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The 5th seminar on hydrogeology and  
environmental geochemistry  
"B. Bølviken Seminar -95"

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<p>Summary:</p> <p>The 5th seminar on Hydrogeology and Environmental geochemistry -"B. Bølviken Seminar -95" was arranged on Nov. 9. og 10. 1995 in Trondheim. The lectures dealt with the three main topics: Groundwater as a resource, Hydrogeochemistry and Environmental Geochemistry. Participants came from Denmark, Finland, Lithuania, Norway, Russia and Sweden. Abstracts are sorted alphabetically according to the surname of the first author, and include both oral presentations and posters</p> <p>Abstract</p> <p>9. - 10. nov. -95 ble det 5. seminar om Hydrogeologi og Miljøgeokjemi - "B. Bølviken seminar -95" arrangert i Trondheim. Foredragene omhandlet de tre hovedtemaene Grunnvann som ressurs, Hydrogeokjemi og Miljøgeologi. Det var deltagere fra Danmark, Finland, Litauen, Norge, Russland og Sverige. Sammendragene er systematisert alfabetisk etter første forfatter og dekker både foredrag og plakatpresentasjoner.</p>				
Keywords: Geokjemi		Grunnvann		Regional Kartlegging
Hydrogeologi		Miljøgeologi		
		Geokjemiske undersøkelser		Fagrapport

**Thursday November 9:  
Grunnvann som ressurs -  
stadig nye utfordringer?**

08.30 - 09.00 Registration

**Foredrag (09.00 - 10.40):**

09.00 Åpning av seminaret v/ Stedf.adm.dir.  
Bjørn A. Follestad - NGU

09.05  
\* Hva er Norsk Hydrologiråd?  
Arne Tollan - Norges Vassdrags og Energiverk.

09.20  
\* Brønnboring i Norge - en historisk gjennomgang.  
Tidemann Klementsrud - NGU

09.45  
\* Beskyttelse av grunnvannskilder. Hva kan vi  
gjøre bedre?  
Knut Ellingsen - Folkehelse

10.05  
\* Bruk av grunnvann kombinert med kunstig  
infiltrasjon for drikkevann for Tynset sentrum.  
Ole Ivar Folstad - Reinertsen Engineering ANS

10.25  
\* Et år med økt satsing på bruk av grunnvann!  
Bjørn A. Follestad - NGU

10.40 - 11.00  
Kaffe pause

**Foredrag (11.00 - 13.00):**

11.00  
\* Hydrogeologisk undersøkingsprogram for Sogn  
og Fjordane: resultater og ideer.  
Helge Henriksen - Høgskulen i Sogn og Fjordane,  
avdeling for naturfag

11.20  
\* Spenninger i grunnen og deres betydning for  
grunnvannsstrøm i fjell.  
Morten Fejerskov og Arne M. Myrvang - Norges  
Tekniske Høgskole (NTH), Institutt for geologi og  
bergteknikk

11.40  
\* Salt grunnvann; potensiale for norsk  
oppdrettsnæring.  
Oddmund Soldal & Noralf Rye - Geofuturum,  
Universitetet i Bergen.

12.00  
\* Fordeler med bruk av salt/ferskt grunnvann  
innen akvakultur og krav til vannkvalitet.  
Arne Kittelsen - Akvaforsk

12.20  
\* Georadar ved kartlegging av impermeable  
avsetninger ved Englandsskogen i Alta.  
Eirik Mauring et al. - NGU

12.40  
\* Lokale variasjoner i grunnvannskjemien i  
fjellbrønner.  
Petter Snilsberg - Jordforsk

13.00 - 14.00  
Lunch

**Session: Hydrogeochemistry  
(in English)  
Oral presentation 14.00 - 15.00**

14.00  
\* Groundwater Quality in Sweden.  
Bo Thunholm et al. - Sverige geologiske  
undersökning (SGU)

14.20  
\* Groundwater quality and trends in Finland  
during the years 1976-1993.  
Jouko Soveri & Kimmo Pessonen - Finnish  
Environmental Agency

14.40  
\* Radon in tap water - doses by ingestion and  
release of radon to indoor air.  
Terje Strand - Statens Strålevern (The Norwegian  
Radiation Protection Authority)

15.00  
\* Trace element content of 150 hardrock  
groundwater samples from the surroundings of  
Bergen and Oslo.  
Clemens Reimann et al. - NGU

15.20 - 16.20 Poster session  
including  
coffee and tea break

**Cont. Thursday Nov. 9 at 15.20**  
**Poster session (5 min. oral presentations)**

- \* *Miljø i grunnen - Faneprojekt Gardermoen. Delprosjekt 2 Spredning, binding og nedbrytning av akutte forurensningsutslipp fra flyplasser.*  
**Per Aagaard et al.** - Universitetet i Oslo
- \* Arsenic contamination in groundwater at multilevel aquifer systems of Indo-Gangetic delta plains in West Bengal, Eastern India.  
**Prosun Bhattacharya et al.** - Royal Institute of Technology.
- \* Intensifying groundwater acidification at Birkenes, Southern Norway.  
**Patrice de Caritat** - NGU
- \* The air- and groundwater flow in unsaturated and saturated zone in the vicinity of an air-sparging well.  
**Atle Dagestad** - NTH, Dep. of geology and mineral resources engineering
- \* The Nordic lake survey 1995 - Co-ordination and design.  
**Arne Henriksen et al.** - NIVA
- \* *Grunnvann i løsmasser fra Nord-Trøndelag.*  
**Bernt Olav Hilmo et al.** NGU
- \* Composition of ground water from two Arctic catchments (NW Russia and NE Norway) and comparison to stream water composition.  
**Øystein Jæger et al.** - NGU
- \* Wetland liming in the Røyneilandsvatn catchment effects on soil chemistry and deacidification properties in the soil profile.  
**Jens Kværner & Per Kraft** - Jordforsk
- \* Hydrochemistry and drinking water quality of shallow groundwater in Lithuania.  
**Virgina Micudiene** - Geological survey of Lithuania
- \* Hydrogeologiske undersøkelser av kilder for vannekspert, Nordland, Norge.  
**Arve Misund et al.** - NGU
- \**Bruk av grunnvann i Norge.*  
**Geir Morland** - NGU

\* *Resning av løst jetdrivstoff i umettet sone på Gardermoen.*

**G. Olstad et al.,** Universitetet i Oslo

\* A Groundwater Vulnerability Assessment of Korgen Waterworks, Lillehammer.  
**David Segar** - NGU

\* *Overvåkning av grunnvannsbrønner ved Brønnøysund.*

**Gaute Storrø** - NGU

\* Chemical composition of hard- and soft groundwater's from central Norway with special consideration of fluoride and Norwegian drinking water limits.

**Ola M. Sæther et al.** - NGU

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**Oral presentations (16.20 - 18.10):**

16.20

\* The chemistry of urban groundwater and connection to different environmental factors in Gothenburg, Sweden.

**Anna-Maria Hulten and Malin Norin** - Chalmers University of technology

16.40

\* Findings of pesticides in groundwater in Norway and other countries.

**Ketil Haarstad** - Jordforsk

17.00

\* Geochemistry of stream water in catchments effected by sulfide-bearing sediments.

**Mats Åström** - Åbo Academy University

17.20

\* Mine Water Hydrogeology and Hydrochemistry in the East Midlands Coalfield, UK.

**David Banks** - University of Sheffield

17.40

\* Prediction of post-closure mine pit lake geochemistry.

**Donald D. Runnells & David C. Ettner** - Geocare a.s.

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**20.00**

**Seminar dinner at Astoria hotel**

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**Friday November 10:  
Environmental  
geochemistry:**

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08.30 - 09.00 Registration  
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**Oral presentations (09.00 - 10.20):**

09.00

Introduction by **Knut S. Heier**, former director at NGU

09.05

\* Applied geochemistry: past and future.  
**Bjørn Bølviken** - NGU

09.40

\* Geochemical mapping in Finland during past 25 years.  
**Reijo Salminen** - Geological Survey of Finland (GTK)

10.00

\* Contributions from different sources to the enrichment of trace elements in organic surface soil.  
**Eiliv Steinnes** - University of Trondheim, Department of Chemistry

10.20

\* Ecogeochemistry Kola, selected results.  
**Clemens Reimann** et al. - NGU

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10.40 - 11.00

Coffee and tea break  
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11.00 - 13.00

**Poster session (5 minutes oral presentations)**

\* Ecogeochemical investigation, Kola Peninsula: Sulphur and heavy metal content in snow.  
**Matti Äyräs** et al. - NGU, GTK, CKE

\* Monitoring streamwater chemistry on the Kola Peninsula (NW Russia) and adjacent areas of Finland and Norway.  
**Patrice de Caritat** et al. - NGU, GTK, CKE

\* Status of arsenic contamination in the soils around a former wood preservation facility at Konsterud, Kristinehamns municipality, Värmland county, Western Sweden.  
**Prosun Bhattacharya** et al. - Royal Institute of Technology

\* Modeling contaminant transport at the Koksverk site, Mo i Rana.  
**Tom Bostrøm** - SINTEF, geoteknikk

\* Primary haloes of Cu-Ni Ores.  
**Victor A. Chekushin** & **Vladimir A. Pavlov** - Central Kola Expedition, Russia

\* *Geokjemisk atlas for Finnmark.*  
**Tor Erik Finne**, NGU

\* *Eksisterende geokjemiske datasett for Norge.*  
**Tor Erik Finne**, NGU

\* Geochemical maps showing bootstrap estimates of the moving weighted median.  
**Nils Gustavsson** - GTK

\* Enrichment factors of heavy metals in various media from 8 catchments on the Kola Peninsula and adjacent areas of Finland and Norway.  
**Jo H. Halleraker** et al. - NGU, GTK, CKE

\* *Økogeokjemisk kartlegging og overvåkning i Barents regionen.*  
**Jo H. Halleraker** et al., NGU, GTK, CKE

\* Technogenic heavy metals in northern Taiga soil: distribution and migration.  
**Galina Kashulina** - NGU

\* Rock geochemistry research project (RGRP) in the Geological Survey of Finland: A regional research program giving background information to environmental studies.  
**P. Lestinen** et al., GTK, SF

\* A new combination of geochemical and soil chemical investigations.  
**J. Låg**, NLH

\* The geochemical atlas of southern Norway.  
**Rolf Nilsen** & **Clemens Reimann**, NGU

\* Detection of airborne pollution in overbank sediment profiles.  
**Rolf Tore Ottesen** - Trondheim kommune & **Marianne Langdal** - NTH

**Cont. Poster session:**

\*Heavy metals and sulphur content in snowpack and rainwater samples from eight catchments north of the Arctic Circle in Finland, Norway and Russia.

**Clemens Reimann et al.** - NGU, GTK, CKE

\*Comparison of heavy metal contents in A0- and C-horizon soils from the surroundings of Nikel, Kola Peninsula, using different grain size fractions and leaches.

**Clemens Reimann et al.** - NGU, GTK, CKE

\*Amounts and sources of fluoride in precipitation over Southern Norway.

**Ola M. Sæther et al.** - NGU

\*Regional distribution of manganese, phosphorus, heavy metals, barium and carbon in sea bed sediments from the northern part of the Norwegian Skagerak.

**Ola M. Sæther et al.** - NGU

\*Geochemistry of podzols based on regional till data in Eastern Finland.

**Markku Tenhola et al.** - GTK

\* *Geokjemiske kart for Nordland og Troms.*

**Tore Volden,** NGU

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**13.00 - 14.00**

**Lunch**

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**Oral presentations (14.10 - 15.30):**

14.10

\*Acidification and the hydrochemistry of aluminium in soils, groundwater and surface water.

**Jan Mulder** - Norsk Institutt for Skogforskning (NISK)

14.30

\* Do you know your background?

**Tor E. Finne** - NGU

14.50

\* Long-term changes in Norwegian surface water chemistry in response to changes in atmospheric deposition.

**Brit L. Skjelkvåle & Arne Henriksen** - NIVA

15.10

\* Stable isotopes ( $^{18}\text{O}/^{16}\text{O}$ , D/H) and Strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) as natural tracers in ground-water studies.

**Nils Oluf Jørgensen** - Geologisk institut, Copenhagen University.

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**15.30 - 15.50**

**Coffe and tea breake**

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**Oral presentations (15.50 - 16.50):**

15.50

\* Overbank sediments: a sample medium for environmental studies.

**Rolf Tore Ottesen** - Trondheim kommune & Marianne Langdal - NTH.

16.10

\* Heavy metals in the Kvina river basin: state of pollution and monitoring of spreading.

**Marianne Langdal** - NTH

16.30

\* On the composition, distribution and genesis of oxidate sediments.

**Siv Kjeldsen & Rolf Tore Ottesen**

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 16.50

Closure of the seminar!

## ECOGEOCHEMICAL INVESTIGATION, KOLA PENINSULA: SULPHUR AND HEAVY METAL CONTENT IN SNOW

MATTI ÄYRÄS<sup>1</sup>, PATRICE de CARITAT<sup>2</sup>, VIKTOR A. CHEKUSHIN<sup>3</sup>, HEIKKI NISKAVAARA<sup>1</sup> and CLEMENS REIMANN<sup>2</sup>

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<sup>2</sup>*Geological Survey of Norway (NGU), P.O. Box 3006, N-7002 Trondheim, Norway*

<sup>3</sup>*Central Kola Expedition (CKE), Fersman St. 26, 184200 Apatity, Russia*

CKE, GTK and NGU have undertaken a multi-media investigation of eight catchments situated in Russia (Kirovsk, Kurka, Monchegorsk, Zapoljarniy), Finland (Kirakka, Naruska, Pallas) and Norway (Skjellbekken) to determine the environmental impact of local industrial pollution. Here, results (ICP-MS, ICP-AES, ion chromatography) from snow samples collected in March/April 1994 are presented for both filtered meltwater and filter residues.

Median S content in meltwater is highest in the Zapoljarniy catchment (900 ppb), followed by the Monchegorsk (825 ppb), Kirovsk, Kurka, Naruska, Pallas, Skjellbekken and Kirakka catchments. In terms of heavy metal deposition, the snow meltwater contains: As (up to a median value of 1 ppb), Cd (0.3 ppb), Co (33 ppb), Cr (1.15 ppb), Cu (550 ppb), Mo (0.23 ppb), Ni (250 ppb), Pb (3.4 ppb), Rb (0.5 ppb, Kirovsk), Sr (7 ppb, Kirovsk), V (16 ppb), and Zn (12 ppb), with all highest median values recorded at Monchegorsk, unless stated otherwise.

The filter residues have detectable S content at Zapoljarniy (1500 ppb), Monchegorsk (200 ppb), Kurka and Kirovsk. Highest median values for heavy metals in snow filter residue were also from Monchegorsk, unless stated otherwise: As (5 ppb), Cd (ca. 0.1 ppb, Zapoljarniy and Monchegorsk), Co (45 ppb), Cr (11 ppb, Zapoljarniy), Cu (300 ppb, Zapoljarniy), Mo (1.5 ppb), Ni (ca. 600 ppb, Zapoljarniy and Monchegorsk), Pb (5 ppb), Sb (ca. 0.7 ppb, Zapoljarniy and Monchegorsk), Sc (0.12 ppb, Zapoljarniy), Sr (10 ppb, Kirovsk), Ti (ca. 30 ppb, Monchegorsk and Kirovsk), V (18 ppb), and Zn (6 ppb, Zapoljarniy).

**ARSENIC CONTAMINATION IN GROUNDWATER WITHIN MULTILEVEL  
AQUIFER SYSTEM OF INDO-GANGETIC DELTA PLAINS: A CASE STUDY  
FROM WEST BENGAL, EASTERN INDIA**

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**ABSTRACT**

Groundwater contamination is a priority environmental issue in the context of optimum utilization of water resources. Safeguarding the water resources has therefore been a subject of keen interest in order to sustain the supply of water suitable for human consumption in all the developing countries, especially large countries like India and China. Factors responsible for the contamination of groundwater could be attributed to *either* natural processes, operating over a prolonged period of time *or* might be induced due to anthropogenic activities. The consequences could even be critical, if steps of remediation are not taken at an early stage.

One of the major problem pertaining to groundwater contamination identified in India during the past decade is the problem of high arsenic occurrences in groundwater affecting a large number of rural as well as urban population within the Indo-gangetic delta plains in West Bengal in eastern India. The lateral extremities of arsenic occurrences could also be possible further to the east in Bangladesh.

No significant work has so far elucidated the complex interactions between *water-solid phase* i.e. interaction of water with soils, sediments or the underlying bedrocks which are of key importance to control the mobility and/or retention of the various contaminants under subsurface environments. A proper understanding of the physical and chemical characteristics of the *solid phase* as well as their interactions with water and various contaminant species are therefore considered to be important in evaluating the nature and extent of arsenic contamination in groundwater in the affected areas which inturn can provide adequate base for evolving strategies of effective remediation. The present contribution is therefore aimed to highlight the extent of groundwater contamination and the mechanisms leading to the accumulation and spreading of the contaminant phases in groundwater and to identify the phases controlling the retention or mobility of arsenic under subsurface environment especially under the influence of prevailing tropical climatic conditions in India.

The problem of arsenic contamination in ground water was detected in the early 80's in some areas of West Bengal and nearly 175 cases of *Arsenical Dermatitis* had been reported from several districts. Cases of *Arsenical Dermatitis* were confirmed by clinical symptoms like darkening of skin, hyperkeratosis in palms and soles as well as by examination of nails and hair of several patients. Chemical analysis of groundwater samples from the tubewells revealed high concentration of arsenic, thus relating the incidence of arsenical dermatosis to the consumption of high As groundwater by the population in the region. A major project has been planned to be initiated with an objective to investigate into the nature, extent and cause of arsenic



contamination in order to evolve strategies for subsequent remediation, with an approach to investigate the complex processes of *water-solid phase* interactions which are responsible for the retention and mobility of As under subsurface conditions.

The reported occurrence of As in concentrations in groundwater, higher than the level of intervention were found to be confined within the meander belt zone of the Upper Delta Plain comprising the late Quaternary sediments. Within the meander belt, the arsenic polluted groundwater is mainly confined to the intermediate aquifer (20-80 m b.g.l.). Preliminary chemical analyses of groundwater samples have not so far reported the occurrence of As in the shallow and the deep aquifers (below 100 m) in the region except for some locations. The intermediate aquifer has however proved beyond doubt to contain water with significant As concentration. As contamination has also been reported in the deep aquifer in locations where there is no clay parting in between intermediate and deep aquifers. Although detailed studies are further needed, it has been thought that the sources of the arsenic in groundwater are primarily either in the clay sediments immediately above or intercalated within the intermediate aquifer. These sediments were transported from the Chhotanagpur-Rajmahal highlands and deposited in sluggish meandering streams on the Bengal flood plain under reducing conditions.

The groundwater in arsenic infested zone is characterized by high iron, arsenic, calcium, magnesium and bicarbonate with low chloride, sulfate and fluoride. The pH has been found to be always greater than 7. Much of the arsenic in the silty clay as well as in the sandy layers occurs as coating on mineral grains. SEM and EDX analyses on the ferruginous coatings on the constituent sand grains in the aquifer material has indicated high content of As in the range between 0.92-5.50 wt. %. Small proportions of arsenic could also bound to the associated organic matter. The impersistent clay (silty clay) horizon separating the shallow and intermediate aquifers has yielded relatively high arsenic in the sediment with occurrences of distinct grains of arsenopyrite. Leaching experiments indicate that at certain locations a significant proportion of arsenic in the sediment is leachable at a pH of 7-8.

Chemical analyses of water samples after long-duration pumping tests, from six borehole sites spread over three districts, indicate a flow of As at the rate of 10g per hour. In three of the boreholes, distinct trend of increasing arsenic content is noted with pumping time, suggesting the presence of As at several depths in the sediment column as well as flow from distant sources. Such huge amounts of arsenic could not be attributed directly to any anthropogenic influx, thus implying a natural source for the As contamination.

Removal of arsenic from groundwater has therefore been realized to be of extreme importance in safeguarding the water resources in this region. Remediation strategies developed so far clearly indicate the possibilities of the removal of arsenic as well as other toxic metals from groundwater through chemical treatment selecting a suitable adsorbent depending on the prevailing physico-chemical characteristics. Detailed research in this direction is needed towards physical and chemical characterization of the solid phases to establish the most suitable methods of remediation in order to safeguard the large groundwater resources in the region.

**MINEWATER HYDROGEOLOGY AND HYDROCHEMISTRY IN THE EAST  
MIDLANDS/SOUTH YORKSHIRE COALFIELD, U.K.**

*by David Banks*

The South Yorkshire / North Derbyshire coalfield has been one of the UK's most productive. It has a history of production stretching back some several hundred years, the earliest mines being developed in Upper Namurian and Westphalian strata on the Coal Measures outcrop in the west. Mining activity gradually progressed eastwards to greater depths until, today, mining occurs on a limited scale at depths of over 1000 m in the eastern coalfield, concealed beneath later Permo-Triassic strata. The western mines are now largely abandoned and mine water level recovery has taken place, leading to ochreous discharges polluting the catchments of the Rivers Don, Sheaf, Dearne, Drone and Barlow Brook. Several of these are still substantially contaminating after a period. In the east, mine dewatering still partially controls mine water levels although recent major mine closures and possible future closures raise the spectre of widespread mine water related problems including acid mine discharge, elevated mine gas emissions, contaminant mobilisation, spring reactivation, corrosion of services, geotechnical and contamination of groundwater in overlying Permo-Triassic aquifers. The regional scale of the potential problem calls for legislation empowering an Authority with responsibility for integrated and catchment-wide responsibility for mine water management

## MODELING CONTAMINANT TRANSPORT AT THE KOKSVERK SITE, MO I RANA

by Tom Bostrøm, SINTEF Geoteknikk

The site of the former Norwegian Coke factory in Mo i Rana is contaminated by heavy metals and organic compounds. A major survey of the Koksverk site is carried out by SINTEF. The project has three main objectives; determine amount of contaminant leakage into the nearby Ranafjord, determine the sources of leakage and to understand the movement of water and contaminants in the groundwater.

To assist in the evaluation of the Koksverk site a groundwater flow model is constructed using the finite difference flow code MODFLOW. The model domain covers a 25 000 m<sup>2</sup> area subdivided into 10x10 m<sup>2</sup> grid. The Koksverk site consists of fill above natural sea bottom. The fill contains cokegravel, sand, gravel and blocks. The permeabilities are estimated from grain size distributions using Gustafson's formula. The recharge to the groundwater is calculated using the hydrological model SINBAD, which is linked to MODFLOW. The average recharge rate for the period 1985 to 1993 is 1108 mm/year.

The groundwater model is calibrated against water levels measured at 46 observations wells. The results from the steady state calibration shows a good fit. A transient calibration is performed using timeseries of spatial distributed recharge values to the groundwater and observed groundwater levels between measurements period.

The groundwater model determines the velocity field which is the framework for modeling contaminant transport. The main factors influencing the transport of a contaminant by groundwater are advection, adsorption, dispersion, diffusion and decay. At the Koksverk site advection and adsorption are considered to be the main effects of contaminant transport. Adsorption is modeled as a linear and instantaneous equilibrium relation between contaminants dissolved in groundwater and the contaminants sorbed on the soil. In this approach the contaminant is carried along the pathlines of the water at a velocity of a factor R times the velocity of water. The retardation factor R is a function of porosity (n) and the distribution coefficient (K<sub>d</sub>).

The advective transport of contaminants are solved by coupling the groundwater flow model to MODPATH particle tracking code. In the contaminant particle tracking simulation, particles were placed at the source locations and tracked to the flow field. The results of the analysis include particle pathlines with discharge locations and average travel times. Transport of five different contaminants (arsenic, copper, phenol, phenanthrene and benzo(a)pyrene) were investigated.

The groundwater model is a valuable tool that can be used to help understand the movement of water and chemicals in the ground, recognize limitations in data and guide collection of new data and assist in design of remedial programs.

**APPLIED GEOCHEMISTRY; PAST AND FUTURE**

*Bjørn Bølviken, NGU*

Earlier the term applied geochemistry signified geochemical prospecting. Since World War II geochemical surveys have been extensively used in mineral exploration, and numerous deposits have been found around the world by this technique. Nowadays applied geochemistry is rather synonymous with environmental geochemistry, including also the utilization of geochemical data in fields such as pollution, human and animal health (epidemiology), agriculture and areal planning. Applied geochemistry is still a very young branch of science, and the author thinks it has a great potential for further development. It is a common misunderstanding among environmentalists that the contents of some chemical elements in natural materials are more or less consistent and invariable both in space and time. Even professionals have a notion that e.g. the natural concentrations of heavy metals in earth material are close to zero everywhere at the earth's surface. Geochemical maps and other geochemical data as well as the existence of mineral deposits and metallogenic provinces show, however, that this notion is wrong. The natural contents of many, perhaps all, chemical elements vary in a systematic way both in space and time. Contrasting geochemical dispersion patterns may exist in many natural materials and at all scales from local to continental or global. In many places the natural geochemical environment may be suboptimal for the health of certain organisms. These natural variations make estimations of the degree of pollution and its health effects often difficult. Pollution may be defined as man-made deviations from the natural chemical state of the environment. This implies that a number of chemical parameters describing the natural environment in various places must be known before an evaluation of the effects of pollution can be made. In the past, geochemical exploration has mainly relied on chemical analysis of stream sediments. This sampling medium suffers, however, from many disadvantages, not only in prospecting, but even more so in other fields of application of geochemical mapping. The author believes that in the future, data will be required about the natural contents of a great number of chemical elements in numerous materials representing bedrock, overburden, water bodies, flora, fauna and air. The geological surveys and other governmental institutions all over the world (individually and in cooperation) have a challenging task in documenting the natural background distributions of chemical elements in the environment.

## HEAVY METALS CONTENT IN STREAM WATER FROM EIGHT CATCHMENTS ON THE KOLA PENINSULA (NW RUSSIA) AND ADJACENT AREAS OF FINLAND AND NORWAY

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The Central Kola Expedition (CKE) and the Geological Surveys of Finland (GTK) and Norway (NGU) are carrying out a major, cooperative regional geochemical mapping project of a 170,000 km<sup>2</sup> area north of the Arctic Circle on the Kola Peninsula (NW Russia) and adjacent areas in Finland and Norway. The aims are (1) to establish regional geochemical maps of the distribution of heavy metals and radionuclides in an ecologically very vulnerable area, (2) to build up soil sample data banks at the two Geological Surveys, and (3) to assess the environmental impact of the nickel smelting and other heavy industry of Nikel, Zapoljarniy and Monchegorsk (NW Russia).

As one part of this project, element content in various sampling media (precipitation, snow, stream water, different soil horizons and moss) was monitored in eight catchments located at various distances from the smelters, and in different geological settings. Four of these catchments are situated in Russia (Kirovsk, Kurka, Monchegorsk and Zapoljarniy), three in Finland (Kirakka, Naruska and Pallas) and one in Norway (Skjellbekken). The stream water samples discussed here were collected approx. every 4-6 weeks in five catchments and weekly in the Monchegorsk, Pallas and Skjellbekken catchments, between March and August 1994. All stream water samples were analyzed at GTK, using ICP-MS for the determination of 29 cations and ion chromatography for the determination of six anions.

Results indicate that stream water samples from the Monchegorsk catchment, which is the one most affected by pollution from the local nickel smelting industry, have the highest (median) contents in Cd, Co, Cu, Ni, S, Sb, Se, Tl, V, NO<sub>3</sub><sup>-</sup> and SO<sub>4</sub><sup>2-</sup>. Additionally, very strong positive correlations ( $r > 0.9$ ) exist between Ni and As, Cd, Co, Cu, Tl, suggesting that these heavy metals have a common origin. In terms of time-series, the peak of Ni content in the stream water (end of April 1994) coincides with snowmelt and stream-water pH dip, suggesting that the heavy-metal surge to the stream is caused by snow melting and mobilizing its contained load of pollutants. Ca, Mg and NO<sub>3</sub><sup>-</sup> contents are significantly depressed by the snowmelt event. The stream water samples from the Kirovsk catchment, situated near an apatite mine and processing plant, have the highest (median) contents in Mo, Rb, Sr and F, whereas neither Ca nor P nor PO<sub>4</sub><sup>2-</sup> (major constituents of apatite) contents are particularly elevated there. At Pallas, the most remote and therefore unpolluted («background») catchment of the study, highest (median) contents in Fe, Li, Pb, Si and U were recorded in the stream water, reflecting a geological influence.

**PRIMARY HALOS OF Cu-Ni ORES**

*V.A.Chekushin, V.A.Pavlov, Central Kola Expedition, Russia*

Composition, morphology and zonality of Cu-Ni ores halos have been studied for deposits of the Kola peninsula. Peculiar centreclinal ("coveral") zonality is offered as a basis of modelling and methodical recommendations for data processing and interpretation of lithochemical sampling results in order that such a type of ores to be researched and forecasted.

The 10 main elements are used as indicators of Cu-Ni ores: Ni, Cu, Cr, Ag, Pb, Sn, Mo and As. Such the elements as Ti, V, Mn, Ga, Sc are included in the additional group, character of which gives an opportunity in the future to work out geochemical indexes to define the ratio between syngenetic and epigenetic ores of an object studied.

At the example of the Soucker deposit (Pechenga ore district) composition and morphology of primary halos have been studied on the surface level, along some vertical cross - sections and at the horizontal projections of ore zones. Like the signal element - indicators else peculiarities of the polyelement (multiplicative) halos (both the element groups and its special combination) were considered. As an alternative the factors calculated were used to generalize information for geochemical cross - sections and maps.

Cross - section and longitudinal zonality have been studied for separate ore bodies, ore zones as well as for deposit on the whole. The row of cross - section zonality (from a centre to up and down contacts) is: Ni, Cu, Ag, Co, As, Pb, Mo, Zn, Sn. The row of longitudinal zonality (from a centre to halo border in different direction) is: Ni, Cr, Co, Cu, Mo, Ag, Sn, As, Zn, Pb. More early data for the other deposits (Vostok, Lovno, Verkhnee, Kaula, Lastjavr) and these results are confirmed that Cu-Ni ore primary halos have peculiar centreclinal ("coveral") zonality. The multiplicative coefficients K4, K5 and the factors F1, F2 show these two parts of the "coveral" model of halos: central (Cu-Ni ore) part - K4, F1 and bordeal (iron sulphide ore) part - K5, F2. This unusual type of zonality is used as a basis for primary halo model of Cu-Ni ore bodies with its own method of geochemical data processing and interpretation, which is rather different from the classical vertical zonality of hydrothermal deposits. Zonality coefficients of different ranges  $n(1-1V)$  and  $DF=F2-F1$  were calculated to describe the inside composition of the halos. Its peculiarities gave an opportunity to research and prognosticate the new ore bodies.

The method of data processing and interpretation has been worked out on the basis of these results.

## THE AIR- AND GROUNDWATER FLOW IN UNSATURATED AND SATURATED ZONE IN THE VICINITY OF AN AIR- SPARGING WELL

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The radius of influence from an air sparging well has been investigated at Moreppen hydrogeological field research site, near the Gardermoen airport, 40 km north-east of Oslo. The purpose for the study was to evaluate the applicability of the in situ bioremediation technology air-sparging as an effective technique to remediate fuel contaminated sites. The investigated area is situated on a large glacial fluvial delta plain and the geology is fairly homogeneous and consists of coarse to medium sand ( $K=4 \cdot 10^{-4}$  m/s) down to 10 meter below the surface (mbs) which is fining downwards. The groundwater table is 4-5 mbs and the natural groundwater gradient is approximately zero. The investigated area is without any known human contaminants.

The objective was to determine the air flow within the saturated and unsaturated zone as well as the groundwater flow in the vicinity of an air injection well. An air injection well and seven multi-level samplers (MLS) have been installed. The screened part of the injection well was placed between 9.5-10.5 mbs. The MLSs, which are equipped with 5-9 separated filters at different levels for both gas and water samples, surround the well with a spacing of 0.5-6.0 m. Air, at a rate of 2 l/s and 0.5 bar pressure, was injected for 34 hrs. During the air-injection dissolved oxygen was measured in the saturated zone at different levels and distance from the well. Propane was added to the injected air and acted as a gas tracer when soil vapor was sampled from the unsaturated zone. To investigate the groundwater flow NaBr-brine was pumped into the air injection well during the air-injection. Conductivity measurements were carried out and groundwater samples taken from the MLSs during the air-injection period. The groundwater and gas samples were analysed with ion- and gas chromatography to detect Br<sup>-</sup> or propane in the samples.

The results from these analyses indicated that a major part of the injected air migrated along the well-pipe. Measurements did not show any difference in dissolved oxygen or conductivity in the groundwater in the vicinity of the injection well. Traces of propane were recorded in the unsaturated zone in the nearest MLS.

Due to these analyses new installation procedures for the implementation of air-injection wells have been worked out and new wells are under construction and will be tested out during this fall.

**BESKYTTELSE AV GRUNNVANNSKILDER. HVA KAN VI GJØRE BEDRE**

av Knut Ellingsen, Statens institutt for folkehelse, Geitmyrsv. 75, 0462 Oslo (fra 01.01.1996: PB 4404 Torshov, 0403 Oslo). B. Bølviken seminar -95, NGU, Trondheim, 1995.11.9-10

Grunnvannsforsyning til drikkevann framheves som fordelaktig både av helse- og miljøvernmyndighetene. Grunnvannets fortreffelighet forutsetter imidlertid at grunnvannskilden er godt beskyttet, ikke bare fra naturens hold, men ved bestemmelser og tiltak i kildens influensområde. Restriksjonene på arealene må godtas av de kommunale helsemyndighetene og settes i verk og handheves av vannverkseieren. Disse instansene er avhengig av best mulig input fra fagfolkene dersom restriksjonene skal bli tilstrekkelige, men minst mulig omfattende. Dette behovet ble akutt etter at de nye drikkevannsforskriftene fra 1995 la godkjenningsansvaret for vannverk i hovedsak til kommunene. Hver kommune har jo ikke anledning til å besitte ekspertise innen disse felt. De er helt avhengig av ekstern bistand, som helst skal være så objektiv og uavhengig som mulig.

Den faglige bistanden bør selvfølgelig være *grundig*. Folkehelsa har arbeidet med slike saker i flere tiår som godkjenningsmyndighet, siste året som rådgiver for kommunene. Fra vår standplass framstår mangelen på grundighet som et problem fordi det i stor grad må overlates til vår tvil og tro hvordan sonегrenser bør trekkes, hvilke aktiviteter som kan tillates hvor, m.v. Med mer viten om grunnforholdene ville dette vært minimalisert: Det er naturlig at *de geofaglige instansene sørger for at saken er tilstrekkelig utredet* til at myndighetene kan velge mellom tilstrekkelig klare alternativer framfor å måtte gå inn med geofaglig synsing. Grundigheten er nok i mindre grad avhengig av fagfolkene enn av oppdragsgivernes vilje til rundelig finansiering av grunnundersøkelser. Likevel er det trolig at mange fagfolk er engstelige for å ta tilstrekkelig i når de skal foreslå undersøkelser av akviferer, av redsel for at de skal framtre for dyre i innledende fase, og at dermed kanskje hele grunnvannsalternativet elimineres. Bedre opplysning om grunnvann generelt overfor potensielle oppdragsgivere og behov for utredning spesielt, kan være et botemiddel her.

Det er videre et problem for oppdragsgivere og deres rådgivere at ulike geofaglige aktører som utreder grunnvannskilder opererer med ulike framgangsmåter og begreper i anbud og rapporter. Det ville være et framskritt om alle presentere den samme "pakke" overfor oppdragsgiver, laget likest mulig rapporter, som inneholder de samme ting, beregnet hydrauliske parametre på samme måte etc. Med andre ord burde fagbistanden være mest mulig *standardisert*.



**BERGSPENNINGER OG DERES BETYDNING FOR GRUNNVANNSTRØM I BERG**

*Morten Fejerskov og A. M. Myrvang*

*Inst. for geologi og bergteknikk, NTH*

Kjennskap til bergspenninger er meget viktig for forståelsen av en bergmasses oppførsel. Innen såvel tradisjonell bergteknikk som petroleumsteknologi har det vist seg at det ofte er en nær kobling mellom permeabilitet/sprekkekonduktivitet og bergspenninger. Det er derfor veldig interessant å koble disse observasjonene og kjennskapen om spenningsbildet i Norge opp mot grunnvannsproblematikken.

Både i tunneler og petroleumsbrønner med anisotrope bergspenninger observeres det ofte retningsavhengige forskjeller i strømningsegenskaper. Under ellers like forhold viser det seg at sprekeste som løper parallelt med den største bergspenning er mer åpne og derfor mer vannførende enn sprekesett som er orientert normalt på den største bergspenningen.

Lang erfaring med bergspenningsmålinger gjør at en i dag har en relativt god kjennskap til det regionale spenningsbildet i Norge. Hovedobservasjonene kan sammenfattes i følgende punkter:

- De observerte horisontalspenningene er tildels mye høyere enn rent gravitative spenninger skulle tilsi. I mange tilfeller overstiger horisontalspenningen også vertikalspenningen. Norge kan derfor sies å være påvirket av store tektoniske spenninger.
- Regionalt sett roterer de tektoniske spenningene fra N-S i Barentsområdet til NW-SE i midt- og sør-Norge.
- Hovedforklaringen til de tektoniske spenningene og den observerte rotasjonen i spenningsretning er den midt-Atlantiske spredningsryggen, men faktorer som kontinentalmarginen, sedimentbasseng og deglasiasjon vil også bidra.

I tillegg til de regionale effektene vil lokale forhold være av stor betydning for hvordan spenningsbildet endres. Spesielt vil topografi og bergmassivets mekaniske egenskaper være viktig for forståelsen av lokale variasjoner.

### Topografi

Dype daler og fjorder vil gi opphav til høye topografiske bergspenninger. Generelt sett vil bergspenningene dermed være lavere i flate områder enn i områder med høyt relieff, noe som skulle tilsi mer åpne sprekker og økt strømningspotensiale i relativt flate, åpne områder. Daler som er orientert normalt på den tektoniske spenningsretningen vil ofte ha kun en høy horisontalspenning, i motsetning til daler der de tektoniske spenningene virker parallelt med dalforet og en ofte observerer to høye horisontalspenninger. I områder med høyt relieff vil derfor orienteringen av dalene i forhold til de tektoniske spenninger påvirke sprekkenes konduktivitet.

### Bergmassivets mekaniske egenskaper

Massive, lite oppsprukne bergarter som f.eks. grunnfjellsvinduene har generelt sett høyere bergspenninger enn mer oppsprukne kaledonske massiver. Sprekke-konduktiviteten skulle derfor antas å være lavere i massive grunnfjellsområder enn i omkringliggende bergarter.

**DO YOU KNOW YOUR BACKGROUND?**

*by Tor Erik Finne, Geological Survey of Norway, P.b. 3006, N-7002 Trondheim, Norway*

**Abstract**

In all branches of science as well as in everyday language, the term background is in frequent use. The term has different meanings from field to field. Workers in the various branches of natural science often apply the term differently, and they are themselves products of their social and educational background. This work is limited to a discussion of the field of chemistry.

It appears that the educational and professional background of the natural scientist determines the perspective with which the topic of interest is viewed. A petrologist refers the chemical findings to cumulative knowledge of bedrock chemistry of the world, or even the universe, if the application calls for it. A medical doctor working on muscular tissue will give reference to findings of healthy and unhealthy muscular tissue, perhaps to other types of tissue, or even to the chemistry of the dietary intake. In many cases, a limitation of one's horizon is appropriate, but certainly there should always be room for an evaluation of the proper viewpoint.

Describing natural variation of chemical properties of the geological strata of Norway has for more than a century been one of the tasks of the Geological Survey of Norway. In 1986, field work of a nation wide mapping of overbank sediments was completed, and in 1992, the Ministry of Environment appointed the Survey to the group of key institutions coordinating environmental information. For SFT Report 93:22&23, the Survey was the major contributor with regards to data about soils and sediments, whereas the SFT Reports 95:09 «Handling of Ground Pollution Cases» and 95:18 «Heavy Metals in Soil» have not involved the present full knowledge of geological data.

A number of cases illustrating the immense variation in natural (background) values for soils and sediments are given, both on a national and regional scale. The question is raised whether action levels should be defined on international, national or regional level, or if there should be given absolute administrative levels at all.

## BRUK AV GRUNNVANN KOMBINERT MED KUNSTIG INFILTRASJON FOR DRIKKEVANN FOR TYNSET SENTRUM.

Overing. Ole Ivar Folstad, REINERTSEN Engineering ANS

### Beskrivelse:

#### Historie / bakgrunn

Allerede i 1959 fikk Tynset sentrum eget privat fellesvannverk. Så lenge det har vært felles vannverk for deler av Tynset sentrum (fram til 1995), har vannkvaliteten vært svært variabel. Nesten årlig har det vært restriksjoner på bruk av drikkevannet. Selv tilsetning av klor har ikke løst problemet.

Med bakgrunn i ovennevnte ble det allerede i 1980 startet undersøkelser for å se på mulig grunnvannsforsyning for Tynset sentrum.

#### Behandling - vannets veg fram til abonnent!

- Ubehandlet vann tas inn fra elva Auma.
- Ubehandlet vann overføres til infiltrasjonsbasseng på (Geitryggen). Infiltrasjonsbassengene er grunne og er utformet med ei sandpute som vannet filtreres gjennom på sin videre vandring gjennom grusryggen. I grusryggen blandes samtidig det infiltrerte vannet med grunnvann.
- Etter en vandringstid på ca. 60 døgn har vannet nådd fram til inntaksbrønnene på nedsida av Geitryggen. Herfra føres vannet i tett ledning fram til Brekka høydebasseng. Høydebassenget er bygd for å gi abonnentene samme vanntrykk som før, for å ivareta ujevnt forbruk over døgnet og for å ha nok vann tilgjengelig ved brann, samt for å være en reservekilde ved eventuell svikt i hovedkilden.
- Fra høydebassenget føres vannet i ledningsnett fram til abonnentene i sentrum.

#### Oppstart

Etter innkjøring og prøvedrift våren 1995 har anlegget vært i vanlig drift siden juli 1995. Allerede i prøvedriftsperioden var vannkvaliteten vesentlig forbedret. Best merkes dette med at det ikke er klorsmak på vannet og at det ikke får den tidligere "vanlige brunfargen" ved snøsmelting og lengre regnvær.

## Sikkerhet

For best mulig å unngå fare for framtidig forurensing, er det satt opp gjerde rundt infiltrasjonsbassengene og inntaksbrønnene. Samtidig er det også satt strenge restriksjoner for arealbruk i og like ved disse anleggsdelene.

## Mange kan forsynes

Tynset vannverk forsyner i dag (1995) ca. 2500 personer i tillegg til noen store abonnenter som sykehus, slakteri og offentlige institusjoner inklusive skolene. Behandlingsanlegget kan ved enkle utvidelser ha kapasitet til å forsyne ca. tre ganger så mange.

## Kostnader

Sum årlig kostnad for Tynset kommune er ca. 1,5 mill. kr. Med et årlig forbruk på ca. 400.000 m<sup>2</sup> gir dette en behandlingskostnad på ca. 0,4 øre pr. liter vann.

## Spesielle trekk ved anlegget:

- Utnyttelse av grunnvann kombinert med kunstig infiltrasjon av ellevann.
- Utnyttelse av naturgitte fallforhold. Ikke ei eneste pumpe er montert.
- Behandlingskostnad er bare ca. 0,4 øre pr. liter.
- Driftssikkert anlegg.
- Forurensinger som avsettes i grusen nedbrytes over tid, slik at anlegget i sin helhet har uendelig levetid.

## ØKOGEOKJEMISK KARTLEGGING OG OVERVÅKING I BARENTS REGIONEN

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Et trenasjonalt samarbeidsprosjekt har pågått siden 1991 mellom Central Kola Expedition (CKE), Russland, Geologiska Forskningscentralen (GTK), Finland og Norges geologiske undersøkelse (NGU). Prosjektet startet med en pilotundersøkelse i 1992, fortsatte med nedbørfeltstudier i 1994 og skal ende opp i en regional geokjemisk kartlegging sommeren 1995. Hovedmålet er å framskaffe oversiktlige kart over fordelingen av mer enn 30 elementer i terrestrisk mose, humus/toppjord, og upåvirket morenemateriale fra C-sjiktet i podsolprofiler. Kartleggingsområdet dekker 188.000 km<sup>2</sup> i deler av Finnmark fra 24° Øst, det meste av Lappland i Finland og vestre deler av Murmansk fylke i Russland til 35°30' Øst.

For å få samkjørt felt- og analysemetoder var første fase av dette prosjektet en multimedia studie fra 45 lokaliteter fordelt på 12.000 km<sup>2</sup> rundt Kirkenes, Pechenganikel i Russland og nordøstre del av Lappland i Finland. I dette området ligger bl.a. Europas største nikkelforekomster, og på russisk side har det vært drevet med metallindustri i snart 50 år. Følgende 8 media ble prøvatt i 1992; I) snø, II) de 3 siste årsskudd av terrestrisk mose (*Hylocomium splendens* og *Pleurozium schreberi*), III) humus (A<sub>0</sub>-sjiktet), IV) topp-jord (de øverste 5 cm unntatt strø), V) løsmasser upåvirket av jordsmonndannende prosesser (C-jordsjiktet), VI) filtrert elvevann, VII) bekkesedimenter og VIII) flomsedimenter fra topp og bunn.

Resultatene viste at snø, mose og humus er best egnet til kartlegging av luftbåren forurensing i området. For kartlegging er det et problem at moser og humus forsvinner i de sterkest forurensede områdene. Prøvetaking av snø kan da være et alternativ. Den kjemiske analysen av elvevann viste klart forhøyede verdier av flere metaller i nærområdene til de antatt største forurensningskildene. Det ble funnet at tungmetaller i liten grad holdes tilbake i det terrestriske systemet, men i stor grad vaskes ut. Dette kan være en følge av at evnen humus har til å binde metaller i deler av området er ødelagt eller skadet. Dataene for flere media viste forhøyede verdier av Ni, Cu, Cd, Cr, As, S, Ca og muligens Mg og Fe som kan knyttes til smelteverksindustrien i Nikel/Zapolyarny. Betydelige utslipp av hovedelementene Ca og Mg er trolig med på å redusere de økologiske skadene i området. I tillegg viste snøanalysene maksimumsverdier for følgende elementer nærmest nikkel-industrien på russisk side; Al, Ba, Fe, Li, Mg, Mn, Mo, Sb, Tl og V.

Gjennom 1994 ble 8 utvalgte nedbørfelt studert i detalj. Noen av nedbørfeltene er utsatt for Europas tyngste metall og svovelbelastning, mens andre gjenspeiler den naturlige variasjonen som en følge av ulik geologi, vegetasjon og avstand fra kyst. Den ulike beskaffenheten og avstanden nedbørfeltene har til forurensningskilder gjør at elemenfordelingen ble ulik, og viste seg å variere høyst forskjellig gjennom året. I nedbørfeltene ble flere media prøvetatt jevnlig gjennom sesongen; nedbør, elvevann, vegetasjon (mose), humus og topp-jord. Snø, flomsedimenter, organiske bekkesedimenter, alle sjikt i podsolprofil, løsmasser, berggrunn og enkelte steder grunnvann ble innsamlet fra flere lokaliteter i hvert nedbørfelt.

## THE NORDIC LAKE SURVEY 1995 - COORDINATION AND DESIGN

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Regional lake surveys have previously been carried out in the three Nordic countries, Finland, Norway and Sweden. Finland carried out their first survey in 1988 comprising 987 lakes. Norway started already in the mid 70's, and followed up with an extensive regional survey in 1986 (1005 lakes). Sweden has carried out several lake surveys, the most extensive one in 1990 (4018 lakes). The Finnish and Swedish latest surveys were based on statistical selection of lakes from their national lake registers, while the Norwegian survey was based on subjectively selected lakes within each topographic map located in areas with geology giving lakes sensitive to acidification. This autumn (1995), the three Nordic countries are simultaneously carrying out new national lake surveys in their respective countries based on statistical selection of lakes. In co-operation with NGU, and INEP at Kola, Russia, also the Kola peninsula will be surveyed. The purpose of The Nordic Lake survey will be to assess the status of the Nordic lakes with respect to: 1. the general water quality 2. the occurrence and large scale regional variation in acidification 3. establishing a new baseline of chemical data to follow up the future effects of the new sulfur protocol that was signed in Oslo in June 1994, 4. establishing the effects of nitrogen deposition on lake water chemistry in connection with the development of critical loads for nitrogen under Working Group on effects established by the United Nations Economic Commission for Europe's (UN/ECE) Executive Body on Long Range Transboundary Air Pollution., 5. the eutrophication status and 6. levels of heavy metals.

The Effect Group of the Nordic Council of Ministers supports the joint planning and reporting of the three surveys. The poster will present the common lake registers, lake size distributions, purpose of the surveys, descriptions of the sampling strategies, analytical methods, quality control routines etc.

**HYDROGEOLOGISK UNDERSØKNINGSPROGRAM FOR SOGN OG FJORDANE -  
RESULTATER OG IDEER***by førsteamanuensis Helge Henriksen*

Hydrogeologisk undersøkingsprogram for Sogn og Fjordane startet i 1987 som et samarbeidsprosjekt mellom SFdh, NGU og Sogn og Fjordane Fylkeskommune. Den første delen av programmet var en fylkesomfattende oppdatering av NGU sin database over borebrønner i fjell. Senere er programmet videreført i regi av SFdh, de siste år med økonomisk støtte av NFR og NGU. **Regionale studier relatert til grunnvann i fjell** har tatt utgangspunkt i den oppdaterte databasen over fjellborebrønner. Databasen er supplert med attributt-data om bergartstype og topografisk lokalisering, og er lagt inn i GIS-systemet PC Arc/Info. Databasen vil bli supplert med ytterligere attributt-data. Databasen er å betrakte som et verktøy for utvelgelse av data som vil kunne analyseres videre vha. romlige analyser eller statistiske metoder som signifikanstester og multivariat analyse. De første resultatene av dette arbeidet er publisert i *Ground Water*, og antyder at topografi er en viktigere parameter for vanngiverevnen enn bergartstypen. **Objektrettede studier** har vært fokusert på naturlig grunnvannskjemi (inklusive oksygenisotoper) og studier av strømningsforhold og oppholdstid i fjell- og løsmasseakviferer. For grunnvann i fjell synes det å være store variasjoner i grunnvannskjemi i én og samme bergartstype i det samme geografiske området. Dette kan ha sammenheng med et mangeartet strømningsmønster der grunnvannet har forskjellig oppholdstid. Forsøk med oksygenisotoper til undersøkelser av oppholdstid i små elveavsetninger har også vært utført.



**FUNN AV PLANTEVERN MIDLER I GRUNNVANN I NORGE OG UTLANDET***av forsker Ketil Haarstad***Sammendrag**

Ifølge de nye drikkevannsforskriftene er det kommunene selv som skal godkjenne en vannkilde og vernetiltak for denne. Det finnes ingen konkrete og enkle retningslinjer for vurdering av enkelte plantevernmidler eller kjemiske stoffer i forbindelse med bruk i nærheten av vannkilder. Vurderinger er derfor basert til en viss grad basert på skjønnsmessig sammensetning av tilgjengelig informasjon i rapporter, publikasjoner og oppslagsverk. Godkjenning av plantevernmidler gjelder i 5 år, men kan trekkes tilbake innen dette tidsrommet. Stoffutvalget som brukes til kjemisk plantevern er under stadig revidering. I veiledere fra Folkehelse er det listet opp 21 plantevernmidler som under visse forutsetninger og etter spesiell vurdering i hvert enkelt tilfelle har vært tillatt brukt i nedbørfeltet til enkelte vannverk. Av disse midlene er 4 midler ikke lenger tillatt brukt i Norge, 10 % av midlene tilhører fareklasse A og 43 % av midlene tilhører fareklasse B. Slike lister mister på denne måten hurtig sin verdi og er således i utgangspunktet til liten nytte i vurderinger av beskyttelse av nedbørfelt rundt drikkevannskilder. Vi må gå ut ifra at kun plantevernmidler som består av stoffer som i sammensetning og mengde er lik naturlige næringsstoffer for mennesker kunne anses som uproblematisk innen et nedslagsfelt for en drikkevannskilde.

Vi har valgt å gjennomgå undersøkelser av bruk av plantevernmidler i tilknytning til vannforekomster generelt og grunnvannskilder spesielt. Midler som er påvist å ha blitt transportert gjennom umettet sone i jord og som er rapportert funnet i grunnvann vil ikke kunne anbefales tillatt brukt innen nedbørfeltet til en drikkevannskilde. Midler med høy motstand mot nedbrytning og høy mobilitet i jord vil generelt bare kunne anbefales brukt dersom deres helsefare er lav. Midler som er rapportert funnet i jord, grøftevann og i umettet sone, og som kan forventes å motstå nedbrytning, må kun anbefales brukt i sammenhenger som gir minst mulig sannsynlighet for skadelig påvirkning for konsumenter av drikkevann og

for miljøet forøvrig. Ifølge forskrifter for drikkevann er grensen for enkeltstoffer av plantevernmidler i drikkevann 0.1 µg/l, og for sum av plantevernmidler 0.5 µg/l.

Vi har konkludert at for en konkret norsk grunnvannskilde med bær dyrking i nedslagsfeltet kunne 7 av 24 anvendte midler skjønnsmessig tillates brukt i sone I og II. I sone III kunne ytterligere 3 midler tillates.

## THE CHEMISTRY OF URBAN GROUNDWATER AND ITS CONNECTION TO THE ENVIRONMENTAL FACTORS IN GÖTEBORG, SWEDEN.

by: *A-M. Hultén & M. Norin*

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The work forms a part in a larger project, financed by the Swedish Council for Building Research. A field study has been carried out since 1989. The groundwater composition in an urban environment was analysed and the result from that study showed large differences between the chemistry of rural and urban groundwater. It indicated that the shallow groundwater at the experimental site has a high buffering capacity with high alkalinity and a total hardness. Also other, analysed parameters point out differences from rural groundwater. The shallow groundwater is not acidified as a consequence of the high buffering capacity. The chemistry composition of the urban groundwater changes between different measure points in the city of Göteborg. This is an indication of large heterogeneities of the urban environment.

The composition of the filling shows great differences over very small areas. That is due to (1) the repairing of building foundations, streets, pipes etc, (2) refilling of the ground due to subsidence in the clay, (3) filling material from earlier houses and other human activities which can be found in the upper layers of the ground, (4) garbage and waste from building houses which has been left in the ground, (5) old pipes that are no longer in use and are sometimes left in the ground, (6) a relatively muddy clay that is found as lenses in the filling material, underneath the centre of Göteborg.

The explanation to the difference in the water chemistry must probably build on information from different subjects. When an area is being built a lot of changes take place in many different ways. The geochemistry, the hydrogeology and hydrology are affected. Some examples of what happens are (1) the biological processes in the ground are affected among others due to the absence of an A-horizon, (2) the ground receives different pollutions and substances from the decomposition and corrosion of material that has been put down in the ground, (3) the infiltration capacity and the evapotranspiration decreases, (4) the ground receives water from leaching sewer and fresh water pipes, with a composition that is different from the surrounding groundwater, (5) the material in the uppermost part of the ground is changed.

The further work will be to make a more detailed study of the connection between the chemistry of urban groundwater and the filling material. To collect more detailed information, a experiment is going to start with field lysimeters. These are going to be filled with material from different places in Göteborg. The filling will be leached with rainwater. One type of filling will be treated with salt and acid solutions to simulate extreme environments.

## STABLE ISOTOPES ( $^{18}\text{O}/^{16}\text{O}$ , D/H) AND STRONTIUM ISOTOPES ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) AS NATURAL TRACERS IN GROUNDWATER STUDIES

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The occurrence of natural groundwater types unsuitable for domestic purposes is a common phenomenon in Denmark. Well-known examples are chloride-contaminated groundwater and "Brown Water" which may result in serious problems in water resources management.

Saline groundwaters are recognized to have three principal origins in Denmark: (a) seawater infiltration into near-coastal aquifers, (b) saline formation water in aquifers of marine sedimentary origin and (c) intrusion of brines from deep saline formation water and dissolution of evaporitic deposits in the subsurface by circulating meteoric water.

"Brown Water", i.e. organic-rich groundwater, in Denmark is generally found in western Jutland and northern Zealand and is related to deeper aquifers. Naturally occurring organic solutes can be present in large concentrations and the organic solutes are generally assumed to derive from organic matter in subsurface formations.

Previous isotopic investigations of Danish aquifers have shown that isotopic hydrochemical criteria provide a strong tool to characterize groundwater qualities that are affected by naturally occurring sources such as water-rock interactions, intrusions of seawater and other sources of saline and organic-rich groundwater. The relationship between  $\delta\text{D}$  and  $\delta^{18}\text{O}$  in meteoric waters is linear and is represented by the *meteoric water line* with the equation:

$$\delta\text{D}_{\text{smow}} = 8\delta^{18}\text{O}_{\text{smow}} + 10 \text{ (Craig, 1961).}$$

The oxygen and hydrogen isotope compositions of meteoric water in Denmark are  $\delta^{18}\text{O} \sim -8$  o/oo and  $\delta\text{D} \sim -55$  o/oo, respectively. The  $\delta^{18}\text{O}$  and  $\delta\text{D}$  of oceanic seawater are close to zero and only vary within narrow limits. The isotopic composition of brackish seawater in the inner Danish seas varies considerably and depends upon the mixing of meteoric water (i.e. precipitation and run-off from rivers) and oceanic seawater from the North Sea. However, groundwater influenced by intruding seawater will show a stable isotopic composition which correlates with the *meteoric water - seawater mixing line*.

The strontium isotopic composition of precipitation in Denmark reflects the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio in modern seawater, i.e.  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7092$ . However, the strontium concentration in the precipitation is extremely low and, therefore, groundwater will have  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios which primarily reflect the isotopic composition of the strontium-bearing mineralogical components in the host rock as a result of the chemical equilibrium between formation and porewater. Groundwater in aquifers influenced by intruding seawater, saline formation water or Sr-containing fluids from organic-rich formations will show a Sr isotopic composition related to a mixing hyperbola between the end members of the groundwater and the infiltrating fluid.

The objective of this presentation is to demonstrate by use of case studies the applicability of isotope hydrochemical criteria in the classification of groundwater and to use stable isotopes and strontium isotopes as natural tracers in groundwater studies.

## COMPOSITION OF GROUND WATER FROM TWO ARCTIC CATCHMENTS (NW RUSSIA AND NE NORWAY) AND COMPARISON TO STREAM WATER COMPOSITION

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The Central Kola Expedition (CKE) and the Geological Surveys of Finland (GTK) and Norway (NGU) are carrying out a major, co-operative regional geochemical mapping project of a 188,000 km<sup>2</sup> area north of the Arctic Circle on the Kola Peninsula (NW Russia) and adjacent areas in Finland and Norway. The aims are to establish regional geochemical maps of the distribution of heavy metals and radionuclides in an ecologically very vulnerable area, to build up a soil sample data bank, and to assess the environmental impact of the nickel smelting and other heavy industry of Nikel, Zapoljarniy and Monchegorsk (NW Russia).

As one part of this project, element content in various sampling media (rain, snow, stream water, ground water, different soil horizons and moss) was determined and/or monitored in eight catchments located at various distances from the smelters, and in different geological settings. Four of these catchments are situated in Russia (Kirovsk, Kurka, Monchegorsk and Zapoljarniy), three in Finland (Kirakka, Naruska and Pallas) and one in Norway (Skjellbekken). The ground and stream water samples discussed here were collected in 1994-1995 from the Monchegorsk and Skjellbekken catchments, the former being located ~5 km downwind from the major SO<sub>2</sub> and trace element pollution source of the Monchegorsk smelter complex, the latter being located ~30 km away from the Nikel smelter in a direction perpendicular to the dominant wind direction. All water samples were analysed at GTK, using ICP-AES or ICP-MS for the determination of 33 cations and ion chromatography or spectrophotometry for the determination of six anions. pH and electrical conductance were also determined at GTK.

Analytical results indicate that the median content of trace elements in the ground waters are generally low, even for the Monchegorsk catchment: Ag (<0.01 µg/l), Be (<0.3 µg/l), Bi (<0.02 µg/l), Br (<0.2 mg/l), Cd (<0.03 µg/l), Cr (<0.2 µg/l), P (<0.1 mg/l), PO<sub>4</sub> (<0.02 mg/l), Sb (<0.03 µg/l), Se (<0.05 µg/l), Th (<0.01 µg/l), Tl (<0.01 µg/l) are all below detection limit in both areas. In terms of Cd, Cr, As, Cu, Pb, the analysed ground waters are below the 'background' levels defined in the literature for ground water. For Zn, only ground water from Skjellbekken is below 'background', whilst for Ni the median ground water values from both catchments are above 'background' level. This is consistent with the dominant basic/ultrabasic lithologies there.

Compared to the ground water from Skjellbekken, the ground water from Monchegorsk is more enriched in Zn, Ni, NO<sub>3</sub>, Fe, Cl, S, SO<sub>4</sub>, Ba, Ca, Cu, Li and Mg. It also has a higher electrical conductance. The Skjellbekken ground water is enriched in Al, Mo, As, Pb, F, K and V relative to the Monchegorsk ground water. Both ground waters have circum-neutral pH values.

Ground water was compared to stream water for both catchments. In the Skjellbekken catchment, ground water is enriched in Co, Mo, Mn, Pb, Al, F, V and Zn with respect to stream water, and is depleted in Fe and Ca. Overall, element content in both water types is well correlated and clusters around the 1:1 line. In Monchegorsk, ground water is more enriched than stream water for Fe, Cl, Na and Rb, and more depleted for Ni, Cu, Co, As, V, NO<sub>3</sub>, Mg, S, SO<sub>4</sub>, Mo and Pb. The observed relationships can be used to interpret the origin of elements in the waters, esp. with respect to geogenic versus anthropogenic sources, and biogeochemical processes at the catchment scale.

## TECHNOGENIC HEAVY METALS IN NORTH TAIGA SOILS: DISTRIBUTION AND MIGRATION

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The heavy metals behaviour in the soils around one of the biggest and long acting sources of pollution ("Severonickel" smelter complex, Kola Peninsula, Russia) are discussed on the base of long period geographical and complex biogeocenological investigation.

The organic horizon of podzols and upper part (0-20 cm) of histosols are a complex biogeochemical barrier and are capable of accumulating very large quantities of heavy metals. Depending on the distance from source of pollution, the prevailing wind directions, soil types and some other factors, the total content of Cu in these horizons vary from 20 to 4000 ppm, Ni - from 40 to 9000 ppm and Co from 3 to 600 ppm. Such high capability of upper organic horizons of soils to accumulate heavy metals make them the best index for estimation of accumulative effect of pollution on the ecosystems. However these horizons have not retained all heavy metals which enter to the soil. According to lysimeter observations done in natural conditions organic horizon of podzols accumulate only 70-90 % of Cu and 0-40 % of Ni (Yevtyugina, 1990). In the modelling experiments the accumulation of Cu was about 40-60 %, for Ni 75-100 %. A decrease in Ni accumulation with as much as 50 % occur when the organic layer is close to saturation by this element. According to this data the saturation limits for Ni (ion-form) was about 1000 ppm. Besides of that, the observation of the heavy metals accumulation dynamics from 1978 up to 1985 show that the maximum accumulation occur at the distance 10 km from source of pollution. For the next 4 year the heavy metals contents in the organic horizons in the severely disturbed ecosystem at 7 km from source decreased twice. The lysimeter observation and some additional experiments have confirmed that as for as disturbance of vegetation and development of soil erosion the organic layer decrease its possibility to accumulate heavy metals and than lost it at all. So, under the very high level pollution and the strong ecosystems disturbance this parameters can't be use as a state ecosystem index.

The tree layer is actively distributing the flux of heavy metals into the soil and account for significantly higher level of heavy metal input into the soils under spruce canopy as compared with between canopy space. This difference is at maximum (about 10 times) in slightly degraded ecosystems with the absence of visual disturbance of spruce canopy, and decrease with the tree canopy defoliation. The spatial distribution of Cu content in the organic layer (g/m<sup>2</sup>) within and between ecosystems reflects to a high degree the spatial distribution of its input. The condition for Ni accumulation under canopy space are less favourable.

The fact that organic layer have higher saturation limits for Cu and retains it stronger, does this element more suitable for monitoring.

The behaviour of these elements in the lower horizons is determined by the types of soils and by state of the above barrier (the degree of soil erosion and/or its saturation by these elements).

Yevtyugina, Z.A., 1990 Peculiarities of Copper and Nickel migration by Al-Fe-podzol profile under condition of airborne pollution. In: Research of Soils in European North. Proceedings of Scientific Session. USSR Geographical Society. Archangelsk. P.106-107. (In Russian).

## FORDELER MED BRUK AV SALT/FERSK GRUNNVANN INNEN AKVAKULTUR OG KRAV TIL VANNKVALITET

*Arne Kittelsen AKVAFORSK*

En av særtrekkene ved oppdrettsnæringen er det store behovet for en kontinuerlig tilførsel av vann. Laksen har et krav til vannmengder som vil variere fra 0,3- til 4,0 liter/minutt pr. kilo fisk, alt avhengig av vanntemperatur og fiskestørrelse.

En av vannkildene til denne næringen er fersk- og salt grunnvann.

En lønnsom oppdrettsnæring er avhengig av god vekst, som igjen er temperaturavhengig. Det største forbruket av energi innen akvakultur i Norge i dag skjer ved temperaturheving av vann i settefiskanleggene. Grunnvannstemperaturene vil for mange lokaliteter gi grunnlaget for god vintervekst med innsparinger på energisiden. Temperaturen vil til enkelte deler av produksjonssyklusen gi optimale forhold, men kan også være grunnlaget for drift av varmpumper som gir et ønsket temperaturløft.

Det største tapsområdet til næringen har vært utbrudd av fiske sykdommer og vanninntakene til produksjonsanleggene har vært en smittekilde. I produksjonssammenheng kan det vises til fordeler ved bruk av grunnvann som gir en stor reduksjon av fiskepatogene mikroorganismer. Bruk av grunnvann vil være med å redusere utbrudd og spredning av fiske sykdommer og oppfyller myndighetenes krav til vannkilder.

Den stabile kvaliteten som vi ofte finner i grunnvannet vil for mange regioner i Norge gi en stabil pH som ligger i et ønsket område. Dette sammenlignet med de årstidsvariasjoner i pH som kan forekomme når fisken får tilførsel av overflatevann.

Et potensiale i norsk akvakultur er bruken av andre arter enn laksefisker og i denne sammenheng gjelder dette hovedsaklig saltvannsfisker. Et spennende forskningsområde er bruken av brakk- og salt grunnvann som vil ha klare fordeler til deler av en produksjonssyklus. Dette gjelder igjen mulige produksjonsfordeler med mer optimale temperaturer og bedre kontroll med patogene bakterier i vannkilder.

## ON THE COMPOSITION, DISTRIBUTION AND GENESIS OF OXIDATE SEDIMENTS

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### Introduction

Oxidate sediments are sediments formed by oxidation of solute ferrous and manganous ions to the tri- and quadrivalent state, respectively. Oxidate sediments can be efficient sinks for heavy metals others than Fe and Mn. This has been regarded as a problem in geochemical exploration, because varying amounts of Fe and Mn oxides in stream sediments may cause heavy metal anomalies that are not related to mineralisation.

### Materials and methods

125 samples of oxidate sediment nodules, crusts and coatings were collected from stream beds and lake bottoms in southeastern Norway. The samples were analysed for up to 52 chemical elements by a variety of methods. Mineral components were identified in 33 of the samples by X-ray diffraction spectrometry and microprobe back-scattered electron image and secondary electron image analysis. Carbon-14 dating was performed on 2 samples.

### Results

A variety of chemical elements occur in wide concentration ranges in oxidate sediments. Depending on location, the elements are enriched or depleted relative to their normal contents in granites. For the HCl soluble fraction of the trace elements, the four highest average enrichment factors are 175(Mo), 164(Cd), 77(U) and 63(W). Maximum enrichment factors for single values may be up to five times higher. These results confirm determination of the contents of trace elements in samples of oxidate sediments can be used as a sensitive method in regional geochemical exploration.

Stream nodules from the northern Oslo Graben were found to have an age of  $1220 \pm 120$  years B.P., while corresponding figures for concretions from lake Storsjøen in the Solør region were  $2760 \pm 200$ .

### Geographical distribution of oxidate sediments

Occurrences of oxidate sediments tend to cluster within large provinces. Such provinces were found to be associated with granites and other acidic rocks. Moreover, our observations indicate that oxidate sediment bearing granites are in general magnetic and connected with major tectonic zones.

### Suggested genesis of oxidate sediments

We suggest that the formation of all types of oxidate sediments follows the same sequences, namely 1) reduction of  $\text{Fe}^{3+}$  and  $\text{Mn}^{4+}$ , 2) dissolution of the bivalent ions and subsequent migration, and 3) reoxidation and precipitation if the dissolved species encounter oxidising environments. The ultimate oxidation agent will be atmospheric oxygen. The reducing agent will vary with the circumstances; the existence of oxidate sediment provinces implies that it must be active over large areas.

Our work has shown that there are no univereal associations between oxidate sediment provinces and features such as bogs, sulphide mineralisations and carboniferous shales. Factors possibly contributing to reduction of  $\text{Fe}^{3+}$  and  $\text{Mn}^{4+}$  are 1) life processes (such as bacterial activity), 2) deep seated reducing gases and 3) cathodes in natural galvanic cells.

**BRØNNBORING I NORGE. HISTORISK OVERSIKT.**

*Tidemann Klemetsrud, NGU-Oslo*

Alt 2 500 år før Kristus hevdes det at kineserne var kjent med brønnboring i fjell. På tegninger og stikk framgår boremaskiner som har stor likhet med det vi hos oss kaller linestøtmaskin, som var enerådende innen norsk brønnboring i 50 og 60 årene. Det kan synes noe merkverdig at kineserne kunne bore i fjell, når jernet ikke var kjent. Jernalderen starter i Kina 700 til 800 år før Kristus.

Brønnboring i fjell ble vanlig i Amerika og Europa utover fra 1970. Først i Norden var som vanlig svenskene. Foranledningen til de første brønnboringer i Sverige var i forbindelse med malmleting. En prøveboring ved Arkø til 35 m gav 450 l krystallklart vann. På bakgrunn av dette resultatet satte den svenske geolog Nordenskiöld i gang 30 prøveboringer i fjell som alle ga godt resultat. Ingen av boringene var dypere en 30m. Nordenskiöld hevdet at det hadde ingen hensikt å bore dypere..

I Norge fulgte geologen A: Helland opp med boringer for en del fiskevær i Nord Norge. Boringenes dyp var fra 30 til 45 m. Alle boringene gav godt resultat, utenom en, som var salt. Brønnene ble boret av Svenske Diamantsbergborrnings Aktiebolag, som fortsatte å bore i Norge til langt ut på 1950 tallet.

Det første norske firma som starter brønnboring i Norge er Norsk Diamantboring omkring 1920. Dette firma hadde tidligere boret etter mineraler for den Norske Stat. Etter krigen og utover 1950 tallet ble det dannet en rekke nye brønnboringsfirmaer. Diamantboreutstyret som til da hadde vært enerådende, ble erstattet av linestøtmaskiner, som boret raskere og krevde bemanning av bare en mann.

I 1951 tok NGU hydrogeologi opp på sitt program. Brønnboringsarkivet ble etablert etter dansk mønster. I 1953 var det totalt registrert ca. 1 300 boringer i fjell. I 1958 ca. 3 000. Utenom geskjeften med brønnboringsarkivet ble det bistått med plasseringer av boringer.

Denne geskjeften utviklet seg raskt utover på 60 og 70 tallet, og medførte at grunnvann som vannkilde ble allment akseptert, ikke bare til mindre enheter, men også til byer og tettsteder, fra rørbrønner i sand - grusavsetninger.

Linestøtmaskinene, som også ble anvendt til brønnboring i løsmasser, ble gradvis fra midten av sekstitallet avløst av hurtigborende trykkluftmaskiner med senkborhammer. Borekapasiteten ble med disse maskinene tidoblet, og medførte at en ny generasjon av yngre startet opp med brønnboring. Midt på syttitallet skjedde en ny revolusjon på borefronten, ved O-dex utstyret

Det nye utstyret medførte at borhammeren ved rørdrijving, ved hjelp av en eksenterarm som ble slått ut når borkrona hadde passert enden på drivingsrøret, både boret under røret og samtidig slo an på en borsko.

De første trykkluftmaskinene var utenlandske, men i 1976 dukket en norskprodusert maskin opp på markedet under navnet Nemek (Nestestog mekaniske) fra Vinje i Telemark.. Denne maskinen er utviklet og råder i dag det norske markedet med ca. 100 maskiner. I tillegg er det levert ca. 120 maskiner til Sverige og Finland.

Når det gjaldt brønnboring var også en av nyvinningene at det kunne bores nær sagt i alle vinkler.. Utenom brønnboring har utstyret stor anvendelighet innen anleggssektoren. Når det gjelder økning av vannkapasitet i borehull i fjell er sprengning en gammel akseptert metode, som gjennom de senere år har blitt avløst av hydraulisk trykking. Dette er en metode som kom fra Amerika på 80 tallet, og som ble utviklet i forbindelse med oljeleting. NGUs bidrag utenom den rene hydrogeologi, er tjenester ved bruk av ulike geofysiske og elektriske målinger.



**LIMING OF WETLANDS IN THE RØYNELANDSVATN CATCHMENT - EFFECTS ON SOIL AND SOIL WATER CHEMISTRY**

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In 1990, wetlands in the Røynelandsvatn catchment in Southern Norway were limed with finely ground limestone powder at a rate of 20 t ha<sup>-1</sup> to remediate acid discharge. JORDFORSK has investigated changes in the chemical properties of soil over a three year period in a selected limed fen.

Calcium (Ca) contents above natural background levels were found in the uppermost 20 cm of the peatsoil. The major part of Ca introduced by liming was in the uppermost 3 cm of the peatsoil. Remaining Ca from liming is roughly estimated to be 2,5-3 t ha<sup>-1</sup>. Similarly, pH of the uppermost cm of the peatsoil of the limed fen was around 7. Deeper peatsoils (> 20 cm) had pH-values around 3,8-4,9. After liming the dominance of hydrogen (H)- and aluminium (Al) ions in the exchangeable cation pool was replaced by Ca in the uppermost cm of the fensoil. In deeper peatlayers (> 20 cm) the exchangeable cations were still dominated by H<sup>+</sup> and Al-ions. A smaller part of organically bound Al in the lime-influenced mire topsoil than in other peatsoil may indicate that Al has changed from an organically bound to a mineral (amorphous) phase.

Similarly, elevated concentrations of Ca and pH-values and decreased concentrations of Al were found in soil water of the uppermost 10 cm of peatsoil. Even four years after liming, concentrations of Ca above natural background values were not found in samples below 20 cm depth.

The liming has changed chemical properties of the uppermost part of the soil. This will counteract acidic and Al-rich input. The results underline the origin of acid-neutralising effects and stress the importance of hydrology and patterns of water flow in the surface layers of mires for neutralisation effects of mire liming.

## DETECTION OF AIRBORNE POLLUTION IN OVERBANK SEDIMENT PROFILES

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**Abstract**

Overbank sediment profiles from floodplains in five drainage basins in east Finnmark, Norway (the Grense Jakobselv river, the Karpelva river, the Sametielva river, the Sandfjordelva river and the Skjellebekken river) were sampled in depth intervals of 1 cm. Every other sample (c.150) were analysed for the HNO<sub>3</sub> soluble fractions of 29 elements by ICP. In addition, all samples (61) from the profile in the Grense Jakobselv drainage basin, were analysed for 32 aqua regia soluble elements by ICP. Loss on ignition was determined on 116 samples. The profiles from The Grense Jakobselv and the Skjellebekken drainage basins were dated by <sup>210</sup>Pb. Their ages show that the floodplains contain sediment deposited before and after the start-up of the smelter. Ni and Cu concentrations in the old sediments are quite stable (10-15 ppm) and originate from local, natural sources. Overbank sediments in the Grense Jakobselv drainage basin show a 3-fold increase of Ni concentrations in the sediment deposited after the start-up of the smelter in 1932, compared to the underlying sediments. Ni concentrations in the post-1932 sediments are higher than expected from the Ni deposition rates in the area (10 mg cm<sup>-2</sup> yr<sup>-1</sup>). It is suggested that the increased Ni concentrations are resulting from both direct deposition of Ni from the smelter, and from natural enrichment mechanisms. Such mechanisms are selective erosion of fine grained, airborne Ni deposits in the drainage basin and subsequent deposition on the floodplains. In addition Ni is probably concentrated in organic matter. In the nearby Karpelva drainage basin, there are also tendencies of increased Ni concentrations in the upper part of the overbank sediments. As concluded by other surveys in the area, the influence of the smelter is less in the three remaining drainage basins. The results indicate that overbank sediment might be a suitable sampling medium for detection of particle bound, airborne heavy metal pollution.

## HEAVY METALS IN THE KVINA RIVER BASIN: STATE OF POLLUTION AND MONITORING OF SPREADING

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### Abstract

Intensive molybdenum mining was carried out by Knaben Molybdenum Mines, Norway in the period 1918-1973. During this time, eight million tonnes of mine waste were discharged into two lakes in the upper part of the Kvina drainage basin. The course of particle bound heavy metals through the drainage basin has been traced by samples of deposited sediment (floodplain surface sediment, overbank sediment profiles, riverbar sediments, stream sediments, and fjord sediments). The influence of river dynamics on spreading was investigated by monitoring of sediment transport. Samples of suspended sediment were collected twice a day in the frost free periods of 1993 and 1994. The acid soluble concentrations of 32 elements in c 600 samples were determined by inducted coupled plasma spectroscopy (ICP), and the organic content was determined as loss on ignition. The overbank sediment profiles had a distinct polluted upper part, with Cu and Mo concentrations 8-50 times higher than the older, underlying sediment. There is no systematic reduction of the enrichment factor with downstream distance from the waste deposit. The Cu and Mo concentrations in floodplain surface, riverbar, and stream sediments were clearly influenced by the mine waste throughout the drainage basin. Mine waste was also incorporated in the fjord sediments. The persistently high concentrations are probably due to the fact that there are few unpolluted sediment sources along the river, resulting in little dilution of the polluted material. The readily erodible mine waste along the river constitutes the main sediment source, and floods are the controlling factors of spreading of particle bound heavy metal pollution.

**ROCK GEOCHEMISTRY RESEARCH PROJECT (RGRP) IN THE GEOLOGICAL SURVEY OF FINLAND: A REGIONAL RESEARCH PROGRAM GIVING BACKGROUND INFORMATION TO ENVIRONMENTAL STUDIES**

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The Rock Geochemistry Research Project (RGRP) was initiated in the Geological Survey of Finland (GSF) in 1991. The main objective of the eight year regional research program, is to acquire a data base including field, analytical and petrophysical data of bedrock from the whole Finland. Except different kinds of petrological classifications, the data enable evaluation of areal background variations of chemical elements in Finnish bedrock, e.g. for studies having environmental purposes.

Samples are taken from outcrops and the sampling density varies from one sample per 30 square kilometres to one sample per 120 square kilometres depending on the degree of lithological variation. The sampling strategy is based on the available bedrock maps and all the major rock types are included. The sampling sites are distributed as evenly as possible and sampling is carried out by portable mini drill with a diamond bit. Each sample normally comprises five sub-samples with all taken from the same lithological unit. Four sub-samples are used for analysis and the fifth is for petrophysical and petrographical studies. The samples are analyzed in the GSF chemistry laboratory for over 50 elements. The main analytical methods are XRF, ICP-MS, ICP-AES and GAAS. The results will be published as regional reports in the GSF report series. The field and analytical data, including petrophysical data, are stored in the Alkemia-data base which also includes data from e.g. till, stream sediment and water thus enabling the simultaneous study of different natural materials.

The sampling stage was finished in 1995 and a total of about 7000 samples was collected until then. The results of the pilot project carried out in the Tampere-Hämeenlinna area in 1989, and the first regional reports will be published in 1996.

## A NEW COMBINATION OF GEOCHEMICAL AND SOIL CHEMICAL INVESTIGATIONS

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There are large variations for many of the factors regulating soil properties in Norway. Natural conditions should accordingly be quite favourable for explaining interesting regularities in soil science. In a lecture in Bergen in 1946 I mentioned this optimistic view and present a diagram showing direct and indirect influences of important soil-forming factors.

Both climate, topography, mineral material and living organisms can vary considerably within relatively small areas. The longest possible time for soil formation is, as a rule, limited to the end of the last glaciation.

Collaboration between the Department of Soils at the Agricultural University of Norway and the National Forest Survey was started in spring 1954. Soon after this, analyses of the chemical composition of precipitation were started. The analytical figures showed large geographical differences.

During a conference at the National Laboratory of Raw Material 01.12. 1959 I proposed a wider cooperation including collecting forest humus samples for analysing elements of interest in geochemistry. After that time Bjørn Bølviken and I have had close research contact.

The expenses for collecting forest humus samples were relatively low owing to the combination to the ordinary work of the Forest Survey. A similar combined activity was started in Sweden a few years later.

A comparison of figures of humus samples from the county of Nord-Trøndelag, collected in 1960, showed a relative decrease of the seasalt elements sodium and magnesium with increasing distance from the coast. Somewhat similar distribution patterns were later found for chlorine, bromine, iodine and selenium. The concept chemical climate was introduced. Comparatively comprehensive geomedical investigations were started, partly on the basis of these results.

Geomedicine is the science dealing with the influence of ordinary environmental factors on the geographical distribution of health problems in man and animals. The Norwegian Academy of Science and Letters established a geomedical committee where Bølviken is a member. The committee has arranged, partly alone and partly together with other organizations, 9 geomedical symposia resulting in proceedings. Bølviken has contributed to 8 of them.

## GEORADAR VED KARTLEGGING AV IMPERMEABLE AVSETNINGER VED ENGLANDSSKOGEN I ALTA

by *Eirik Mauring, Tidemann Klemetsrud & Jan Steinar Rønning, NGU*

I forbindelse med sikring av grunnvannsforekomst ved Englandsskogen i Alta er det utført georadarmålinger. Målingene ble utført for å kartlegge utbredelsen av et område med silt/leir-dominert materiale mellom grunnvannsbrønner og en trafikkbelastet veg like nord for brønnene. Det var av spesiell interesse å få vurdert hvorvidt silt/leir-materialet opptrer på en slik måte at det hindrer innstrømming av forurensning fra vei mot brønnområdet ved eventuelle uhell/ulykker.

Georadar ble valgt som målemetode fordi den ofte er anvendelig ved kartlegging av grunnvannsspeil og lagdeling/strukturer i løsmasser. Metoden er basert på at elektromagnetiske (EM) pulser sendes ned i jorda og blir reflektert fra grenseflater som representerer endring i dielektrisitet. Reflekterte pulser blir registrert av en mottakerantenne på overflaten. I geologiske materialer representerer variasjoner i dielektrisitet endringer i vanninnhold. Dybde- rekkevidden (ved 50 MHz antennesystem) kan være i størrelsesorden 10-40 m i grovkornige avsetninger, men betydelig mindre i finkornige avsetninger på grunn av økt ledningsevne og dermed større demping av EM-bølgene.

Løsmassene i brønnområdet er tilknyttet en randavsetning der massene er dominert av sand/grus med stein. Mellom brønnområdet og veien opptrer finstoffmateriale (marint) under fluviale avsetninger i følge tidligere utførte boringer. Georadaropptakene viser tydelig grunnvannsspeil og skrå lagdeling i området ved grunnvannsbrønnene. Ca. 25-50 m fra brønnområdet i retning mot veien viser georadaropptakene en tydelig reflektor som opptrer på 2,5-10 m dyp. Under denne sees verken fritt grunnvannsspeil eller skrå lagdeling, og reflektoren representerer trolig overflaten av finstoffmateriale. Reflektoren ligger grunt (2,5-4 m) og opptrer høyere enn nivået på grunnvannsspeil mot brønnområdet. Dette indikerer at finstofflaget opptrer som en barriere mot avrenning fra vei mot brønnområdet ved eventuelle uhell/ulykker. Ut fra georadarundersøkelsene kunne en konkludere med at ingen spesielle tiltak ville være nødvendig for sikring av veitrasé.

## HYDROCHEMISTRY AND DRINKING WATER QUALITY OF SHALLOW GROUNDWATER IN LITHUANIA

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In Lithuania, shallow groundwater is used for drinking and household needs by about a million of population taking it from 300 thousand dug wells. Chemical composition of shallow groundwater in the dug wells, drilled wells and springs is studied by two institutions in Lithuania: Geological Survey of Lithuania and State Nutrition Centre.

Hydrochemical data is stored in the computer data base applying the EXCEL software at the Geological Survey of Lithuania. At present, there are over 8 thousand data in the data base. The majority - about 7 thousand - is related to dug wells, less to springs and drilled wells. The hydrochemical data cover the following main parameters: pH, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, Ca, Mg, Na+K, NO<sub>3</sub>, NO<sub>2</sub> and NH<sub>4</sub> concentrations, total hardness, organic (according to KMnO<sub>4</sub> consumption). Depending on the information source, these data are supplemented by the parameters of aquifer deposits (data of the Geological Survey of Lithuania) and/or microbiological and physical characteristics (data of the State Nutrition Centre).

In order to determine regional regularities in changes of chemical composition for shallow groundwater and evaluate drinking water quality, the 4 thousand hydrochemical data of geological mapping scale 1:200 000 and 1:50 000 have been applied. The statistical analysis has been carried out within the EXCEL software package.

As a result of processing of hydrochemical data the regional regularities of shallow groundwater chemistry formation and drinking water quality have been determined.

Salinity of shallow groundwater ranges from 0.06 to 3.4 g/l. Clay deposits are notable for higher salinity than sand deposits: 23% of water samples taken from clay deposits are mineralized and 17% - from sand deposits. Groundwater of low salinity (up to 0.5 g/l) is formed in the upland areas of sandy and rarely cultivated lands. Mineral water is formed mainly in the

clayey lowlands of Lithuania. These areas are under most intensive agriculture activities. Another source of mineral water is formed by artesian mineral water discharge in South and Middle Lithuania rivers valleys.

Concentrations of all main chemical components, except for iron, are higher in the water of clayey deposits if compared those to water of sandy deposits (Table 1). Salinity is well-correlated with main ion concentrations: Cl, Ca, Na+K, Mg, SO<sub>4</sub>, HCO<sub>3</sub> and NO<sub>3</sub>. Their correlation coefficients vary, respectively from 0.843 to 0.608. The organic (according to KMnO<sub>4</sub> consumption) and NH<sub>4</sub> content does not depend on salinity; their correlation coefficients are 0.13 and 0.05, correspondingly. Depending on different physic-chemical conditions, the increase of concentration of chemical components is different. As a result, the relative amounts and priorities in the formation of chemical water type change.

HCO<sub>3</sub> and Ca ions prevail in 90% of samples. Four chemical types of water are distinguished. Three of them, determined for 90% samples, reflect changes in chemistry under the conditions of anthropogenous load.

The difference of chemical composition of shallow groundwater of sandy and clayey deposits predetermines different quality of drinking water of them. The basic quality differences are very obvious on salinity and total hardness. So, water formed in sandy deposits is of better quality, according to these indices, than that in clayey deposits: only 7% of them exceed MAC (Lithuania) for salinity (1000 mg/l) and 21% accordingly for total hardness (7 mg-ekv/l). In the case of clay deposits - 25% and 60% accordingly.

Lithology of deposits has no affect on concentrations of nitrates and organic. Water pollution with nitrates (42-43% of samples) and organics (37-43% of samples) was found equal in both lithological types of deposits (Table 2).

Shallow groundwater of good quality, corresponding to the Drinking Water Quality Standard (Lithuania) according to all parameters, is defined the hydrochemical data of 13% in sand deposits and 7% in clay deposits.

Chemical composition and quality of drinking water in the dug wells and drilled wells or springs is different. Hydrochemistry of dug wells is being formed under the conditions of anthropogenous load at the urban territories. Therefore concentrations of all main components (except for iron and ammonium) are the highest if compared to those in drilled wells and springs. Drilled wells and springs are at remote and accordingly less polluted areas.



Dug well's water is most affected by anthropogenous pollution, hence, its quality is the worst, judging by nitrates and total hardness, i.e. 48% of nitrate and 60% of total hardness values exceed MAC (Lithuania) The values for drilled wells are lower - 20 and 37% correspondingly (Table 2).

On 1993 -1994 in cooperation with State Nutrition Centre the chemical composition of about 3 thousand water samples from dug wells in different parts of Lithuania were investigated. The aim of this cooperation is to get a rapid estimation of drinking water quality of shallow groundwater and further to control it at hygienic monitoring network of dug wells. The map of shallow groundwater quality for all counties of Lithuania is compiled according to these dug well data The maps are compiled on GIS topographic background scale 1:200 000 applying the MAPINFO software (Fig.2).

**UNDERSØKELSER AV VANNKILDER FOR EKSPORT, NORDLAND FYLKE**

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Nordland ligger fjernt fra de store kildene til lufttransportert forurensning, og ingen forurensende aktivitet er registrert i nedbørsfeltet i de undersøkte områder. Det gjennomførte analyseprogrammet viser gjennomgående god vannkvalitet ved samtlige undersøkte kilder. Tar en hensyn til både vannføring og kvalitet peker kilden Jordelvhav i Sørfold kommune seg ut. Et pluss her er fin beliggenheten samt nærliggende industrianlegg med dypvannskai. Kilden ved Kattdalen i Saltdal kommune er best undersøkt, men lav vannføring i vinterhalvåret (ca. 1 l/s) kan være et problem, det er imidlertid flere kildeutslag i nærheten som kan kobles sammen. Lav vannføring i vinterhalvåret er også et minus for kilden Gjerskogkjelen i Gildeskål kommune, men ved denne kilden er målingene mer usikre. Kilden ved Skauvoll har god vannføring, men beliggenheten nedenfor riksvei 17 trekker ned på helhetsinntrykket. Isvannet, Vestrenøkkvann og Storvannet kan være aktuelle for eksport av vann innen kategorien bordvann. Dette vannet kan behandles i henhold til de nye drikkevannsforskriftene fra Helse- sosialdepartementet (1995). Det er ikke foretatt befaring ved disse kildene, men den registrerte vannkvaliteten er gjennomgående god.

Prøveprogrammet viser at det er en klar sesongavhengig variasjon mellom vannføring og innhold av kjemiske elementer. For at kildeutslagene skal kunne betegnes som 'naturlig mineralvann' er det krav til at de «ikke påvirkes av mulige variasjoner i vannets bevegelse i grunnen» (forskrift om naturlig mineralvann, Sosial- helsept. 1993). Det er imidlertid et åpent spørsmål hvor trang definisjon som brukes for variasjonen av de enkelte parametre. Målinger ved bakgrunnsstasjonen ved Tustervatn viser klar sammenheng mellom nedbørsmengde og innhold av Na og Cl. For noen kilder vil det derfor være en økning i Na og Cl under snøsmelting og høstregn. De viktigste kriteriet bør likevel være å vise at kildevannet er fritt for 'skadelige' bakterier og at det har en tilstrekkelig lang oppholdstid i grunnen.

Generelt sett har vannet som er prøvetatt i Nordland et lavt innhold av mineraler. Dette er ikke nødvendigvis en ulempe; forskjellige vannkvaliteter passer til forskjellige kulturer. Mens en i Øst-og Sentral Europa er vant til å drikke mineralrikt vann (nærmest brakkvann i Litauen), kan det f.eks. i Japan være et marked for vann med lav til meget lavt mineralinnhold, slik det er funnet i Nordland. Vannet fra Kattdalen og Jordelvhav er klassifisert som kalsium-bikarbonatvann med lavt mineralinnhold, i motsetning til Farris, som har et mye høyere mineralinnhold og med natrium-klorid som hovedkomponenter. Dersom en ønsker å drikke vann av typen natrium-klorid, men med lavere mineralinnhold enn Farris, kan overflatevannene Vestrenøkkvann og Storvannet, med eller uten tilsetning av kullsyre (CO<sub>2</sub>), være mulige kandidater innen kategorien bordvann.

## BRUK AV GRUNNVANN I NORGE

Geir Morland og Jørgen Ekremsæter, NGU

Befolkningsmønsteret i Norge basert på folketellingen i 1980 er digitalisert. Dette mønsteret har generelt ikke endret seg vesentlig de siste femten årene. Statistisk Sentralbyrå (SSB) definerer tettbygde strøk som områder med minst 200 bosatte der avstanden mellom husene som regel ikke overstiger 50 meter. I dag representerer disse byene og tettstedene ca. 73% av landets befolkning.

Opplysninger om de ulike vannverkens vannkvalitet er sammenholdt med størrelse og beliggenhet av byer og tettsteder som defineres som tettbygde strøk. Av de drøyt 3,1 mill. mennesker som pr. 1. jan. 1994 bor i tettbygde strøk, forsynes ca. 86% (448 byer og tettsteder) fra vannverk basert på overflatevann og ca. 6% (108 byer og tettsteder) fra vannverk basert på grunnvann. For ca. 8% (322 byer og tettsteder) har vi ennå ikke innhentet opplysninger.

Av de 448 byene og tettstedene som i dag forsynes med overflatevann, tilbyr langt de fleste sine innbyggere vann av god kvalitet. 187 byer og tettsteder har imidlertid for dårlig vannkvalitet, noe som gjelder ca. 400.000 personer. Etter en gjennomgang av NGUs arkiver, anses det at 109 av disse byene og tettstedene, med tilsammen ca. 175.000 personer, kan ha muligheter for grunnvannsforsyning. Av de 40 norske byene med mer enn 10.000 innbyggere, er det kun seks byer som har etablert vannforsyning basert på grunnvann (3,7% av de 40 byenes befolkning). Dette gjelder Lillehammer, Kongsberg, Elverum, Kongsvinger, Hønefoss og Alta. Dette viser at grunnvann i det alt overveiende er benyttet til mindre vannforsyningsanlegg og enkeltanlegg.

Tidligere undersøkelser har vist at ca. 13% av Norges befolkning har grunnvann som vannforsyningskilde. Andelen av befolkningen som forsynes med grunnvann og som samtidig bor i tettbygde strøk er kun 4,2% av landets befolkning. Dette betyr at av alle personer som bor i spredtbygde strøk, har rundt 30% grunnvann som vannforsyningskilde.

## ACIDIFICATION AND THE HYDROCHEMISTRY OF ALUMINIUM IN SOILS, GROUNDWATER AND SURFACE WATER

by Jan Mulder, NISK

Aluminium, one of the dominant elements in the earth's crust, is potentially toxic for biota. Fortunately, the solubility of this metal is generally low. Only where soils are acidic may aluminium concentrations be considerable (a) due to metal complexation by dissolved organic acids, or (b) due to high inputs of strong mineral acids. Here, data will be presented with respect to the behaviour of aluminium in acidic soils, with an emphasis on the effects of acid deposition. The presentation will focus on (1) sources (2) solubility controls and (3) transport of dissolved aluminium. Quantitative examples of vertical transport of dissolved aluminium in sandy soils to the groundwater will be given for sites in The Netherlands. The potential for vertical and lateral aluminium transport in Norwegian forest soils, which are typically shallow, as well as the potential for the transfer of aluminium to surface water will be illustrated with examples from the acid-rain impacted Birkenes catchment (Aust Agder) and the relatively unpolluted Høylandet site (Nord Trøndelag).

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## A GEOCHEMICAL ATLAS OF SOUTHERN NORWAY

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A high quality regional geochemical database presents information on the natural distribution and variability of chemical elements in different media on the earth's surface. Techniques originally developed in the early 1950's for mineral exploration purposes are well suited to providing data urgently needed by policy makers as a base for setting meaningful action levels for heavy metals in the environment and for the interpretation of environmental studies. The enormous economic consequences of setting action levels without any knowledge of regional geochemical background variations to society are still not realized to their full extent.

North of Trondheim, Norway is relatively well covered with regional geochemical data from different media collected at widely varying sample densities for mineral exploration purposes. From southern Norway, however, no regional geochemical datasets exist other than one from an overbank survey covering the whole of Norway at a density of one sample per 450km<sup>2</sup>. There are, however, a number of stream sediment datasets from different areas, collected in different years, providing some base data for southern Norway. This project attempts to collect all these presently scattered information into one dataset and to present geochemical maps giving a preliminary overview of the distribution of chemical elements in stream sediments from southern Norway.

The very nature of the data sets used, widely scattered throughout southern Norway, combined with very high sample densities in certain areas, results in a number of problems related to map presentation and interpretation of the results. In addition to geochemical maps, data are presented in the form of different graphical summaries, including box-plot comparisons of element levels and variability in the different counties and lithologies as taken from the geological maps. These plots can be directly used to distinguish normal element contents and variations for any on area/lithology from unusual results.

The datasets were collected for mineral exploration purposes and are of limited use for environmental studies (e.g. selection of elements analysed). Presently we are still in the process of evaluating which elements can be presented. The need for more detailed geochemical mapping to provide information on the natural distribution of heavy metals in the most densely populated areas of the country is clear.

**RENSING AV LØST JETDRIVSTOFF I UMETTET SONE PÅ GARDERMOEN.****Hvordan påvirkes prosessen ved tilførsel av avisningsvæske**

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Oslo hovedflyplass bygges på Gardermoen over en av Norges største grunnvannsmagasiner. Moderne flyplassdrift kan true disse grunnvannsressursene hvis utslipp av jetdrivstoff og avisningskemikalier skulle trenge ned til grunnvannet. I hvilken grad vil beskyttelsen og rensning gjennom umettet sone kunne hindre nedtrengning?

Vi har ved laboratorieforsøk undersøkt hvordan den vannløselige fraksjonen av jetdrivstoff vil bindes, nedbrytes og transporteres i den umettede sonen. Våre analyser viser at jetdrivstoff har en løselighet i vann på omtrent 20 mg/l. Den vannløselige delen består hovedsakelig av de aromatiske hydrokarbonene toluen, etylbensen, xylene, trimetylbensen og naftalen. Basert på naturlig vannløselighet ble det laget en representativ modelløsning bestående av toluen (2mg/l), o-xylene(4 mg/l), 1,2,4-trimetylbensen(4 mg/l) og naftalen(2 mg/l).

Uforstyrrede jordsylindere fra aktuelt område for jordrensning ble tatt både fra de øvre 50 cm med podsolutvikling og fra 2-2.5m dyp med mineraljord. Fra hvert lag ble det kjørt 4 parallelle kolonner med gjennomstrømning av den hydrokarbonholdige modelløsningen: en med bare modelløsning, en med avisningskomponenten KAc (10 g/l), en med næringsstoffer N/P, og en med både KAc (10 g/l) og N/P. Det var umettede forhold i kolonnene hele tiden med en hydrauliske belastning på 50 mm pr døgn.

I kolonnene med organisk rik toppjord ble ingen hydrokarboner detektert i løpet av de 45 døgn som forsøket varte, hvis ikke KAc var tilstede. Med KAc derimot, slapp o-xylene gjennom etter 10 døgn, med en maksimumskonsentrasjon på 60 (g/l etter 40 døgn. Tilførselskonsentrasjon var 12 mg/l. Kolonnene med mineraljord viste dårligere retensjon. Selv uten KAc slapp det gjennom hydrokarboner i detekterbare mengder etter 4 døgn. Etter en initiell tilpasningsfase fikk man imidlertid brutt ned hovedmengden av hydrokarbonene. I nærvær av KAc ble nedbrytningen hemmet slik at renseevnen ble betydelig redusert. Tilsetning av små mengder nitrogen og fosfor hadde ingen merkbar effekt.

Den naturlige toppjorda viste god renseevne for løst jetdrivstoff, med en fjerningshastighet som er sammenlignbar med tilsvarende laboratorie- og feltforsøk i USA/Canada. Nærvær av KAc reduserte hastigheten merkbart og må unngås. Denne reduksjonen skyldes etter alt å dømme oksygenbegrensninger og/eller substrat konkurranse. Disse forsøkene viser at skreddersydde jordreanseanlegg burde være et høyst aktuelt alternativ i rensing av overvann med drivstofforurensninger.

## OVERBANK SEDIMENT: A SAMPLE MEDIUM FOR ENVIRONMENTAL STUDIES

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### ABSTRACT

Chemical analysis of lake sediment cores have commonly been used to describe the pristine conditions and changing chemical environment through time. However, the sample type suffers from several drawbacks, e.g. sampling difficulties, vertical migration of elements due to biological activity, decomposition of organic matter, resuspension and re-sedimentation and circulation of water. Overbank sediment on floodplains consist like lake sediment of nearly horizontal strata. They are deposited in flood situations in river systems. In these situations, sediment supply is rich. A vertical section through overbank sediment reflect the history of sedimentation, such a section will give a picture of the chemical and mineralogical conditions back through time. Recent floodplains contain sediments deposited during the last 400 - 4000 years. The mobility of chemical elements in overbank sediment profiles were studied in 46 floodplains. Both acid- and water soluble elements were determined by ICP. The porosity and permeability were calculated from grain size distribution in all profiles. The results indicates:

- The permeability is good. Rain and river water drains rapidly through the profiles.
- There are little decomposition of organic matter.
- The soil development is unmaturing.
- The vertical migration of chemical elements is limited.
- The chemical and mineralogical history is well preserved in the profiles.
- The samples are easily collected.
- Overbank sediment are suited for environmental studies.

## EKOGEOCHEMISTRY KOLA - SELECTED RESULTS

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The Geological Surveys of Finland (GTK) and Norway (NGU) and the Central Kola Expedition (CKE) are carrying out a major collaborative regional geochemical mapping project in a 188,000 km<sup>2</sup>-area north of the Arctic Circle in the three countries involved. The aims are to establish regional geochemical maps of the distribution of heavy metals and radionuclides in this ecologically vulnerable area, and to assess the impact of the nickel smelters at Nikel and Monchegorsk and as of other heavy industries in this area on the environment.

As a preparation for the major mapping project, a pilot study was carried out in the surroundings of the nickel smelter and mine at Nikel and Zapoljarniy, close to the Norwegian and Finnish borders, taking a variety of sample media (snow, stream water, terrestrial moss, A<sub>0</sub>-horizon-soil, C-horizon-soils, stream sediment and overbank sediment) at 15 stations in each of the three countries.

In addition, a detailed study of 8 small catchments from the whole project area (4 in Russia, 3 in Finland, 1 in Norway) was carried out as part of the main project, studying element contents in precipitation (snow and rainwater), vegetation (terrestrial moss), soil («topsoil 0-5 cm» and podzol profiles), stream water, organic stream sediment, quaternary deposits and bedrock and, in some catchments, groundwater.

Results indicate that precipitation is especially well suited to «fingerprint» the emission spectrum from the different industries in the area. Moss (*Hyloconium splendens*) is very well suited to map the regional extend of airborne pollution. However, moss is no longer present at the most polluted localities and is not as well suited for «fingerprinting» of a large suite of elements as precipitation because of the preferred uptake of certain elements. A<sub>0</sub>-horizon soils are suited for regional mapping as well, but may create some problems with interpretation in the background areas due to geogenic input, which can be avoided when sampling moss. In addition, organic soil horizons are absent in the most polluted areas due to severe environmental damages. Stream water delineated the extend of contamination very nicely and is a very cheap and practical sampling medium. The other media present a varying degree of mixture of geogenic and anthropogenic influences, and cannot be easily used for mapping the anthropogenic element input but are needed for the interpretation of the results.



**COMPARISON OF HEAVY METAL CONTENTS IN A<sub>0</sub>- AND C-HORIZON SOILS FROM THE SURROUNDINGS OF NIKEL, KOLA PENINSULA, USING DIFFERENT GRAIN SIZE FRACTIONS AND LEACHES**

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The Geological Surveys of Finland and Norway in cooperation with the Central Kola Geological Expedition in Russia presently carry out a large geochemical mapping programme in the three states border area in the Barents Region, covering an area of approximately 170.000 km<sup>2</sup>. Sample media are terrestrial moss, humus (A<sub>0</sub>-soil), topsoil 0-5cm, and complete podsol profiles. In the centre of the area are the nickel smelters of Monchegorsk and Nikel, polluting the environment since more than 50 years.

As a preparation for the major mapping project a pilot study has been carried out in the surroundings of the nickel smelter at Nikel, close to the Norwegian border, taking a variety of sample media at 15 stations in each of the three countries. Two of these media were A<sub>0</sub>-soil and C-soil. Different leaches and different sieve size fractions of these samples were analysed to aid the decision on the best suited approach for the main project. The analytical results were compared using graphical exploratory data analysis methods.

The different leaches used resulted, of course, in different heavy metal levels. There is, however, a very close correlation between Ammonium Acetate leach and HNO<sub>3</sub>-leach of the A<sub>0</sub>-soils for the major contaminants. The different grain size fractions used for the C-soil samples show some marked differences. In general, however, independently of grain size fraction or leach used, the regional extent of the contamination can be easily outlined.

An interesting result of these studies was that the contamination of the upper soil layer in the investigated area is so extreme that the correlation between the A<sub>0</sub>-soil and its parent material, the C-soil, is totally lost. The contamination can be clearly outlined when using the A<sub>0</sub>-soil, no matter which leach is used, while the C-soil-samples still describe the background contents of the heavy metals in the area. Heavy metal contents of stream water samples taken from the area show a strong correlation with the A<sub>0</sub>-soil samples, but not with the chemistry of the C-horizon soils, hence demonstrating the easily leached heavy metal input from the smelters to the upper soil layer and the fact that the final sink is the aquatic system.

## TRACE ELEMENT CONTENT OF 150 HARDROCK GROUNDWATER SAMPLES FROM THE SURROUNDINGS OF BERGEN AND OSLO

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In 1994, several hundred private drinking water wells drilled in different hardrock lithologies in the surroundings of Oslo and Bergen were sampled for the analysis of Rn and F. Sampled were household tap waters after the water was left running for 5 minutes. At the same time a second set of samples was taken for chemical analysis to study the content and variation of elements not routinely analysed in drinking waters. The samples were collected in 100 ml PE-bottles and neither filtered nor acidified in the field.

The first set of samples was analysed at the Norwegian Radiation Protection Agency for radon contents and both at the Norwegian Foodstuffs Directorate in nordre Vestfold and the University of Bergen for fluoride. A total of 150 samples of the second set were selected at the Geological Survey of Norway to give a good aerial coverage and to include well waters from all lithologies present in the survey area. These were forwarded to the method development laboratory of the Geological Survey of Canada (GSC) for further analysis. After arrival at the GSC laboratory, the samples were acidified with 10 ml of ultrapure HNO<sub>3</sub>, shaken for 24 hours and analysed for (in brackets: detection limit in µg/L): Ag (0.05), Al (2), Ba (0.2), Be (0.005), Cd (0.05), Ce (0.01), Co (0.02), Cr (0.1), Cs (0.01), Cu (0.1), Dy (0.005), Er (0.005), Eu (0.005), Fe (5), Gd (0.005), Ho (0.005), In (0.01), La (0.01), Li (0.005), Lu (0.005), Mn (0.1), Mo (0.05), Nd (0.005), Ni (0.1), Pb (0.1), Pr (0.005), Rb (0.05), Sb (0.01), Sm (0.005), Sr (0.5), Tb (0.005), Tl (0.005), Tm (0.005), U (0.005), V (0.1), Y (0.01), Yb (0.005) and Zn (0.5) by ICP-MS, and for Ca (0.2 ppm), K (0.1 ppm), Mg (0.2 ppm) and Na (1 ppm) by ICP-

AES. 17 samples, selected at random, were then sent on to BGR in Germany for control analysis. Two elements were analysed with lower detection limits here (Ag and In) and a number of additional elements to those listed above were determined: As, B, Bi, Br, Ga, Ge, Hf, Hg, I, Nb, P, Sc, Se, Sn, Ta, Te, Th, Ti, W and Zr. The concentrations for 64 elements can therefore be reported for 17 of the samples.

For Ag and In, most values returned were below detection. For Cd, Co, Eu, Ho, Lu, Ni, Tb, Tl and Tm, more than 50% of all samples gave values below detection. A further reduction in the detection limits is needed for these elements. For all other elements, more than 50% of all samples were above detection. The spread of data covers between 2 and 6 orders of magnitude. Maximum obtained values are (in µg/L): Ag (0.07), Al (2537), Ba (237), Be (2.2), Ca (88000), Cd (0.64), Ce (232), Co (4.9) Cr (5.9), Cs (1.6), Cu (1332), Dy (1.7), Er (1.3), Eu (1.1), F (9200), Fe (5323), Gd (3.8), Ho (0.36), In (0.012), K (24000), La (112), Li (60), Lu (0.37), Mg (33000), Mn (2975), Mo (289), Na (508000), Nd (49), Ni (6.9), Pb (57), Pr (15) Rb (17), Rn (6840Bq/l), Sb (0.78), Sm (6.2), Sr (1871), Tb (0.38), Tl (0.16), Tm (0.23), U (2018), V (11.5), Y (18.5), Yb (1.85), Zn (1325).

## SNOWPACK SAMPLING USED TO FINGERPRINT ENVIRONMENTAL CONTAMINATION IN THE SURROUNDINGS OF THE NICKEL SMELTER AT NIKEL, KOLA PENINSULA, RUSSIA

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A large cooperation project on the environmental pollution of the Kola Peninsula and neighbouring territories is carried out by the Geological Surveys of Finland (GTK) and Norway (NGU) and the Central Kola (Geological) Expedition (CKE) in the years 1992-1996. 45 snowpack samples were collected in March/April 1992 in Finland, Norway and Russia from the surroundings of the nickel smelter at Nikel, Kola Peninsula, Russia as one part of this project. The samples were delivered to GTK's laboratories, carefully molten and filtered through blue ribbon cellulose acetate filters. The filtrates were analysed by ICP-MS for 29 elements (Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Si, Sr, Tl, U, V and Zn), for the anions Br, Cl, NO<sub>3</sub> and SO<sub>4</sub> by ion chromatography, for F, pH and electrical conductivity by potentiometry and for alkalinity by titrimetry.

The filters were digested in conc .nitric acid (microwave oven) and analysed by ICP-MS and ICP-OES for above list of elements plus La, P, S, Sc, Th, Ti and Y to distinguish «wet»deposition from particulate deposition.

Results indicate that snowpack sampling in combination with an analytical technique guaranteeing very low detection limits are a very powerful tool to fingerprint the emission of a large pollution source such as the nickel smelter. The element contents observed in the study area are governed by at least three different processes: (1) seaspray input from the Barents Sea, (2) dust input from local geogenic or anthropogenic sources and (3) the environmental pollution coming from industry.

**PREDICTION OF POST-CLOSURE MINE PIT LAKE GEOCHEMISTRY**

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A geochemical model was designed to simulate the water quality of a 34m deep lake predicted to form after closure of an open pit mine in the western US. The wall rocks in the pit walls are composed of potentially sulfide-bearing Tertiary volcanic rocks. The chemistries of the first 25 pore volumes of groundwater flowing into the lake were expected to be affected by the oxidation of the sulfide-bearing wall rocks, as simulated by kinetic humidity cell and column testing, followed by lake filling with clean background groundwater and meteoric precipitation. Limnologic modeling using CE-THERM-R1 and CE-QUAL-R1 predicted that an anoxic bottom would develop and that lake overturn would occur annually. A conservative estimate of the pit lake water quality during and after filling was modeled by combining the geochemical codes PHREEQE and MINTEQA2. A mixing scenerio was conducted with the allowed precipitation of gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), manganite ( $\text{MnO}(\text{OH})$ ), otavite ( $\text{CdCO}_3$ ), and amorphous ferric hydroxide ( $\text{Fe}(\text{OH})_3$ ) with allowed metal sorption. The first 25 pore volumes had pH values below 5.2 which increased to 8.4 with the addition of clean groundwater. The precipitation of amorphous ferric hydroxide and gypsum occurred at lower pH values and were constrained by iron and calcium. The low pH of the waters limited the sorption potential of the amorphous ferric hydroxide but minor sorption of sulfate, lead, copper, cadmium, zinc, and arsenic occurred. Manganite and otavite precipitated under higher pH conditions. The modeling showed that oxidized rinse-out resulted in elevated concentrations of cadmium, manganese, selenium, zinc, sulfate, and TDS. The addition of background groundwater and meteroric water significantly improved the modeled pit lake water quality. Modeled evaporation showed that water was replaced by clean groundwater and therefore did not degrade the modeled pit lake water quality. Appreciation is expressed to Santa Fe Pacific Gold Corporation, and Mr. John Young, project manager, for support and permission to publish this work.

## GEOCHEMICAL MAPPING IN FINLAND DURING PAST 25 YEARS

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Regional geochemical mapping began in Finland in the beginning of the 1970's. The original goal was to produce maps covering one third of the country in the areas most critical for the occurrence of ore deposits. But as the methodology developed, the usefulness and the need for geochemical mapping data expanded.

It became necessary to adopt a systematic approach, and according to this concept, a geochemical mapping programme begins with reconnaissance scale surveys, usually covering the entire country. During this phase, an overview of the geochemical landscape is obtained over large areas based on very sparse sampling and large number of elements. This is followed by regional scale mapping to delineate geochemical provinces that are several tens of square kilometres in area. This consolidates the information about the geochemistry of a study area and enables an evaluation of whether geochemical prospecting techniques are applicable in a given area. Local and detailed scale studies follow in selected areas producing data used for prospecting and environmental purposes.

To date, Finland has been entirely surveyed at two different scales: 1) 1:2 mill. reconnaissance scale, with sampling density of one site per 300 km<sup>2</sup>; and 2) 1:200,000 regional scale, with one sample site per 4 km<sup>2</sup>. Till, stream water, organic stream sediment and ground water were used as sampling media in the reconnaissance scale mapping. In the regional scale programme, till, organic and clastic stream sediments and lake sediments were collected at first. But it was soon realized that in the geological conditions prevailing in Finland, till is the most appropriate sampling material because, having derived directly from bedrock, it represents the bedrock better than the other media. The sediments, on the other hand, are mostly derived from till and during erosion and sedimentation, they are modified to the extent that interpreting geochemical data derived from them is very complicated compared to data derived from till. After the geochemical mapping of the overburden, a thorough regional study of bedrock geochemistry is now going on in order to complete the knowledge of geochemistry of Finland.

The Geochemistry department of GSF acquires and manages the geochemical data from glacial and post glacial deposits, lake sediments, stream sediments (mainly organic) stream water, ground water, and bedrock. Most of them are published and are available to both Finnish and foreign researchers; they are stored in a relational database called ALKEMIA.

The interpretation of regional geochemical data and the application of systematic follow-up procedures has recently resulted in several promising ore finds in Finland. Also users for the data from environmentalists, from forest researchers, from researchers for medical geology, from governmental authorities etc. have appeared, and some modifications of methods were accordingly done.

## A GROUNDWATER VULNERABILITY ASSESSMENT OF KORGEN WATERWORKS, LILLEHAMMER

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Korgen waterworks is today the principal water source for Lillehammer kommune and was upgraded in 1993 to provide for the increased demand during the Winter Olympic Games in February 1994. The study described here is the result of a collaboration between the Geological Survey of Norway, Berdal Strømme a.s., Jordforsk and Intergraph Norge a.s..

The objective of the study was to assess the risk of groundwater pollution at the Korgen waterworks through a consideration of the potential pollution sources and their impact following a hypothetical pollution event. The study included: i) the collation of existing data, ii) the production of a digital terrain model, iii) a MODFLOW 3-d finite-difference groundwater flow model, iv) a MODPATH particle tracking model, v) a groundwater vulnerability assessment and vi) a groundwater protection zone scheme proposal. This study is intended to demonstrate an alternative approach to assessing the pollution vulnerability of the waterworks through the use of mathematical modelling techniques. A three-layer MODFLOW finite-difference groundwater flow model was coupled to the particle-tracking model MODPATH which was used to determine groundwater pathlines and travel times.

The MODFLOW groundwater flow model was successfully calibrated using the available geological and hydrogeological data. The MODPATH particle tracking studies indicate that the main groundwater source for the waterworks is from the Lågen to the west. Groundwater travel times to the wellfield are low. Five potential pollution sources were identified: i) the Lågen, ii) the Bæla stream, iii) a road traffic accident on the E6, iv) a railway accident on the Oslo-Trondheim line northeast of the wellfield and v) the quarry in the Hovemoen area.

The Korgen waterworks is vulnerable to a pollution event in the Lågen. The short travel times mean that both bacteriological and chemical pollution are potential problems. However, a corollary of this is that rapid flushing of the aquifer would be possible should a pollution event occur. Infiltration from the Bæla stream is not considered to pose a serious pollution threat across the Korgen fan as infiltration from the Bæla is very low under normal conditions. During flood conditions, when significant infiltration may occur, dilution of any pollutants is likely to significantly reduce the pollution threat. The MODPATH simulations showed that the E6 road, the railway line and the quarry in the Hovemoen area pose no significant pollution threat to the waterworks.

Three groundwater protection zones are suggested. Zone I is based on the 60 day travel time to the wellfield recommended by the Norwegian State Institute for Public Health (SIFH). Zone II is designated as the groundwater recharge area supplying the Bæla fan area, including the Korgen waterworks. Zone III represents the surface water catchment area and the Hovemoen area.

## LONG-TERM CHANGES IN NORWEGIAN SURFACE WATER CHEMISTRY IN RESPONSE TO CHANGES IN ATMOSPHERIC DEPOSITION

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In order to evaluate the cause-effect relationships of acidification and the changes over time, a monitoring programme for long-range transported air pollutants covering deposition, surface- and groundwater, soil, fish populations and invertebrates was initiated by the Norwegian Ministry of Environment in 1980. The Norwegian Pollution Control Authority (SFT) is responsible for the overall co-ordination of the programme (Johannessen, 1995). Surface and ground water monitoring is designed to give a regional coverage with most of the stations (calibrated catchments, rivers, lakes and ground water magazines) in areas with acidification and some stations in unpolluted areas that give background values. All monitoring sites are considered sensitive to acidification and are chosen to minimise the effects of anthropogenic catchment based impacts.

Sulphate concentration in precipitation 1994 in Southern Norway have decreased by 30-45% from 1980 to 1994 (Tørseth and Semb, 1995). Total deposition of sulphate does not, however, show the same tendency due to year-to-year variations in precipitation amounts. Sulphate concentrations in all calibrated catchments and rivers decreased by 25-35% during the same period and the lakes (monitoring started in 1986) show a clear decrease from 1986 to 1994. The changes in sulphate concentrations have been compensated by changes in base cations and ANC (Acid Neutralising Capacity;  $(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) - (NO_3^{-} + SO_4^{2-} + Cl^{-})$ ). ANC is increasing in the calibrated catchments, rivers and lakes in southern Norway except for coastal areas, where the influence of seasalt episodes (Hindar et al. 1993) has counteracted the positive development of ANC (e.g. Birkenes). All groundwater stations show decreases in sulphate, and, except for Birkenes, increase in ANC.

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## UTNYTTING AV SALT GRUNNVANN

*Oddmund Soldal og Noralf Rye*

Interessen for salt grunnvann knytter seg særlig til problemene som har vært fokusert m.h.t. sykdom og forurensing ved oppdrettsanlegg.

Salt grunnvann har ikke vært noen faktor som er blitt tillagt vekt ved lokalisering av oppdrettsanlegg. Det er heller ikke aktuelt at bruk av dette vil kunne brukes av en dominerende del av næringen. Dette skyldes særlig at slike anlegg bruker så store vannmengder at kun større løsmasseavsetninger er aktuelle.

Langs kysten finnes det mange store postglasiale deltaavsetninger der det kan være muligheter for utnytting av salt eller brakt grunnvann.

Typisk for disse er at akviferene består av sandavsetninger over finkornede marine avsetninger. Dateringer av organisk materiale fra overgangen mellom akvifer og underliggende marine sedimenter viser C14-aldre fra 1000 til 2000 år BP.

Dette medfører høyt innhold av organisk materiale i avsetningene og dermed fare for reduserende forhold som kan føre til sulfatreduksjon med dannelse av hydrogensulfid og høyt innhold av oppløst jern i grunnvannet.

Disse problemene henger nøye sammen med grunnvannets strømningsretninger og deltaets overflate. Det ser fra våre data ut som om gressdekket overflate fører til mindre sulfatreduksjon enn om det er vegetasjonsfri overflate.

Ved utnytting av salt grunnvann nær vassdrag kan det skje innstrømning av ferskt grunnvann som fører til redusert saltinnhold. Gamle elveløp på deltaflater virker som dreneringskanaler og vil kunne hindre denne innstrømning hvis de ligger mellom brønnene og vassdraget.

Geometrien av disse gamle elveløp gjør at det er mulig å dele deltaene inn i ulike områder som er mer eller mindre uavhengige av hverandre. Deltaområdene er ofte av interesse til mange ulike formål. Derfor er det svært mange av dem som er nedbygt. Ved grundige vurderinger av forholdene er det mulig å lage flerbruksplaner for deltaene.

Glasifluviale avsetninger i tilknytning til saltvann er trolig best egnet til utnytting av salt grunnvann.

## GROUNDWATER QUALITY AND TRENDS IN FINLAND DURING 1976 - 1993

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**Abstract.** Ground water quality has been systematically monitored in Finland since 1976 by the Finnish Environment Agency. The network consists of 51 groundwater observation stations in nearly natural state, located in areas where the groundwater quality has not been appreciably affected by local environmental disturbances. Snow samples have also been taken at the sites of the groundwater stations for determination of background levels of wintertime atmospheric deposition.

In this study groundwater acidification trends were evaluated by moving averages, regression analysis and other statistical methods. The relation between total hardness ( $\text{Ca}^{2+} + \text{Mg}^{2+}$ ) and alkalinity ( $\text{HCO}_3^-$ ), in meq/l, was calculated in order to reveal impacts of strong acids. Hydrogeochemical characteristics caused by natural or anthropogenic factors on different groundwater formations was outlined by cluster analysis. Concentrations of fluoride were distinctively high on rapakivi areas. One station clearly stood out with high chloride concentration due to use of road salt.

Areas having granitic bedrock, shallow and slowly weathering soils and waters with low buffer capacity are known to be particularly sensitive to groundwater acidification during the spring thaw, when a plug of pollutants accumulated in snow is mobilized. The sulphate, calcium and nitrate concentrations of groundwater have increased in southern Finland, wherein the highest rates of wintertime acid deposition were encountered. On several stations in southern Finland the ratio of  $\text{Ca}^{2+} + \text{Mg}^{2+}/\text{HCO}_3^-$  is in the range of 1.5 to 2, which is an indication of weathering caused by anthropogenic strong acids.

Keywords: Groundwater, groundwater quality, acidification, time series, Finland.

**CONTRIBUTION FROM DIFFERENT SOURCES TO THE ENRICHMENT OF TRACE ELEMENTS IN ORGANIC SURFACE SOILS**

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The humus layer of natural soils is frequently used as a sampling medium in geochemical exploration surveys. This procedure has been questioned because the concentration level in the humus layer does not necessarily reflect the geochemistry in the underlying mineral material. Four sources of metals to the organic surface layer are identified: (1) bioturbation; (2) the 'vascular pump'; (3) atmospheric input of marine origin; and (4) airborne pollution. Two methods to define and discuss the contributions from these sources are presented for a survey of Norwegian soils. The first method is based on calculation of ratios of concentrations between humus and undisturbed subsoil within regions of similar topography, climate and air pollution. Concentration ratios consistently below 0.1 and low inter-region variation, such as for Al and Fe, characterize elements supplied to the humus by mixing-in of mineral soil, while concentration ratios appreciably higher than 0.1 identify some additional mechanism. The latter is evident for elements such as Pb, Zn and Cd (air pollution), Sr and Mg (atmospheric input of sea-salt) and Ca (the 'vascular pump'). The second method involves subtraction of the contributions from mineral matter, assuming that the ash content reflects the mass, and C-horizon soil the composition of the mineral matter in the humus layer. As mineral grains mixed into the humus layer are often fairly strongly weathered compared with the undisturbed mineral soil, this method will result in a certain over-compensation; nevertheless it leads to some interesting conclusions as is shown for Ba (the 'vascular pump'), and Zn and V (long-range transport and local air pollution).

**GRUNNVANNSKJEMI VED HOVØYA FYLLPLOSS, BRØNNØY KOMMUNE**

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Gjennom et detaljert studium av endringer av fysiske og kjemiske parametre for grunnvann er det dokumentert at sigevann fra Hovøya fyllplass påvirker grunnvannskjemien. Forurensings-spredningen foregår i høyeste grad episodisk. Dette faktum blir i meget liten grad påaktet i forbindelse med kartlegging av grunnvannsforurensing, hvor forurensingssituasjonen ofte blir karakterisert utfra analyse av et fåtall grunnvannsprøver innsamlet på tilfeldige tidspunkt. En slik praksis fører i beste fall til veiledende konklusjoner og vil i verste fall kun virke villedende.

Kjemidataene gjenspeiler en del av de kjemiske prosesser som er involvert ved sammenblanding av grunnvann og forurenset sigevann. Dataene indikerer både redox-reaksjoner, ionebytte, mineralutfelling/oppløsning samt ren fortynning/oppkonsentrering. En kvantifisering av disse prosessene vil bli gjennomført i neste fase av databearbeidingen ved hjelp av kjemiske modellerings-programmer.

## RADON IN TAP WATER - DOSES BY INGESTION AND RELEASE OF RADON TO INDOOR AIR

by

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Radon has been identified as the most important source of exposure to ionizing radiation of the Norwegian population. From a nation-wide survey of residential radon concentrations in Norway, the mean radon concentration in indoor air has been estimated to between 60 and 70 Bq m<sup>-3</sup> [1]. It has further been estimated that between 5 and 7% of the housing stock has an annual average radon concentration exceeding the national action level of 200 Bq m<sup>-3</sup>. The predominant route of radon entry is by infiltration of soil gas through cracks and openings in the sub-structure and foundation walls. Degassing of radon from building materials and household water are of less importance as radon sources. However, high concentrations of radon in tap water has been observed in water from deep (70-130 m) drilled boreholes [2,3]. So far, approximately 1000 measurements have been performed by the Norwegian Radiation Protection Authorities and the highest values (>1 000 kBq m<sup>-3</sup>) have been obtained in typical granite areas in the south-east of the country.

In assessments of the proportion of radon derived in indoor air from a water source it is necessary to take into consideration factors like water-usage rates, household air volume, air exchange rate, type of water use and degassing efficiency. Studies by Strand and Lind show that a concentration of 1000 kBq m<sup>-3</sup> in tap water under normal circumstances would correspond to an average radon concentration of radon in indoor air of between 50 and 100 Bq m<sup>-3</sup>.

Application of the modified ICRP model to the ingestion of radon in water leads to a value of 10<sup>-8</sup> Sv Bq<sup>-1</sup> for the committed effective dose per unit intake [4], with virtually all of the dose coming from the radon gas rather than the decay products. The corresponding doses to children and infants, scaled from body masses, are 2 · 10<sup>-8</sup> Sv Bq<sup>-1</sup> and 7 · 10<sup>-8</sup> Sv Bq<sup>-1</sup>, respectively. An annual intake of 100 l of untreated tap water with an average initial concentration of 1000 kBq m<sup>-3</sup> could lead to an annual effective dose of 7 mSv for infants, 2 mSv for children and 1 mSv for adults.

In this presentation the main results of Norwegian surveys will be presented and the doses by ingestion and inhalation will be evaluated.

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**AMOUNTS AND SOURCES OF FLUORIDE IN PRECIPITATION OVER SOUTHERN NORWAY**

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Fluoride is a ligand which forms complexes with  $Al^{3+}$  in natural waters with relatively low pH. It is not well established the extent to which fluoride in precipitation is primarily recycled from seawater, derived from dust or volcanic emissions or has an anthropogenic origin.

The average concentration of  $F^-$  as determined by ion-chromatography assuming no interference with simple organic acids in over five hundred samples of precipitation collected at four sampling stations in southern Norway in 1983, is 20  $\mu g/L$ . A comparison of the concentrations and amounts of fluoride measured in the precipitation samples with internally consistent measurements of other components such as  $Cl^-$ ,  $Br^-$ , and  $SO_4^{2-}$  on the same samples using correlation analysis, indicates that a major portion of the fluoride, i.e. more than 90%, have a non-marine origin.

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**REGIONAL DISTRIBUTION OF MANGANESE, PHOSPHORUS, HEAVY METALS, BARIUM, AND CARBON IN SEA BED SEDIMENTS FROM THE NORTHERN PART OF THE NORWEGIAN SKAGERRAK**

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The distribution of manganese, phosphorus, heavy metals, barium, and organic carbon in sea bed sediments (0-2 cm) from the northern part of the Norwegian Skagerrak is mapped and the results discussed in view of dispersion processes from natural and human sources. Similar distribution patterns are found for manganese, phosphorous and the heavy metals Cr, Cu, Ni, Pb, V and Zn which all intercorrelate well. The highest levels of these elements occur in the deepest parts of the Skagerrak Basin. Barium is concentrated at stations located in the shallower waters in the southern part of the investigated area. Mercury, on the contrary, has a bimodal distribution being enriched in the northernmost area and along the Norwegian south coast. The highest concentrations of total carbon and organic carbon are found at intermediate water depths around the perimeter of the deep Skagerrak Basin. Compared to the Norwegian Pollution Authorities (Statens Forurensningstilsyn 1993) classification of the condition of sediments based on concentration of heavy metals (Category I = Good, II = Fair, III = Poor, IV = Bad, V = Very bad) , the sea bed sediments in the northern part of the Norwegian Skagerrak fall in Category II with respect to Ni and Pb and in Category I with respect to Cr, Cu and Zn. For all other parametres discussed in this paper classification levels have not been defined.

CHEMICAL COMPOSITION OF HARD- AND SOFTROCK GROUNDWATERS FROM CENTRAL NORWAY WITH SPECIAL CONSIDERATION OF FLUORIDE AND NORWEGIAN DRINKING WATER LIMITS

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Groundwaters from crystalline and metamorphic rocks («hardrocks») and from Quaternary deposits, i.e. alluvial and glacial deposits («softrocks») from the Counties of Nord-Trøndelag and Sør-Trøndelag were analysed for major and minor elements and ions including fluoride. The median concentration of F<sup>-</sup> in water from the hardrock aquifers is 0.28 mg/L (14.7 µeq/L) in contrast to water from softrock aquifers in which it is found to be 0.05 mg/L (2.6 µeq/L). More importantly, ca 15% of the locations where water was abstracted from hardrock wells contain 1.5 mg/L (78.9 µeq/L) F<sup>-</sup> or more. Thus 15% of all hardrock wells returned F<sup>-</sup>-results that are at or above the maximum recommended value for drinking water. Of the softrock wells, none are above 1 mg/L.

Geologists would normally expect higher F<sup>-</sup>-contents in groundwaters derived from acid rocks, e.g. in granitic or gneissic areas. When comparing the host lithology with the observed F<sup>-</sup>-contents, however, no clear relationship between F<sup>-</sup>-content and lithology is visible. The highest observed F<sup>-</sup>-values actually occur in gneissic host rocks. However, wells drilled in amphibolites/greenstones, mica schists, calcareous rocks and sedimentary rocks all returned some analytical results above 1.5 mg/L F<sup>-</sup>. These results suggest that all hardrock wells drilled should be tested for F<sup>-</sup> and the users informed about the results and any necessary precautions.

When applying the recently proposed Norwegian drinking water limits to our data, 51% of all softrock well waters and 56% of all hardrock well waters are unfit for consumption without prior treatment although we analysed only for about half of the proposed elements/parameters. This result seriously questions the concept of fixed action levels - many of them with totally incomprehensible health implications for so many parameters/elements for hardrock groundwaters.

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## GEOCHEMISTRY OF PODZOLS BASED ON REGIONAL TILL DATA IN WESTERN FINLAND

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The common aim of the geochemistry subproject of the Mid-Norden project was to collect podzol profile samples using the density of 1 profile/ 300 km<sup>2</sup>. In Finland, altogether 3345 samples from 459 profiles were collected in 1990-1991, prior to the subproject's termination.

This research was a pilot study for an area of 122 profiles, which extends from the coast of western Finland to central Finland. The samples were selected so that the soil type in every profile is till.

Composite samples of 2 - 3 profiles were taken from all podzol horizons with a distance between the pits 3 - 5 m. Duplicate samples were taken from every second point and the samples relate to only one profile. The -0.064 mm fraction of till was analysed with ICP after a aqua regia leach.

The element concentration of the C-horizon in till in relationship to the upper soil horizons, was studied. The susceptibility to acidification of different podzol horizons to has been determined using the ratio Al/Ca+Mg.

The results indicate that the correlation coefficients of the element concentrations between C- ja BC-horizons are very high: *i.e.* Al, 0.64; Ca, 0.77; K, 0.83; Mg, 0.88; Na, 0.85; Cu, 0.86; Ni, 0.83; Zn, 0.80. The corresponding correlations between the C- and B-horizons are weaker, but significant nevertheless: *i.e.* Al, 0.42; Ca, 0.57; K, 0.59; Mg, 0.66; Na, 0.66; Cu, 0.63; Ni, 0.62; Zn, 0.65. Accordingly, regional anomaly patterns are also very similar, especially among the C- ja BC-horizons.

A c. 30 km wide coastal zone with young podzols (less than 5000 years old) as well as older podzols rich in clay content are strongly resistant to acidification. This is indicated specially by the data from B-horizon.

## **GROUNDWATER QUALITY IN SWEDEN COUNTRY-WIDE MAPS OF GROUNDWATER IN SHALLOW QUATERNARY DEPOSITS AND IN BEDROCK**

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Based on chemical analyses of water from 28 000 dug- and drilled wells, country-wide maps are produced showing the concentrations of some of the major ions as well as some minor constituents of special importance for the quality of groundwater. Data from shallow and deeper wells are shown on separate maps.

The basic groundwater quality is related to geological factors governing the chemistry as:

- weatherability of bedrock,
- lime content of soils,
- soil texture.

Digitalized maps of these geological factors has enabled the production of a combined map, showing the geological conditions for the chemical composition of groundwater, whereby GIS (ArcInfo) has been used.

Other factors are well depth and acid deposition. The well depth, as an indication of turnover time, has an importance for the degree of mineralisation (ion strength) of the water, and the acid deposition changes the chemical composition of groundwater in an unfavorable way, for instance, making it more aggressive.

The use of fertilizers and manure in agriculture is one of the threats to the groundwater resources.

The geological conditions have a significant importance on groundwater quality, especially on total hardness, alkalinity and pH. Groundwater in bedrock is characterized by high pH, total hardness and alkalinity compared to shallow groundwater in unconsolidated deposits.

Acid rain is a source of sulphate in groundwater, but high concentrations seem to occur in connection with cambrian-silurian sedimentary bedrocks. In addition high sulphate content in groundwater may emanate from the sulphidebearing postglacial clays with high gyttja content. This is common along the northern part of the east coast and around the Lake Mälaren in the Stockholm area.

## MILJØ I GRUNNEN - FANEPROSJEKT GARDERMOEN. DELPROSJEKT 2 SPREDNING, BINDING OG NEDBRYTNING AV AKUTTE FORURESNINGSUTSLIPP FRA FLYPLASSER.

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Faneprosjekt Gardermoen er et nasjonalt hydrogeologisk forskningsprogram for perioden 1992-95 på spredning av forurensninger i mark og grunnvann. Programmet hadde som mål å øke den hydrogeologiske kompetansen i Norge, og representerer et organisert samarbeid mellom de 4 institusjonene: Norges landbrukshøgskole, Universitetet i Oslo, SINTEF og Norges tekniske høgskole.

Faneprosjektet har klare generelle grunnforskningsmålsettinger:

1. *Klarlegge de hydrogeologiske mekanismer som påvirker nedtrengningen og spredningen av forurensende stoffer i den umettede sonen og grunnvannet.*
2. *Utvikle, tilpasse eller forbedre det hydrogeologiske verktøy som behøves for å påvise utslipp, begrense utslippenes skadevirkninger og restaurere forurenset grunn og grunnvann.*

men har likevel vært fokusert på mulige forurensninger fra moderne flyplassdrift. Faneprosjekt "Gardermoen" er finansiert av Forskningsrådet, Luftfartsverket og de deltakende institusjoner.

Delprosjekt 2 (UiO) har spesielt sett på hydrofysiske og hydrokjemiske virkninger av akutte utslipp av jetdrivstoff fra lufthavner på umettet sone og grunnvannsmagasinet. Det er utført både felt- og laboratorieforsøk, og ulike typer transport-modellering.

Den nye hovedflyplassen vil ligge på Gardermoen avsetningene som ble dannet 9500 år siden som et iskontaktdelta da breen gjorde et kortere opphold i tilbaketrekningen. Gjennom modellsimuleringer har vi søkt å kvantifisere deltaets hydrofysiske egenskaper - lagdeling, strukturer sedimentfordelinger og kornstørrelsesvariasjoner.

Gardermoendeltaet inneholder Norges største grunnvanns-forekomst og kan dekke forbruket til ca 150 000 mennesker og likevel bevare verneinteressene i området. Beskyttelsen av grunnvannet og de vernetede raviner, kildehorisonter og grytehullssjøer i området, krever at store mengder forurenset overvann (avisningskemikalierne glycol og acetat, og jetdrivstoff) fra flyplassdriften først må renses og så infiltreres til grunnen igjen. Dette vil bli gjort ved jordbaserte renseanlegg.

*(Posteren vil bli presentert av Kim Rudolph-Lund)*

## GEOCHEMISTRY OF STREAM-WATER IN A CATCHMENT EFFECTED BY SULFIDE-BEARING SEDIMENTS

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In coastal regions of Western Finland large areas are covered with sulfide-bearing postglacial sediments. When these are exposed to atmospheric oxygen, either as a result of isostatic land-uplift or artificial drainage, metal sulfides are oxidized which result in the liberation of large quantities of sulfate, hydrogen ions and metals. Such components are subsequently leached during the snow melting in spring (April-May) and after heavy rainfall in autumn (October-November). In this investigation, the geochemistry of stream water was studied in a catchment (Petalax Stream) effected by such processes.

Stream-water samples were collected unfiltered at 119 sites within the catchment during high-water flow in autumn 1994. The samples were acidified with ultrapure HNO<sub>3</sub> and were analysed for some 60 chemical elements with ICP-MS. The pH and electric conductivity were measured in untreated samples immediately after the sampling. The occurrence of sulfide-bearing sediments within the catchment was estimated by geophysical methods.

The concentrations of Co, Al, Ni, Zn, Mn, U and Li at the basin outlet of Petalax Stream are more than 20 times higher than the median concentrations in 1161 headwater streams in Finland (Salminen; personal communication) and in 49 Fennoscandian Rivers (Edén and Björklund 1993), while the concentrations of Ca, Cr, Sr and K are higher by factors between 5 and 10. The maximum concentrations of several metals are very high in the studied samples (n=119), e.g. those of Al (225 mg/L), Mn (16 mg/L), Ni (1.2 mg/L) and Cd (25 µg/L) are higher than the levels permitted in drinking water (Medicinalstyrelsen 1990) by factors of 1100, 160, 24 and 5, respectively.

The concentrations of a number of elements including Al, Zn, Li, U, Ni, Mg, Na, Ca, Cd, Co and Mn are much higher in the water in feeder streams draining sulfide-bearing sediments than in those receiving the water mainly from other overburden types (glacial till, peat). Processes such as oxidation of metal sulfides and organic compounds, ion exchange reactions and weathering of silicate minerals are causing the mobilization of these elements in large quantities in the sulfide sediments. Fertilizers added on the farmlands and sea-salts trapped in the pores of the sediments are other potential sources.

The behaviour of V, Nb, Zr and Pb in stream water is considerably different from that of most other elements, as the highest concentrations of V, Nb, Zr and Pb are found in feeder streams draining areas covered with glacial till and peat. Extensive binding by humic substances is a possible explanation for the observed distribution of these metals in stream water.

The concentrations of seven elements (As, Ba, Cr, Cs, Fe, Mo and Ti) in stream water do not follow the Quaternary geology within the catchment, which indicate that some processes unrelated to overburden type largely control the distribution of these elements.

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