberg became the Norwegian SFT delegate and Eilen Arctander Vik became the expert representative in CARACAS. The first meeting was held in Brussels in April 1996. The result of this meeting was that CARACAS would work towards the harmonization of European Guidelines for contaminated sites. A CARACAS core group meeting was arranged in June this year. After this meeting the SFT/GRUF project group decided to coordinate the Norwegian risk assessment project with CARACAS. The Norwegian risk assessment project has now become a three year program in order to be harmonized with the EU work.

Norwegian System

The existing Norwegian policy includes a risk assessment method using a three tiered approach which is carried out site by site, including the use of expert judgement. The environmental risk analysis is based upon the Norwegian Standard for risk analysis (Norwegian Standard, 1996).

The Norwegian Risk Assessment Project

SFT's main objective in this project is to receive recommendations for the revision of their exsisting guidelines.

The subobjectives of this project are to:

- Improve the basic documentation for decisions
- Improve the investigation quality
- Harmonize with the coming EU Guidelines for contaminated sites, and
- Identify further needs for research and development

Additional subobjectives are to:

- Improve national knowledge of environmental risk assessment of contaminated sites
- Encourage cooperation between regulators, problem owners and problem solvers in order to create harmonized soil quality criteria
- Promote development of internationally recognized expertise increasing the possibilities for exporting consultancy and laboratory services related to risk assessment of contaminated sites
- Contribute to the development of national competence
- Promote internationally exchange of information
- Contribute to the establishment of relevant national R & D, and
- Employ a site specific case for evaluation/verification of the system

The project will be conducted during 1996-1998 and has been divided into 7 tasks identical with CARACAS' topic groups, see Figure 1.

For each topic a technical background documentation will be prepared, containing information on:

- National & international status
- Regulations/frameworks and degree of implementation, and
- R & D needs and status

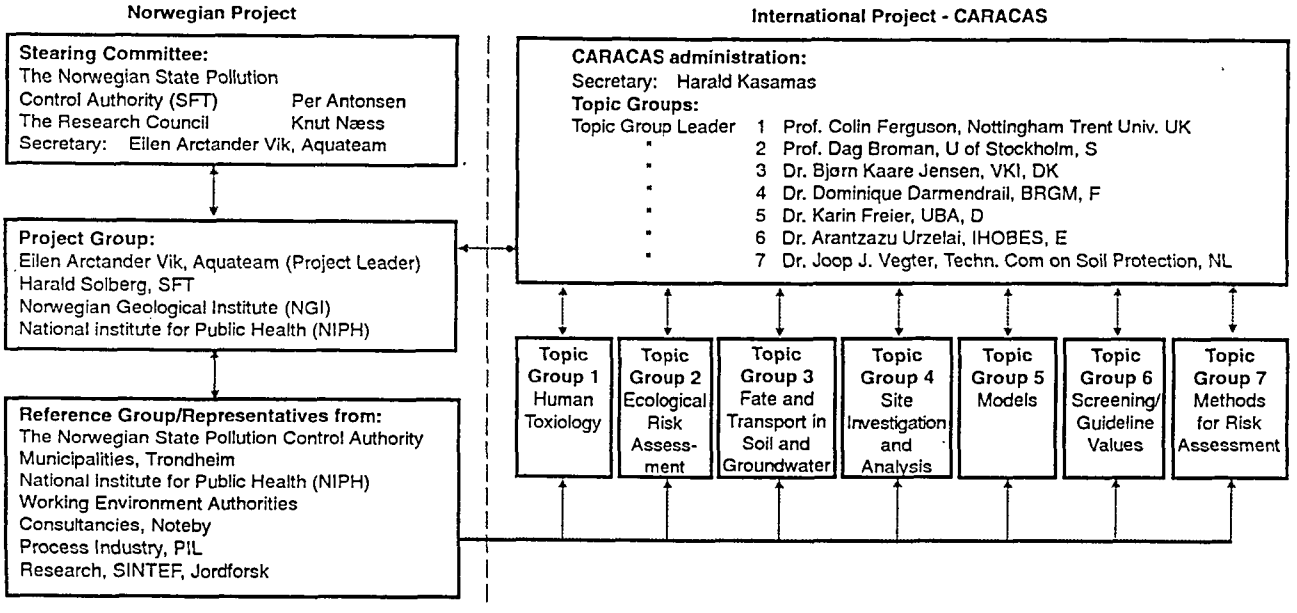

Figure 1. Organization of the national risk assessment project and the relationship to the CARACAS project.

Investigations and Decisions Concerning Polluted Soils: Current Shortcomings

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The importance of well established investigations of polluted soils has been underestimated for a long time. There has been put a lot of effort into improving the quality of the chemical analyses, and into certification of laboratories. However, there is no Norwegian requirement concerning sampling strategies. A sampling strategy includes the sampling method, sampling medium, number of samples and sample placement according to the aim of the investigation. An example from a site in Trondheim shows that different conclusions can be drawn, depending on the sampling strategy used. Duplicate samples collected 1 m apart showed relatively high concentration variability. Thus, collecting only few samples in an initial survey may be insufficient for decisions regarding the need of further investigations or verification of the hypothesis "not contaminated"

Apart from the sampling strategy, the various ways the contamination is evaluated may give different decisions. Of thirteen Norwegian reports from 1989-1994, nine evaluated the soil contamination by comparison with Dutch ABC-values. Three did not give any conclusions or recommendations, while one evaluated the risks connected to land use and the recipient. Since then, the Norwegian State Pollution Control Authorities (SFT) have published tentative Norwegian guidelines for the concentrations of certain pollutants. Several other countries have also issued guidelines, while the Dutch have revised theirs (mostly lowered). The various sets of guidelines indicate that there is no known level where adverse effects occur. SFT has concluded that a risk analysis should be performed for each site where the concentrations exceed the Norwegian guidelines. The risk analysis should be based on the pollution source, dispersion and effects. In order to perform such a risk analysis, representative data and competent decision makers are necessary. Presently, SFT does not have the capacity to evaluate all cases of polluted soils. Thus, the Regional Environmental Administrator, municipalities, and sometimes the problem owner (oil-pollution) will make the decision on whether and which abatements are needed. These instances are rarely capable of evaluating the representativity of the investigation. Thus, they may not evaluate the risks connected to the contamination. As a first step to improve the total quality of the decision making, we suggest that SFT specify requirements for the sampling strategy concerning polluted soils. Such requirements may ensure that risk evaluation is based on a representative investigation.

Heavy Metals in the Soils at Industry-contaminated Sites: Selective Examples from Sweden

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While the present day industries are generally concerned not to contaminate the surroundings, large number of old as well as abandoned industrial sites have been identified as hazardous to the environment. Among different contaminants, heavy metals could be introduced to the environment by uncontrolled human activities around industrial sites which may increase the metal concentrations in the soils manifold, compared to background level. Naturvårdsverket (NV) (1996 a,b) have recently proposed a set of guideline values for concentration of different metals in the soils, depending on their ecotoxicological behavior as well as the nature of future land use. All these developments have triggered our interest to investigate the soils from some industry-contaminated sites in different parts of Sweden, where metals like Pb, Cu, Cr, Zn, Hg and/or As are present in high concentrations as well as to work out the possible means of effective remediation of these contaminated sites.

The present contribution aims to compare the geochemical characteristics of the metal contaminated soils around three old industrial sites, involving: i) a former ammunition industry at *Zakrisdal*, Karlstad in Central Sweden, ii) site of a wood preservation unit at *Fnasbacken*, Ljungby Municipality in Southern Sweden and iii) *Hugelsta* shooting field and waste ammunition dump of Carl-Gustaf Bofors AB at Eskilstuna in South-Central Sweden. The laboratory investigations included grain size analyses, determination of pH, Eh and metal analyses on 1:1 HNO_3 soil extracts (Andersson *et al.* 1991), using the Jobin Yvon (JY24) inductively coupled plasma spectrophotometer (ICP).

The former ammunition industry of Bofors Weapon Systems at *Zakrisdal*, Karlstad, had remained in operation between 1940-1970 for the manufacture of percussion caps/detonators where Hg(II)-fulminate and $Pb(N_3)_2$ (lead azide) had been extensively used as explosive chemicals. Prolonged use of these chemicals, series of test explosions and eventual repositories of the waste materials have led to significant contamination of the soils by heavy metals such as such as Pb, Zn, Cu, Cr and Hg in the area. *Fnasbacken*, adjoining lake Bolmen at Ljungby Municipality, Kronobergs County is the other investigated area where wood preservation had been in operation for several years and resulted in contamination of the soils as well as wooden chips (bark) by Cu as well as to some extent As. Since Bolmen serves as the largest source of water in the region, the use of soluble inorganic preservative chemicals such as copper sulfate as well as possibly chromated copper arsenate (CCA) in the near vicinity has caused a potential threat to the water quality of the lake. The soils around the *Hugelsta* shooting field as well as the waste ammunition dumps of the ammunition industry of C-G Bofors, located at Eskilstuna in Södermanland County is the third area, where soils have been investigated for Pb as the major contaminant.

The contaminated area around the old ammunition industry at *Zakrisdal* comprises two fire places, one of which is located near to lake Vänern and the other more inland, temporary waste ammunition dump on an asphalt surface as well as a firing range in the western part of the area. *Fire place 1* has a total area of ca 500 m^2, while *Fire place 2* is fenced and cover an area of 300 m^2. The depth of contamination at both these places have been envisaged to be about 50 cm. The *firing range* with an area of about 40 m^2 is estimated to have been contaminated upto a depth of 1 m. Representative samples

were collected from different depths, partly from the surface (0-10 cm) and also at depths of about 50 cm spread all over the area. Analytical results on 0-2 mm fraction of the mineral soils reveal Pb content in the range of 42-24329 mg/kg, Zn (20-23695 mg/kg), Cu (6-35128 mg/kg), Cr (4-901 mg/kg) and Hg (16-197 mg/kg). The organic layer in the vicinity of *Fireplace 1* indicated significant enrichment in the metal contents.

The contaminated area around *Fnasbacken* in Bolmen, Ljungby Municipality appears to be a sterile zone devoid of any marked vegetation (KM AB, 1983). The selected samples from the area, represented the wooden chips (bark) from the contaminated site in the vicinity of lake Bolmen and the metal contaminated strand sediments. Analyses of the 0-2 mm fraction of the wooden chip (bark material) revealed Cu and As contents of 6134 and 66 mg/kg respectively, while the strand sediments indicated Cu content between 1414-5057 mg/kg and As contents of 47-55 mg/kg (Bhattacharya and Jacks, 1995).

The site of *Hugelsta* shooting field located south-west of Eskilstuna covers an area of nearly 900,000 m^2, comprising 6 sub-areas with Pb contaminated shooting sand and ammunition waste materials. The area, planned to be developed as an industrial area (Lundgren, 1995), therefore an investigation on the possible means of remediation had been initiated by Bofors AB. The soil samples from the Hugelsta shooting field and the waste ammunition dump of C-G Bofors were analyzed for total Pb which indicated an average concentration in the range of 16344 mg/kg in the 0-1 mm fraction of the composite sample.

All these case studies clearly indicate that the sites around the former industrial activities are contaminated by metals manifold of the desired levels of background as well as the guideline values proposed by the NV. Necessary remedial measures need to be taken in these areas for any future use of these contaminated sites. A series of remediation experiments has been carried out on the different contaminated soil materials using different organic (oxalate) as well as other inorganic (chloride) extractants under different pH conditions. The details of the extraction technique and Effectivity of different extractants at various Eh-pH conditions have been evaluated for the individual contaminated soils and discussed in Bhattacharya *et al.* (1996). Contents of removable As and Cu from the contaminated soil materials through sequential leaching experiments have indicated an effective recovery of about 96-98% of the contaminant metals in respective areas. Results of a sequential leaching experiment on the composite soil sample from *Hugelsta* shooting field revealed removal of around 72% of the total Pb at the first step, while removal of about 98% Cu has been achieved from the wooden chips (bark) material from *Fnasbacken* in Ljungby Municipality using oxalate as an extraction medium (Bhattacharya and Jacks, 1995). The results also reflect distinct variation in the recovery of the contaminant metals based on the soil pH conditions. The metal leachates have been passed through an ion exchange column in order to isolate the contaminant metal species, which is regenerated by a suitable media suitable for further electrolytic separation of the concerned metals.

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Assessing Metal Mobility: Is it Important?

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Unlike most other western (industrial) countries where contaminated groundwater is the principle concern, Norway's waste site problem is mainly associated with pollutants leaching to surface water, both fresh- and saltwater. Half of the 500 most critical sites border the sea, 35% neighbour rivers and streams, 10% are along lakes, and only 5 % threaten groundwater. This waste site distribution reflects the historical industrialisation of Norway: smelters, factories and mills developed close to freshwater hydroelectric power sources and saltwater shipping centers.

This presentation focuses on the two main types of Norwegian waste sites. The first example describes measurements of soil solution samplers in a sea shore waste site that show that sea water intrusion influences pollutant characteristics and macrochemistry behavior. The second example describes assessing mobilisation of wood impregnation salts (copper, chromium and arsenic) at a site adjacent a river. Soil solution collectors were installed at various depths at the site, and measured during different hydrological conditions. Concentrations varied considerably under episodes. Hydrological changes revealed elevated levels of dissolved salts, which agree with the factorial experiment. Soil chemical processes -- not total solid-phase concentrations -- dominated the mobilisation and subsequent leaching. Soil solutions were tested for changes in toxicity by chemical analysis and degree of inhibition of luminescence in Vibrio fisheri (Microtox). Changes in toxicity corresponded to changes in soil solution.

Importance of Chemical Speciation in Risk Evaluation of Heavy Metal Toxicity

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Human intake of heavy metals may occur directly from air, water or soil, or - more likely - through the foodchain. In both cases the actual intake depends quite critically on the physico-chemical form (speciation) of the metals in the source environment. In particular the speciation of the elements in soil determines their mobility and hence their root uptake in plants used as food crops or being eaten by animals constituting part of the human diet. The fractions of a metal in soil which are most readily available for plant uptake are truly dissolved low-molecular species in the soil solution and the exchangeable fraction of metal on soil particle surfaces. The part of the metal more strongly fixed by chemical bonds or incorporated in mineral lattices, which may often constitute the main part of a metal in unpolluted soils, has a very low plant availability.

Many procedures have been proposed over the years to estimate the plant available fraction of key heavy metals in agricultural soils. In recent years a number of sequential extraction schemes have been developed to distinguish between different binding forms of metals in agricultural as well as more undisturbed soils. In the talk examples from the use of sequential extractions to study different metals in soils will be given. It is argued that the readily mobilized fraction of a metal rather than the total concentration should form basis for risk assessments in soil.

Bioavailability of soil contaminants as a determinant of toxicity

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Contaminated sites may endanger the environment as well as the health and general well-being of people in the vicinity. The diversity of the sites with regard to hydrogeological factors, chemicals present, intended future land use, legal issues concerning ownership and responsibility etc. make general risk assessments and remediation strategies complex.

The Institute of Environmental Medicine has been engaged in risk assessment of contaminated sites for some years, starting with the assessment of an old gas works site in Stockholm. During this work, it was found that the soil lead levels in the inner Stockholm area might lead to considerable childhood lead exposure. Furthermore, even higher levels of lead were found in two mining communities in central Sweden. To assess the possible health risk to children from environmental lead exposure a childhood blood-lead screening program was initiated. It was found that the blood-lead levels in small children were similar (around 30 ug/l) in all locations and well below the level of concern identified by the CDC (100 ug/l). However, a general increase in blood-lead levels during the summer months was seen, indicating environmental exposure during this time, probably due to more frequent soil contact.

In another project, arsenic-contaminated soil samples from three wood-treatment plants were tested for acute toxicity in animal experiments. The toxicity of soil-arsenic in one of the samples was similar to that of pure sodium arsenate. The toxicity of soil-arsenic did not correlate with total arsenic concentration in the samples.

These examples illustrate the need for information on bioavailability of soil contaminants in the risk assessment process.

Nickel and lead exposure from Trondheim soils: Health effects?

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Geochemical mapping of surface soils (0-2 cm) in the city of Trondheim has revealed that the acid soluble Ni content exceeds the Norwegian guideline for for what is considered "safe soils" (30 ppm) over most of the city. For Pb, the guideline (50 ppm) is exceeded in the central part of the city and near an ore shipment harbour. The Ni is mainly originating from the local bedrock (greenstone, while traffic exhaust have caused the elevated Pb concentrations. This study seeks to evaluate the risks for childrens health, connected to Ni and Pb exposure from Trondheim soils. A fault tree has been designed to visualise the various exposure routes for metals. Thus, exposure from soil may be compared with other sources. Preliminary results show that for Ni, exposure from soil constitute an insignificant addition to the average exposure from food and appliances. An exception may be road dust produced by studded tyres in winter. This dust contains about 40 ppm Ni but the chemical form and availability for lung uptake is unknown. For Pb, exposure from soil may significantly contribute to the total exposure of children (1-3 years of age) depending on the location of their playground and their soil ingestion rate. American statistics for soil ingestion among children show that 50% ingest 16-55 mg/day, while 10% ingest more than 200 mg/day. In extreme cases, children ingest up to 8000 mg/day. The distribution of soil ingestion and the median soil-Pb concentrations in the various parts of the city shows that 10% of the children in the city centre get 30-40% of the highest tolerable weekly Pb intake (PTWI) from soil ingestion. For 50% of the children playing near the ore shipment harbour, soil ingestion may give a Pb ingestion of 28-96% of PTWI, while 10% of children in this area get 350% of PTWI this way. PTWI is defined by WHO and FAO in order to ensure that Pb is not accumulated in the body. Accumulation of Pb may lead to various health effects as shown by various epidemiological and toxicological studies. Low dose exposure is mostly connected to neurotoxicological effects, such as hyper activity, distracatbility, ability to follow instructions, dependency and other not well defined effects.

Bio-markers for Environmental Contamination - What Can They Tell Us?

Karl Erik Zachariassen

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Biomarkers have an interesting potential in environmmental monitoring to detect the presence of possibly injurious anthropogenic pollutants at an early stage. The rationale behind their application is that exposed organisms may display sublethal effects at a biochemical or physiological level before clinical or ecological injury is developed.

Xenobiotics may have a variety of sublethal effects in organisms. In order to use such effects as sound biomarkers, it is important to consider the various responses in a functional or physiological context. In this way it should be possible to develop a system with different biomarkers, each providing a clear and specific type of information on pollution status. Environmental monitoring may have at least three different aims:

1. Early warning alarm function, i.e. detection of any type of pollutant at low concentration and at an early stage. Requires biomarkers which can be monitored continuously by the use of on line registration techniques.
2. Evaluation of the degree of toxic stress. Not all changes in biochemical or physiological parameters are relevant at a clinical or ecological level. The evalulation of toxic stress must be based on determination of the status of vital physiological processes or conditions that may be affected by pollutants.
3. Identification of pollutants. Pollutants may give rise to specific changes in biochemical or physiological parameters, which, when known, may be used to identify a pollutant, or at least exclude certain categories of pollutants.

No single parameter is likely to be feasible as a biomarker for all categories of pollutants, and a monitoring program directed towards a variety of pollutant categories requires several biomarkers to serve each of the functions listed above.

Examples of possible biomarkers are:
For on line early detection of pollutants in aquatic environments one may use active biomonitoring with continuous monitoring of oxygen consumption of the applied organisms (i.e. mussels).

Evaluation of toxic stress of pollutants which act as inhibitors of metabolism or ionic pumps may be based on determination of energy rich phosphates, transmenbrane energy gradients of sodium or cellular contents of calcium. As a highly potent toxic agent at cellular level, calcium is an obvious candidate.

Identification of pollutants must be based on a number of parameters, which in combination display a pollutant specific response pattern. Examples of parameters which may have a

potential in this context are the transmembrane distribution of free amino acids, the P450 enzyme system, metal specific metallothioneins and a variety of substrates/products of biochemical processes.

In addition to being used in environmental monitoring, biomarkers may be used to evaluate tolerance/sensitivity to pollutants. Biomarkers that may have a potential in this context are specific detoxification systems such as specific metal binding proteins, specific P450 enzymes and specific glutathion s-transferases.

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Assessment of Bioremediation Results Using Toxicity Tests

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Creosote is a complex mixture of several hundred components. This makes toxicity assessment complicated, due to the lack of knowledge of toxicological data. Data on the synergistic or antagonistic effect of mixtures are almost lacking. PAH is the major part of creosote (85 %). The environmental effects are focused on their carcinogenic properties.

Bioremediation of creosote contaminated soil does not result in complete removal of polyaromatic hydrocarbons (PAH). The residue is practically not further degraded. Degradation products are formed during the process. Of these, few are stable in the soil environment and may degrade faster than the original PAH. But some of the components may be enriched, dependant on environmental conditions The residue's environmental hazard is not completely understood. In the present project mobility and toxicity of residues from creosote bioremediation have been studied.

Toxicity variations was studied during the bioremediation of creosote contaminated soil using microbial test systems. An acute toxicity test developed for direct testing of soil samples (DSTTP), was used. The results were compared to results from an acute toxicity test using water extracts (Microtox ®).

The results of both test systems were in good accordance. In samples of sandy soil a connection between reduced toxicity and PAH concentration was observed. In humus rich soil an increased toxic response was observed after bioremediation. No corresponding increased mobility of PAH was observed. The effect may be a result of the development of toxic metabolites, but also other effects may have influenced the test results. pH, humic acid or high content of Cd/Zn, found in the humus rich soil, were studied using DSTTP. A toxic response was found at low pH (2-4) and high concentrations of Cd/Zn.

Chronic toxicity was measured by a microbiological test (SOS Chromotest). Promising results were obtained when water extracts were used, direct testing on soil samples gave diverging results. Ongoing research focuses on improving this test system for direct testing of soil samples.

Acute and chronic toxicity tests are valuable tools in the evaluation of bioremediation results. They give information which cannot be obtained from chemical analysis, and may be a helpful tool in setting clean up goals, based on soil type.

Comparative Study of Geochemical and Medical Data in Norway

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A method of correlation analysis within a spatially moving window was applied to two sets of epidemiological/geochemical data in Norway, 1)mortality/disability rates of multiple sclerosis (MS) versus atmospheric fallout of Mg and concentrations of Se in overbank sediment, and 2) incidence rates of malignant melanoma of skin (MM) versus concentrations of Ca and K in overbank sediment. It appears that n =17 observation sites within the moving window is a practical compromise between noise in the data at small values of n and a spatial resolution good enough to detect trends in the distribution patterns of the correlation coefficient. For MS versus Mg, MS versus Se and MM versus Ca the correlation coefficients are generally negative and depict systematic distribution patterns with anomalous clusters of sites with good correlation. For MS versus Se the correlation coefficients also form an additional cluster of positive coefficients. Tests with permuted data show that the correlation coefficients for MS versus Mg and for MM versus Ca both are significantly different from zero at $p<0.05$, while those for MS versus Se are less significant. For MM versus K the correlation coefficients are randomly distributed and not significant. The described correlations may be effects of confounders and do not *per se* indicate any causal relationships. However, further research based on these results may well lead to the identification of possible etiological factors.

PLAKATPRESENTASJONER

Liming of Wetlands in the Røynelandsvatn catchment - Hydrological and Hydrochemical Response on a Runoff Event in a Limed Fen

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Wetlands in the Røynelandsvatn catchment in Southern Norway have been limed with finely ground limestone powder at a rate of 20 t ha^{-1} to remediate acid discharge. Two years after liming JORDFORSK investigated hydrology and surface- and soil water chemistry in a selected limed fen during a runoff event.

The catchment of the investigated fen consisted mainly of granitic bedrock with marginal areas with coarse morainic material and peatland in the depressions. The uppermost peatsoil (10-20 cm) of the mire was poorly decomposed with an open structure. Deeper peatsoils were highly decomposed and dense. Hydraulic conductivities at 5-10 and 20-25 cm depths were $2* 10^{-4}$ and $2* 10^{-6}$ m/s.

With increasing inflow from the catchment, water levels rised and increasing mire areas were covered with surface water. At low and moderat discharges surface water was floming over only the eastern edge of the fen. At maximum discharge, water was flowing slowly over the whole fen surface.

During the episodic event concentrations of Ca in inflowing surface water were < 1 mg/l, concentrations of Al were 0.5-0.7 mg/l and pH were in the range 4.2-4.4. The runoff water from the limed fen had elevated concentrations of Ca (6-7.5 mg/l), elevated pH (6.5-6.8) and decreased concentrations of Al (0.2 mg/l) in all phases of the event. Maximum pH occurred at peak discharge.

The limed fen was able to respond to increasing inflow of acid water with increasing deacidification. This can be explained by hydrological activation of increasing areas of limeinfluenced peat surface with increasing inflow of water.

The results underline the importance of patterns of surface hydrology and water flow in the surface layers of mires for planning of wetland liming.

Nasjonalt Markvannsnett, Unsaturated zone data in real time

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Nasjonalt Markvannsprogram (The Unsaturated Zone Monitoring Progam) was initiated in 1989 by several Norwegian institutions. The main goals of this project have been to obtain data as time-series on the change of soil-water content and make these available to research workers. The program is organized as an inter-institutional co-operation between the leading Norwegian institutions in this field and is administrated by the Norwegian Water Resources and Energy Administration (NVE). Today, eight stations are established in selected areas. Data from six of these stations are transmitted in real-time to NVE and stored in a central database. Parameters observed is volumetric water content, tension and temperature at different levels, and groundwater level, soil frost and snow depth. The stations are located close to meteorological stations, and the hydrological conditions of the areas are well described.

A 2-D flow model of the Trandum delta

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This poster illustrates a probable flow profile of the Trandum delta from Transjøen to Sogna, based on the present available field data. A 2-D hydrogeologic model developed by Kevin Tuttle et al.(1994) is being used. This model subdivides the saturated zone into three separate units. The lower unit, which consists of the area between the bedrock surface and just below the delta foreset and bottomset transition zone, has a hydraulic conductivity from 10^{-6} m/s or lower. The intermediate zone lies between the upper portion of the bottomset unit and upper delta slope. The k-value there is estimated to be in the order of 10^{-5} m/s. The upper zone extends to the top of the delta foreset unit, with the highest permeability of approx. 10^{-4} m/s.

Flow profiles are then generated by applying different k-values as mentioned above. Simulation program ASM (Aquifer Simulation Model) is used. It is a numerical groundwater flow and transport model in two spatial dimensions based on a finite difference method.

By comparison of the difference between the observed groundwater table and the simulated one at certain locations, a most probable flow profile can be obtained.

However, this profile and the residence time derived from the simulation has not yet been validated by any tracer experiment. It is therefore not possible to evaluate the accuracy and reliability of the applied parameters. In spite of the uncertainty, this model will still give us some insight into the flow pattern in the area.

Estimation of Hydrostratigraphical Architecture by Indicator Kriging

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This poster presents a case study from the Moreppen research site where indicator kriging is applied on Ground Penetrating Radar signals. The main objectives with this poster are to visualize each step in the indicator kriging procedure and to show 3D plots of data and the final interpolated architecture. This poster has been presented previously at the conference on 'Quantification and modelling of spatial patterns in permeable rocks' 13th-15th March 1995, by the Institute of Mathematics and its Applications, Essex, Great Britain, and at the 'Jens-Olaf Englund Seminar - Protection of groundwater resources against contaminants', 16-18 Sept. 1996.

A tracer study in the unsaturated zone of a heterogeneous formation

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A tracer experiment has been carried out in the unsaturated zone of a highly heterogeneous glaciofluvial sand deposit. Tritiated water was injected at the surface of a lysimeter wall and the transport due to natural water fluxes was followed down to 2.5 m. A comparison of the mobility of chloride relative to tritium revealed a retardation factor of approximately 1.15. Longitudinal and transverse dispersivities were estimated by the method of spatial moments and based on the spatial distribution of solute concentrations at discrete instances of time. The observed flow pattern shows characteristics of random effects due to the pronounced soil physical heterogeneity of the formation, and dispersivity values calculated vary within an order of magnitude. Transverse dispersivity is estimated to a few centimetres, whereas longitudinal dispersivity is found up to one order of magnitude larger. The transverse dispersivity tends to depend on the distance travelled.

Oksygenets skjebne i grunnvannssonen

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In-situ biologiske rensemetoder ved organiske grunnforurensninger har i løpet av 90-tallet fått større anvendelse ved opprensningsaksjoner både nasjonalt og internasjonalt. Prinsippet bak disse metodene er at forurensningene skal brytes ned i grunnen ved hjelp av stedegne mikroorganismer. Tilførsel av oksydanter (f.eks. oksygen) og næringssalter (N og P) kan være fordelaktig for optimalisering av den mikrobiologiske aktiviteten. Det vil normalt være oksygenmangel som er den begrensende faktor for biologisk nedbrytning av forurensningskomponenter i grunnen. Dette er ofte tilfelle der forurensningene foreligger i mettet sone hvor oksygentilførselen normalt er svært begrenset. Ulike metoder for å tilføre oksygen til grunnvannsonen har blitt utprøvd. Luftinjeksjon direkte i grunnvannet gjennom injeksjonsbrønner (eng. air sparging) er en metode som har blitt anvendt i økende omfang de siste 3-4 år.

Et omfattende undersøkelsesprogram for kartlegging av anvendelsesmuligheten av luftinjeksjon har blitt utført ved Moreppen hydrogeologiske forskningsstasjon i regi av Faneprosjekt Gardermoen. Som et ledd i denne forskningen har det blitt gjennomført forsøk for å undersøke oksygenets omsetning og bestandighet i et område av Gardermoakviferen som ikke er påvirket av organiske forurensninger. Bakgrunnen for disse undersøkelsene bygger på rapporter fra laboratorie- og feltforsøk som viser at i første rekke akvifersedimenter, men også grunnvann kan ha et betydelig oksydasjonspotensial ved varierende red-oks forhold (Barcelona et al., Korom et al.). Dette kan ha avgjørende betydning i opprensningsaksjoner der oksygenkonsentrasjonen i grunnvannet blir forsøkt endret. Forbrukes det tilførte oksygenet av akvifersedimentene og/eller grunnvannet gjennom oksydasjonsprosesser vil tilført oksygen til vannfasen bli bundet opp i oksyder. Oksygenet vil derfor ikke være direkte tilgjengelig for mikroorganismer for nedbrytning av organiske forurensningskomponenter.

De geokjemiske forholdene i grunnvannet ved Moreppen egnet seg godt til å gjennomføre studier av oksygenstabilitet i grunnvannssonen. Akviferen har i dette området en klar sonering i grunnvannets oksygeninnhold. De øverste 2.5-3 meter av akviferen har nær metningskonsentrasjon (O_2 ~ 10 mg/l) mens oksygenkonsentrasjonen under dette nivå ligger betydelig lavere (O_2 ~ 1 mg/l). Forsøket ble gjennomført ved at grunnvann fra den øvre enheten med høyt oksygeninnhold ble pumpet opp og tilsatt NaBr (500 mg/l) før det ble injisert ned i den undre enheten med lavt oksygeninnhold v.h.a. flernivåprøvetakere satt ned i akviferen.
Det ble i løpet av det påfølgende døgnet tatt ut prøver til oksygenanalyse fra det injiserte grunnvannet i den undre enheten. Fortynning av tilført grunnvann ble kontrollert ved måling av ledningsevne og NaBr konsentrasjon. Likende forsøke ble gjentatt flere steder innenfor et begrenset område av akviferen. Forsøkene viste at oksygenkonsentrasjonen i det tilførte grunnvannet (O_2 ~ 10 mg/l) i løpet av et døgn sank ned mot bakgrunnsverdien for oksygen i den undre enheten av akviferen (O_2 ~ 1-2 mg/l). Injeksjonsforsøket ble repetert i noen av de samme injeksjonspunktene og oksygenreduksjonen fulgte samme forløp som ved tidligere forsøk.

samme injeksjonspunktene og oksygenreduksjonen fulgte samme forløp som ved tidligere forsøk.

Resultatene fra disse forsøkene viser at sedimentene i den dypereliggende delen av akviferen ved Moreppen har et betydelig reduksjonspotensiale. Det er lite sannsynlig at grunnvannet i dette området har reduksjonspotensiale av betydning da innholdet av løste reduserte komponenter (Fe^{2+} og Mn^{4+}) er svært lavt. Kun små mengder av oksygenet kan være forbrukt av mikroorganismer da antallet av disse og tilgjengeligheten på organisk karbon i akviferen er svært lavt..

Konsekvensene av at disse observasjonene er at den forventete effekt av en eventuell oksygentilførsel til grunnvannet ved f.eks. luftinjeksjon reduseres betraktelig. Mulighetene til å stimulere den mikrobiologiske aktiviteten vil følgelig også reduseres og nedbrytningen av organiske forurensningskomponenter i denne sonen av grunnvannsmagasinet forblir lav. Akviferen er derfor svært sårbar overfor forurensninger som måtte trenge igjennom den øverste oksygenrike sonen og ned i den underliggende oksygenfattige sonen.

Injeksjonsforløpet ble også reversert ved at grunnvann med lavt O_2-innhold ($O_2 \sim 1$ mg/l) ble injisert i den øvre enheten med høyt O_2-innhold. Disse forsøkene ga det overraskende resultat at oksygenkonsentrasjonen i det tilførte grunnvann økte opp mot bakgrunnsverdien i den øvre enheten av akviferen ($O_2 \sim 10$ mg/l). Disse forsøkene ble også repetert og oksygenøkningen fulgte samme forløp som ved tidligere forsøk. Årsaken til oksygenøkningen må forklares ved at det finnes gassinneslutninger i akvifersedimentene som er i likevekt med grunnvannet med høyt oksygeninnhold. Likevektforholdene vil endres når grunnvann med lavt O_2-innhold introduseres i den øvre sonen av akviferen slik at oksygen i gassinneslutningene vil diffundere ut i vannfasen og oksygeninnholdet vil øke inntil ny likevekt er oppnådd. Basert på disse målingene ser det ut til at den øvre sonene har et buffermagasin av oksygen lagret i disse gassinneslutninger som vil kunne bli mobilisert ved endringer i grunnvannets oksygeninnhold. Ved nedtrenging av organiske forurensninger til grunnvannssonen, med påfølgende mikrobiologisk forbruk av oksygen, kan gassinneslutninger være med på å opprettholde oksiske forhold over en lengre periode. Akviferens nedbrytningskapasitet overfor organiske forurensninger vil følgelig være større enn beregninger basert på tilgjengelig oksygen i vannfasen. Disse målingene viser at den øvre enheten av akviferen ved Moreppen har et større aerobt nedbrytningspotensialet overfor organiske forurensninger og følgelig mindre sårbart overfor disse forurensningene. Overbelastes imidlertid dette bufferpotensialet vil forurensningene lett kunne trenge ned i den sårbare undre oksygenfattige enheten av akviferen.

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Korom S.F., M.J. McFarland og R.C. Sims. Reduced Sediments: A Factor in the Design of Subsurface Oxidant Delivery Systems. *Groundwater Monitoring and Remediation Winter 1996*: 100-105

The State of Ecosystems in the Central Barents Region: the Database of the Published Literature

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Increasing awareness of the environmental situation in the Barents region has resulted in an increasing number of investigations carried out during the last decades. The areas affected by emissions from the major Russian smelters in Nickel and Monchegorsk have received special attention. However, both linguistic and cultural differences between scientists from different countries hampered creation of the holistic picture. The Kola ecogeochemistry project (see: http://www.ngu.no/Kola/) found it necessary to conduct a background search of existing relevant literature covering the continental part of its mapping area within the Barents region.

A bibliographic database with > 1,200 references concerning a range of environmental aspects covering Finnmark (N Norway), Lapland (N Finland) and the Kola Peninsula (NW Russia) is now built up. The complete reference list of this database is now available on the World Wide Web: **http://www.ngu.no/Kola/bibdb.html**. When creating the database, we paid special attention to data sources which are not widely available due to either presentation form (abstracts, reports, etc.) or to the use of national languages. Presently, the database includes translated references of > 450 Russian publications, 130 of which (containing data on heavy metals) are provided with detailed abstracts. These references indicated that a lot of important information has been collected by Russian scientists starting from late 1960s. Much redundant work has been done and is being done, probably due to linguistic and cultural differences between the scientists and decision- makers interfering in this multilateral area.

The database demonstrated that environmental aspects which have been studied most thoroughly covers the impact of emissions on forest soils, including soil microbial community, and on vitality of pine stands and Scots pine itself. The chemical portion of the investigations focuses mainly on the major pollutants, Ni and Cu. Elevated levels of As, Co, Cu, Fe, Ni, S (SO2), and V seem to be fairly well documented around the major industrial sites in the area, but many elements which may cause negative environmental effects, like Ag, Bi, F, Sn, Tl and the noble metals, are only sparsely studied. Published data on regional distribution of radionuclides are definitely insufficient, keeping in mind their environmental impact, and almost nothing is known about organic pollutants from this areas.

The fact that a lot of new collaborative environmental projects will be carried out across the borders within the Barents region should lead to an enlargement of the area covered by such a database to avoid new redundant work. We hope that a cross-sectional publicly available database related to the environmental situation in the Barents region will serve as a powerful tool for both scientists, environmentalists and decision makers. The number of relevant publications is increasing rapidly, and some earlier publications are undoubtedly missing from the database, so any additional references sent to the first author of this presentation will be greatly appreciated.

Major and trace element chemistry in groundwater from the Skjellbekken catchment, North-East Norway.

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As one part of the «Kola Ecogeochemistry Project (CKE/GTK/NGU)» a catchment study was carried out in the Skjellbekken area, 35 km SSW of Kirkenes. The study included chemical analysis of stream- and groundwater throughout the period September 1994 to November 1995. At the end of the winter 1993/94 snowpack samples were collected and analysed. Monthly bulk rainfall samples were analysed for the period May to September 1994.

One aim of the catchment study was to study the impact of airborne pollution from the smelter industry on the Kola peninsula, on the chemistry of different parts of the hydrological cycle. This poster is focused on the impact on groundwater.

In areas with a cold and dry climate the snowmelt period in the spring (April-June) is the most outstanding hydrological event of the year. It is also the major episode of infiltration of surface water and groundwater renewal. When looking at chemical time series and the covariation between surface waters and groundwater it is therefore both convenient and expedient to focus on the snowmelt period.

At all monitoring stations most chemical components determined in groundwater samples show changes which are clearly related to the snowmelt period. In the uppermost part of the saturated zone, changes in the major components are characterised by dilution. In the deeper parts changes are smaller but the general trend is towards an increasing concentration of major components. One explanation of this is dilution by limited quantities of solute-poor infiltration water, which only reaches the uppermost part of the groundwater aquifer. The increasing concentrations in the deeper parts might be caused by a heavily concentrated pulse of infiltration water which is often observed in the initial stages of a snowmelt period.

The increasing concentration levels of lead and cadmium are clearly related to the snowmelt period and the origin of these heavy metals is most probably the melting snow. On the other hand neither Cu, Co nor Ni, which are the major heavy metals emitted by the smelter in Nikel, show any general increase in groundwater during this period. The reason for this might be differences in mobility of these elements in the snowpack and in the unsaturated zone. High Cu/Ni-concentrations in groundwater then might have occurred without being registered by the weekly sampling. An other explanation might be rapid changes in pH-value, and thus changes in solubility of heavy metals, caused by emissions of SO_2 from the smelter.

A geochemical atlas of the central parts of the Barents Region

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The Central Kola Expedition (CKE), Russia, the Geological Survey of Finland (GTK) and the Geological Survey of Norway (NGU) co-operate since 1991 to produce an eco-geochemical atlas of the central parts of the Barents Region (the Kola Ecogeochemistry Project - see http://www.ngu.no/Kola).

Regional sampling covered 188,000 km^2 north of the Arctic Circle, comprising the entire area between 24° and 35.5° E, with the Barents Sea as the northern project border and the Polar Circle as the southern border. Just under 700 localities were sampled in the summer of 1995, with the highest sample density close to the industrial centres and along the Norwegian-Russian border. Media collected for regional mapping were:

1.) Terrestrial moss (*Hylocomium splendens* or *Pleurozium schreberi*),
2.) Humus (up to max. 3 cm thickness),
3.) Topsoil (0-5cm) (mainly for analysis of radionuclides),
4.) Reindeer lichen (selected places, for analysis of radionuclides)
5.) Complete Podzol profiles (5 horizons),
6.) Lakewater (Russian project area only).

The atlas will present regional distribution maps for more than 50 elements (^{228}Ac, Ag, Al, ^{241}Am, As, Au, B, Ba, Be, Bi, ^{218}Bi, Br, C, Ca, Cd, Co, Cr, ^{134}Cs, ^{137}Cs, total Cs, Cu, Eu, Fe, H, Hf, Hg, K, ^{40}K, La, Lu, Mg, Mn, Mo, N, Na, Nd, Ni, P, Pb, Rb, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Th, Tl, U, V, W, Y, Yb and Zn), pH and LoI, most of these analysed in an accredited laboratory (ISO-Guide 25, EN 45001). Base maps will include: general geology, Quaternary geology, mineral occurrences, industry, climate, topography and vegetation.

The poster shows some examples of colour surface maps (interpolation method: block kriging). The distribution of Ni in humus and moss demonstrates the major influence of airborne deposition on the observed element concentrations. Lithology governs the distribution in the B- and C-horizon. Airborne deposition patterns for V (see moss map) are different to those for Ni: town and harbour of Monchegorsk (oil burning) and the power plant in Apatity can here be identified as major sources, the road/railway line from Monchegorsk to Kovdor is

clearly detectable by elevated V-concentrations in moss. The high Bi concentrations observed in the south-western corner of the project area in humus can not be explained by airborne deposition (compare Moss) or geology (compare B/C-horizon) - an additional factor (e.g. vegetation) must govern this strong enrichment of Bi in humus. Classically the pattern observed in the humus map is interpreted as caused by «long range transport of airborne pollutants» (note the very narrow halo caused by the Monchegorsk smelter).

The distribution of Na in moss and humus is governed by input from sea spray. S-concentrations in moss show the influence of industry, the distribution in humus, however, is largely governed by input of sea spray.

Observed concentrations of the radioisotopes ^{137}Cs and ^{241}Am are rather low and can be explained by fallout from surface testing of nuclear warheads some 20-30 years ago. The dominance of high values along the Norwegian coast, showing a very similar map pattern to the sea spray elements, are open to speculations whether we may see some additional input from Sellafield via the Gulf Stream here. The distribution of the natural isotopes ^{40}K and ^{228}Ac shows a strong correlation with lithology.

Even lakewater chemistry reflects atmospheric input of heavy metals and S in the vicinity of the smelters, the Cl-distribution is, however, governed by input from sea spray.

Gravity minewater discharges from abandoned UK coal mines: Prioritisation for remediation

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Ochreous, acidic minewater discharges originating from abandoned coal mineworkings are currently a major cause for concern among regulatory bodies, environmental groups and the public in those areas of the UK where the discharges have pronounced visual and ecological impacts. Despite a requirement of the 1996 UK Environment Act that any future mine abandonment plans must provide for the control of subsequent discharges, there is no requirement for the enforced control of discharges arising from mines abandoned prior to 1996, ie. the majority of discharges occurring today. The UK Coal Authority, which has overall responsibility for abandoned mines, has nevertheless undertaken to seek the best environmental solution which is achievable with the Authority's available resources.

In Autumn 1995, the Coal Authority, in consultation with the former UK river authorities, commissioned a review of 30 of the most serious gravity discharges in England and Scotland. The geological, hydrogeological and chemical nature of each discharge was investigated, and an initial assessment made of the negative impacts of the discharge, and of the feasibility of effective remediation. The latter included identification of potential treatment sites together with estimation of the land area required for, and the cost of, active and/or passive (wetland) treatment.

The review was undertaken in parallel with the National Rivers Authority's scoping study of selected discharges in England and complemented a previous study of 15 discharges in Wales. Consideration of the combined results from all three studies enabled the Coal Authority to prioritise the discharges in terms of their potential as candidates for treatment in the near future and to select sites for more detailed feasibility studies.

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Bergspenninger på Nordvestlandet

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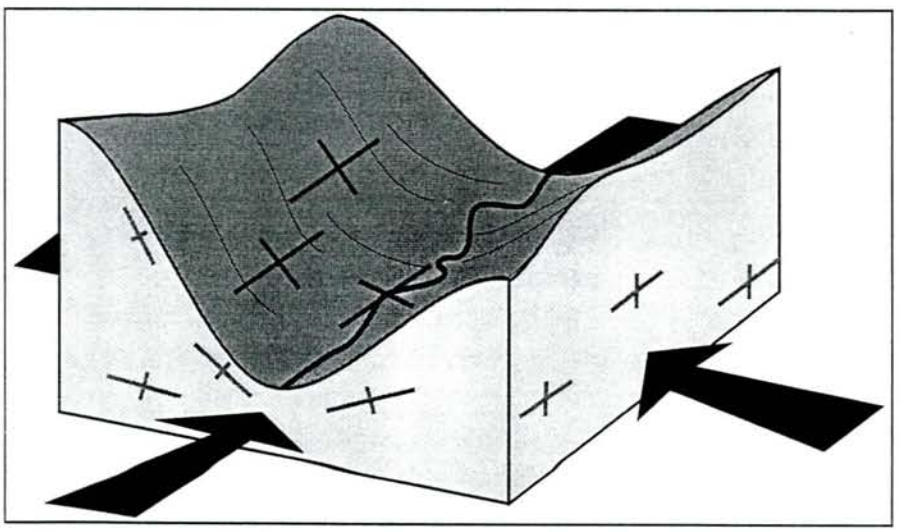
Bestemmelse av in-situ bergspenninger har betydning for mange ingeniørmessige formål. Informasjonen er relevant ved leting og produksjon av hydrokarboner og ved konstruksjon av underjordsanlegg. Bergspenninger har óg vist seg å være av betydning for væskestrømning i fjell. Dette prosjektet sammenstiller 21 eksisterende bergspennings-målinger fra Sogn og Fjordane. Målingene er utført med en tredimensjonal målecelle som gjør det mulig å bestemme retning og størrelse på alle de tre hovedspenningene. De fleste målingene er utført i vegtunneler. Formålet med undersøkelsen er å karakterisere det regionale spenningsbildet i området, for derigjennom å kunne plassere grunnvannsbrønner mer optimalt i forhold til de rådende bergspenningsforhold.

Sammenstillingen viser at de målte vertikale spenningene stort sett stemmer overens med de teoretiske verdiene for vertikalspenningen som følge av gravitasjon. De horisontale spenningene derimot, er mye større enn det som kan tilskrives gravitative spenninger. I de fleste tilfellene er horisontalspenningene større enn vertikalspenningene og i over halvparten av målingene er største hovedspenning orientert parallelt dalsideretningen. Dette indikerer tektoniske spenninger. To av måleområdene er derfor numerisk modellert for å undersøke hvor stor del av det observerte spenningsfelt som kan forklares av topografi og hvor store tektoniske spenninger det er i området.

Topografien kan ikke forklare de høye horisontale spenningene. Topografien er likevel med på å orientere spenningsfeltet parallellt og normalt dalsiden. Det kan óg se ut som om topografien skaper en viss spenningsavlastning på tvers av dalsideretningen.
Utfra de målte verdiene og den numeriske modelleringen ser det ut som om det er to tektoniske spenninger i området, i størrelsesorden 15 MPa og med retning NV-SØ og NØ-SV. De tektoniske spenningene på tvers av dalsideretningene er jevnt over redusert til ~7 MPa.



Skisse som viser hvordan tektoniske spenninger påvirkes av topografien.

Remobilization and Toxicity of Heavy Metals from Lead-Zinc Mine Tailing Deposited under Water in a Natural Lake System

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With experience from results gathered over a ten years period of monitoring effects of effluents from Bleikvassli Mine and processing plant in the recipient, Store Bleikvann, a toxicity and sediment study was set up. This was running through a year to collect more information about remobilization and bioavailability of heavy metals in contaminated lake sediments sampled from the recipient and in different distances from the area where the tailings are disposed. Together with these sediments, fresh tailing with and without acid mine drainage (AMD) from the processing plant were tested. As a control a reference sediment was collected from an unpolluted lake nearby. The heavy metal content in the tested "sediments" ranged from 15 - 7200 ppm Pb, 95 - 7200 ppm Zn, 0,5 - 22,0 ppm Cd, 40 - 1100 ppm Cu (dry weight). Through the test period the heavy metal content in the water over the sediments reached levels of 1978 µg Pb/L, 9,9 µg Cd/L, 44 µg Cu/L and 9438 µg Zn/L from an initial concentration in the water added of less than 0,05 µg/L. The highest concentration was shown over sediments collected in the neighbourhood to the deposition area. But related to the initial concentration it was found that the tailing with the AMD show the highest remobilization of metals to the water. A 1:1 sediment/water test was done with *Daphnia pulex* in the beginning of the test period. Results ranked the lake sediment near the deposition area as the most toxic followed by the sediment taken from the tailing with AMD. tests with the green algae *Selenastrum capricornutum* done to describe the toxicity of the water over the test sediments confirmed this result, but it was also seen an increased toxicity in the water over the sediments taken more distant from the tailing disposal area later in the test period. The amhipod *Gammarus lacustris* earlier an inhabitant of the benthic fauna in the lake system, was used to test the toxicity of the water and the combined effect when the test organisms were allowed to move freely on the sediment. In this last test the toxicity increased drastically and was seen clearly in the test with the sediment taken near the deposition area, where all the test organisms died within 6 hours.

Groundwater Modelling at Oslo Main Airport Gardermoen

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The new main airport for the Oslo region is being built on the largest groundwater aquifer in Norway. To predict the effects of the airport development on the aquifer, a groundwater flow model covering 52 km^2 is established. The aquifer is a coarse-grained ice contact delta deposited 9500 years BP. Geological and hydrological information from more than one thousand borings have formed the basis for the stratigraphical model of the area. The complex geological structure of the aquifer is simplified into four permeable layers above silt and clay layers that are impermeable with respect to groundwater flow. The thickness of the aquifer varies from 10m to 50 m over Gardermoen area. The aquifer is entirely fed by recharge from precipitation. The groundwater recharge is calculated in a hydrological model named SINBAD, specially developed for the Gardermoen area. The groundwater flow model is calibrated against water levels measured at a total of 152 observations wells. The three-dimensional finite difference flow code MODFLOW, is used for groundwater flow simulation.

The groundwater model has been used for predicting changes in water balance due to varying recharge and groundwater withdrawal. By routing clean surface- and drainage water to carefully planned infiltration ditches, the groundwater flow out of the airport area may be maintained.

The experience gained from this study shows that the groundwater model is a necessary tool in water management studies and for the protection of groundwater resources against pollution. The reliability of the model application is dependent on the data used as input for the model. On the other hand, modelling can identify areas where additional investigations are required.

Heavy Metal Uptake in Natural Vegetation - An Outlining of Different Sources

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Zinc, Cu, Pb and Cd concentrations were examined in several plant and tree species and corresponding organic topsoil collected in forest and on ombrotrophic bogs along a temporal (1982-1992) and a spatial (Southern Norway-Central Norway) heavy metal deposition gradient. The objective of the study was to examine possible relations between metal concentrations in vegetation, soil/peat and temporal/spatial changes in atmospheric heavy metal deposition.

Altogether 9 species were sampled at each of 7 locations (4 in southernmost Norway and 3 in Sør-Trøndelag, Central Norway) both in 1982 and 1992: Norway spruce, birch, Scots pine and juniper (twigs/needles or leaves), bilberry, mountain cranberry and bog whortlebery (stems/leaves), heather and crowberry (whole plant).

Distinct decreases were observed in atmospheric deposition of Zn (~ 28 %), Cu (~ 29 %), Pb (~ 68 %) and Cd (~ 53 %) in Southern Norway and Pb (~ 75 %) in Central Norway from 1982 to 1992. This led to significant decreases in plant Pb concentrations in forests and on ombrotrophic bogs both in Southern and Central Norway during the same time period, due to direct deposition of atmospherically derived Pb on vegetation. Soil and peat Pb concentrations were subject to only minor changes from 1982 to 1992. Plant Zn, Cu and Cd concentrations in Southern Norway did not decrease in line with the observed reductions in atmospheric Zn, Cu and Cd deposition from 1982 to 1992. This implies that root uptake is the main contributor to Zn, Cu and Cd in higher plants. A distinct reduction in soil/peat Zn and Cd concentrations in Southern Norway from 1982 to 1992 was not sufficient for lower Zn and Cd uptake into plants. Significantly higher plant metal levels in Southern Norway than in Central Norway were thereby caused by higher atmospheric deposition in Southern Norway in the case of Pb, and higher soil/peat metal concentrations in Southern Norway in the case of Zn, Cu and Cd. Significantly higher Cu concentrations in plants in forest compared to ombrotrophic bogs, indicates that Cu supplied from weathering of mineral material in soils may make up a distinct contribution to Cu levels in vegetation. Contributions from current weathering to plant Zn, Cd and Pb concentrations in forest areas were negligible at the present conditions. The results from the present study also implicate a generally faster reduction towards background levels in contaminated vegetation for Pb compared to Cd. This is important considering the great concern about Pb and Cd as toxic elements.

Chemical Modelling of Early Karstification In Limestone

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In this report a model discribing calcite dissolution along a single fracture in limestone is presented. Dissolution rates of calcite are determined by three processes. Surface controlled dissolution in which the chemical composition at the solid surface determine the rates, diffusion of ions and molecular species to and from the calcite surface, and slow conversion of CO_2 into H_2CO_3 which constitute the aggressive agent in dissolution.

Following the approach according to (Dreybrodt, 1985b) for calculation of dissolution rates from the underlying equations of mass transport and chemical kinetics as functions of $[Ca^{2+}]$ concentration, temperature and partial pressure Pco_2, demonstrated that dissolution rates may be approximated by a linear dependence $F(c) = \alpha([Ca^{2+}]eq - [Ca^{2+}])$. Values of α depend on the initial Pco_2, temperature of the solution and thickness of the water film.

Based on this theory a computer model describing solutional enlargement of a single fracture in laminar flow conditions was adapted from (Dreybrodt, 1992). The parameters defining the problem are the initial aperture width a_0, its length and the hydraulic gradient. Far from equilibrium the model assumes first order kinetics, given by: $F(c) = \alpha(ceq - c)$. Close to equilibrium a slow fourth order rate law $F(c)^4 = \beta(ceq- c)^4$ was used. The performance of the model was assessed by comparing the results obtained to those of (Dreybrodt, 1992) These show that initially the flow rate through the fracture increases very slowly in time until an abrupt increase occurs. At this moment an elementary volume of solution entering the fracture no longer reaches saturation with respect to the concentration of $[Ca^{2+}]$ ions. This moment was termed breakthrough. Breakthrough times were observed to depend on the saturation state achieved by the system, as well as the initial aperture and hydraulic gradient. The level of agreement in breakthrough time and solutional enlargement depended on the saturation state the system was assumed to reach, and the methodology for application of the dissolution kinetics.

As a final exercise modelling of calcite dissolution in turbulent flow was examined.. The results demonstrate that onset of turbulent flow in all cases of interest does not occur before breakthrough. In addition a two order of magnitude increase in the dissolution kinetics occur. Consequently it became necessary to treat modelling of dissolution rates in turbulent flow separately from that in the laminar flow.

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