Miljöforskningsnämnden
Ansökan om projektbidrag inom Naturvårdsverkets forskningsprogram

Forskningsprogram
SNAP ■ **REPROSAFE** □ **FLIPP** Inriktning: Ekonomiska styrmedel □
Inriktning: Informationssystem och indikatorer IPP □

Projekttitel (svensk):
Källspårning av luftföroreningar med hjälp av receptormodellering

Projekttitel (engelsk):
Tracking sources of air pollutants by using receptor modelling

Huvudsökande

Efternamn:	Förnamn:	Födelseår:	Kvinna ■ Man □
Wiberg	Karin	1959	

Organisation:	Institution:
Umeå Universitet	Kemiska institutionen, Miljökemi

Adress:	Postnr:	Ort:
Miljökemi, Kemiska Institutionen, Umeå Universitet	901 87	Umeå

Telefon:	E-post:	Tjänst:
090-786 5672	karin.wiberg@chem.umu.se	Fil. Dr. Foass

Medsökande

Efternamn, förnamn, tjänst, organisation, institution:
Geladi, Paul, Docent
Enheten för biomassateknologi och kemi, SLU, Umeå

Telefon:	E-post:	Kvinna □ Man ■
090-786 9473	paul.geladi@btk.slu.se	

Sammanfattning på **svenska** strukturerad enligt följande: 1) Projektets betydelse för programmet 2) Miljörelevans och förväntad betydelse för miljöpolitiken 3) Mål och hypotes 4) Metodik och genomförande 5) Kommunikationsinsatser i relation till programmet:

1) Det är väl känt att vår omgivningsluft är förorenad av en mängd olika kemikalier. Däremot är det inte alltid känt vilka källorna är, om det är regionala eller transporterade utsläpp (long-range transport), eller hur mycket olika källor bidrar med till den totala belastningen. I detta projekt vill vi spåra och kvantifiera miljöföroreningskällor med hjälp av en multivariat metod som kallas för receptormodellering. Med hjälp av denna kunskap skapar man sedan multivariata modeller som kan ge information om källpåverkan på miljöprov.

2) Vi vill studera polyaromatiska kolväten (PAHer) i stads- och landsbygdsluftluft. Detta är en ämnesklass som klassas som "prioriterad" av myndigheter och kommissioner, och som skall reduceras i största möjliga mån. Det är därför av yttersta vikt att kunna peka ut och kvantifiera föroreningskällorna i olika miljöer.

3) Syftet med projektet är att spåra källorna i den svenska luftmiljön. Detta anses möjligt efter viss modifikation av befintliga modeller för receptor modellering. Projektet skall ses som en pilotstudie för att arbeta fram en strategi som fungerar för andra luftburna organiska miljögifter.

4) Projektet går ut på att man karaktäriserar primära och sekundära källors sammansättning, deras så kallade "fingerprints", som ofta är typiskt för varje källa. Exempel på sekundära källor är återemittering från jord, vatten och växter till luft. Arbetet utförs i fem delsteg: 1. Identifiering av källor, 2. Kemisk karaktärisering av källor och bakgrund. Existerande data kommer att utnyttjas, men det blir också nödvändigt med nya mätningar, 3. Identifiering av lämpliga variabler (fingerprints) 4. Modellering och 5. Validering av modellerna.

5) Projektet förväntas resultera i en rapport till Naturvårdsverket samt publicering i lämplig vetenskaplig tidskrift.

	År 2004	År 2005
Summa sökta medel per år i kr:	658 800	658 800

Miljöforskningsnämnden
Ansökan om projektbidrag inom Naturvårdsverkets forskningsprogram

Sökta projektmedel fördelade på kostnadsslag	År 2004 (kr)	År 2005 (kr)
Personalkostnad inkl. soc. avgifter *		
Sundqvist, Kristina, forskningsassistent 100%	320 000	320 000
Geladi, Paul, forskningsledare 8% (1 månad)	53 000	53 000
Övriga omkostn exkl moms (förbrukningsmtrl, analyser, resor etc)**		
Lösningsmedel	15 000	15 000
Övriga kemikalier, förbrukningsvaror	20 000	20 000
Glasvaror	10 000	10 000
Kromatografikolonner, kirala och akirala	15 000	15 000
Instrumenttid	5 000	5 000
Mjukvara och datortid	10 000	10 000
Provtagningsresor	20 000	20 000
Övriga resor	20 000	20 000
Delsumma av ovanstående poster:	488 000	488 000
Förvaltningspåslag: 35 %	170 800	170 800
Totalsumma per år: (införs sid. 1):	658 800	658 800

*) Specificera namn, tjänst **) Specificera

Samtliga övriga miljörelaterade projekt för vilka de sökande har beviljats anslag eller söker anslag för 2004-2006. OBS Även EU-finansiering.

Projekttitel	Finansiär	Tidsperiod	Sökt kr	Beviljat kr
Källspårning av miljöföroreningar med hjälp av receptormodellering	CMF	2004 - 2005	1 262 300	
Tracking sources of environmental pollutants by using receptor modeling	FORMAS	2004 - 2007	1 742 300	

Miljörelaterade projekt för vilka sökande har beviljats anslag för 2000-2003
OBS Även EU-finansiering

Projekttitel	Finansiär	Tidsperiod	Beviljat Kr
Chiral environmental pollutants as tracers in environmental transport studies (fellow-applicant).	Swedish EPA	2000	150 000
Chiral pesticides as tracers for pollutant transport and accumulation processes (fellow-applicant).	Swedish EPA	2001-2002	300 000
Ansökan till Miljöhögskolan om gästprofessor på Miljökemi under 4 mån, Prof. Terry Bidleman från Meteorological Service of Canada (fellow-applicant).	Miljöhögskolan, Umeå	2001	210 000

Datum och sökandes underskrift, vilken samtidigt ger Naturvårdsverket tillåtelse att publicera sökandes namn på sin webbplats:	Datum och underskrift av prefekt eller motsvarande med namnförtydligande:

Miljöforskningsnämnden
Ansökan om projektbidrag inom Naturvårdsverkets forskningsprogram

Ansökan skall bestå av detta formulär jämte högst sex sidor lång projektbeskrivning på **engelska** (strukturerad som den svenska sammanfattningen samt en redovisning av kunskapsläget). Referenser till egna publikationer ges med sifferhänvisning till CV. Andra referenser ges i löpande text. Sökandes och eventuell medsökandes CV får omfatta högst två sidor. Inga bilagor kommer att beaktas vid bedömningen. Ansökan (max 10 A4-sidor, 12 punkters teckenstorlek) skall inlämnas i **original + 15 kopior samt elektroniskt** till ansok@naturvardsverket.se. Häfta ihop ansökan och använd hålat papper. Ansökan skall ha inkommit senast den 15 oktober 2003 till Naturvårdsverket, Forskningssekretariatet, 106 48 STOCKHOLM.

Research program for SNAP project 2004-2005

Tracking sources of air pollutants by using receptor modelling

Karin Wiberg
Department of Chemistry, Environmental Chemistry
Umeå University, SE-901 87 Umeå

Introduction – environmental relevance and significance to the program

It is well known that the ambient air is polluted with many unwanted chemicals. However, it is not always obvious which the sources are, whether the pollutants are long-range transported or regional, or to which extent each source contributes to the total pollution.

Substances of great environmental concern has been selected and listed on so called "priority lists" by authorities and commissions [1-3]. For these substances, it is of outmost importance to reduce or eliminate their prevalence on earth, and thus it is essential to identify and apportion their sources.

In environmental monitoring, concentrations of pollutants are determined and evaluated. However, the relations between compounds, i.e. the pollution patterns are frequently overlooked. This pattern is often specific for each source and can be used as a fingerprint. In addition, it may carry information on the age and fate of the pollutants.

Receptor modelling is a multivariate modelling technique that has been proven to be useful for tracking and apportioning sources of inorganic pollutants [4]. This technique utilizes knowledge about the composition (fingerprints) of sources and how the releases are affected by aging.

In this project, organic environmental chemistry will be combined with chemometrics. Dr. Wiberg (Assistant Prof.) have comprehensive knowledge about persistent organic pollutants, and have also the facilities and equipment needed for environmental trace analysis. Doc. Geladi will contribute with his expertise within receptor modelling. He has extensive experience of multivariate modelling and has applied receptor modelling before.

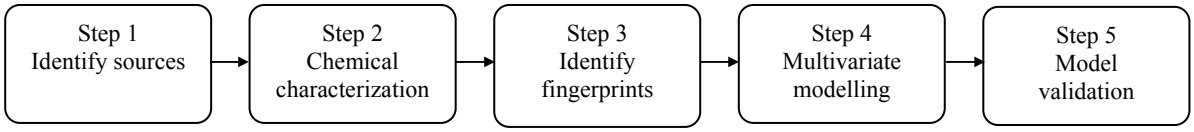
Aim and hypothesis

Our hypothesis is that it is possible to trace and apportion sources for organic pollutants in urban and background air by using receptor modelling. However, it may be necessary to modify current methods, which originally were developed for inorganic pollutants.

The aim of this project is to track and apportion sources for polyaromatic hydrocarbons (PAHs) in Swedish urban and background air by using receptor modelling.

Method

The preliminary strategy of the method is as follows:



1. Identify sources

For each compound or compound group we have to identify possible primary and secondary sources. Examples of primary sources are:

- Technical products
- Industries
- Traffic
- Combustion
- Other human activity
- Natural formation

Secondary sources are those that emit recycled pollutants, such as revolatilization from soil, water and plants to air. For secondary sources, abiotic processes (e.g. photolysis), and biotic processes (e.g. enzymatic degradation) have changed the original fingerprint of the pollutant.

2. Chemical characterization of sources and background

In this step, we will collect typical source and background data. The data will be extracted from literature and databases. Extensive amount of data for the target compounds exist at Environmental Chemistry.

For lacking data, we will acquire complementary chemical data. If possible, we will use existing extracts for analysis. However, additional sampling and subsequent sample analyses will be necessary.

3. Identify fingerprints

At this stage, it is time to determine which variables are the best to constitute the fingerprints. There will be several options to express the pattern:

- an isomer and the sum of this isomer and another isomer
- an enantiomer and the sum of this enantiomer and the other enantiomer
- a congener and the sum of all congeners in that compound group
- a homologue group and the sum of all homologue groups in that compound group
- a compound and the sum of other related compounds

Multivariate methods will be used for interpretation and identification of fingerprints.

4. Multivariate modelling

The next goal is to build multivariate models, which differentiate between different sources. The variables will be the ones that were determined in step 3, and the objects will be the “new” and “aged” releases. The techniques that are often used in receptor modelling are factor analysis and multiway factor analysis, together with derived and related techniques.

5. Model validation

In this final step, known samples will be introduced as unknown samples for validation of the models.

Work plan

This preliminary strategy is general and can be used for various compounds and compound groups. It is therefore necessary to make priorities among chemicals and environments.

For this project we have selected polyaromatic hydrocarbons (PAHs) in Swedish urban and background air because: 1) they are priority substances, known to be toxic (carcinogenic) to humans 2) they have many different sources, 3) a lot of air data are available. However, it is important to keep in mind that our intention is to develop a strategy that works in general for organic pollutants, and that this project serves as a pilot project. We believe that the following time schedule is realistic:

Compound class	Year 1	Year 2
PAHs	Step 1-2	Step 2-5

Financial plan

To be able to accomplish this project we are asking for salary for a research assistant (Kristina Sundqvist) during two years. Kristina holds a Masters degree in Chemistry and is currently employed at Environmental Chemistry, Umeå University as a project assistant. She is the first author of an accepted paper, which deals with air-sea gas exchange and long-range transport of PCBs and pesticides [CV Wiberg 1]. We are also applying for Docent Geladi's supervising time (salary) for one month per year. In addition, we need funding for complementary sampling, sample analysis, computer time and travelling costs. We do not need funding for equipment since the department have a high-volume air sampler and facilities for sample clean up and instrumental analysis.

What has been done so far?

Receptor modelling. The basics of receptor modelling have been described in the literature [4-6]. So far, most applications have focused on aerosols [7] and inorganic compounds such as trace metals [8].

Examples of fingerprints. For compound groups, which include a large number of congeners, normalization of each congener to a prevalent and/or highly recalcitrant congener has been used as tracers in multivariate analyses [9,10]. In that way no chemical information is lost, and chances of finding characteristic patterns are high.

Often, the relation between isomers can be used. One example is the relation between the hexachlorocyclohexane (HCH) isomers α and γ. High fraction of α-HCH indicates a technical HCH source, which is subsequently aged due to long range air transport, whereas low values are typically associated with regional lindane (90% γ-HCH) usage [CV Wiberg 2].

The relation between enantiomers of organochlorine pesticide has been used as fingerprints in a number of studies [CV Wiberg 3, 4]. A composition similar to the technical product (close to racemic) indicates fairly fresh release or that the compound was directly transported in air from its source, while enantio-enrichment indicates that it was released some time ago and has since been subjected to recycling from water and soil.

Related work conducted by the applicants. Dr. Wiberg has been the author or co-author of many publications in which enantiomers and isomers were used as tracers [CV Wiberg 1, 2, 3, 5-7]. In addition, she has experience of multivariate modelling [CV Wiberg 6, 7]. One related study is the multivariate evaluation of North American indoor air, urban air and ambient air [CV Wiberg 6]. Fingerprint variables for the pesticide chlordane was selected and modelled by Principal Component Analysis, which often is used as the first step in receptor modelling. Although this was a simple model (only five variables), conclusions could be drawn concerning the influence of different sources (including the technical product) for the various air types (Figure 1).

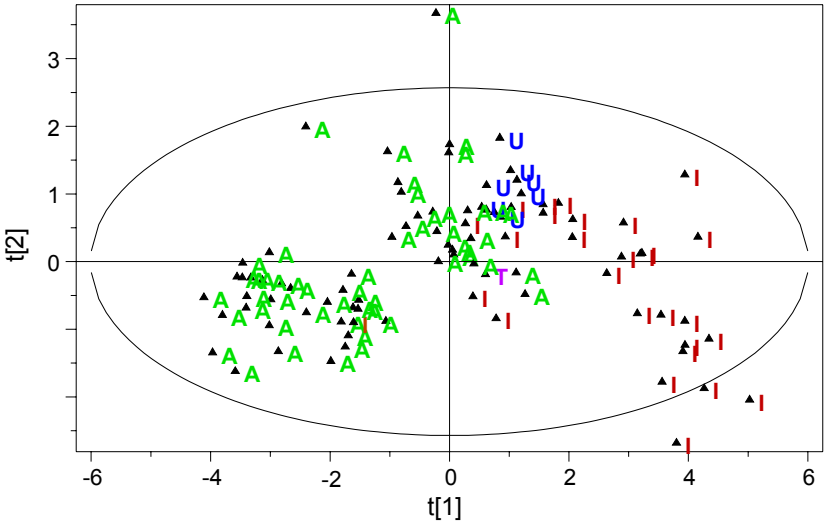


Figure 1. Scoreplot for air samples.
Indoor (I), Ambient (A), Urban (U), Technical Chlordane (T)

Doc. Geladi has worked intensively with three-way modelling, a technique that is highly relevant for receptor modelling data [CV Geladi 2]. Some of his work has been conducted within the environmental chemistry field [CV Geladi 3]. In addition, he has spent several months as a guest professor at the department of Prof. Hopke (Clarkson University, NY, USA), who is a scientist of repute within receptor modelling [4, 6].

Cooperation partners and communications

Karin Wiberg has cooperated with several partners within the air pollution field, e.g. Eva Brorström-Lundén, IVL (Swedish Environmental Research Institute) [CV Wiberg 1, 2] and Terry Bidleman, Metrological Service of Canada [CV Wiberg 2, 3, 5, 6]. It is our intention that the cooperation will continue, and in addition we intend to initiate cooperation with Prof. Hopke.

This project is expected to result in a report to the Swedish Environmental Protection Agency as well as a publication in a suitable scientific journal.

References

1. OSPAR list of substances of possible concern. *The Convention for the Protection of the Marine Environment of the North-East Atlantic ("OSPAR Convention")*, http://www.ospar.org/eng/html/welcome.html
2. List of potential substances of concern to be considered by HELCOM. *Helsiniki Commission*, http://www.helcom.fi//recommendations/app2.html
3. The European Chemicals Bureau (ECB) priority lists. *The European Chemicals Bureau (ECB)*, http://ecb.jrc.it/existing-chemicals/
4. Hopke PH. 2003. Recent developments in receptor modeling. *J Chemometrics* 17:255-265.
5. Malm, WC, Johnson, CE, Bresch, JE. 1986. *Application of principal component analysis for purposes of identifying source-receptor relationships.* In: Receptor methods for source apportionment, Air Pollution Control Association, Pittsburg, PA.
6. Hopke, PH. 1991. *Receptor modeling for air quality management*. Elsevier, Amsterdam.
7. Seigneur C, Pai P, Louis JF, Hopke PH, Grosjean D. 1997. Review of air quality models for particulate matter. Report 4669:
8. Gao N. 1996. Possible sources of some trace elements found in airborne particles and precipitation in Dorset Ontario. *J Air Waste Manage Assoc* 46:1035-1047.
9. Fängmark, IE, Marklund, S, Tysklind, M, Rappe, C. 1993. *Use of principal component analysis to characterise sources for snow deposition of PCDDs and PCDFs.* In: Measurement of airborne pollutants, Butterworth Heinemann, Oxford, UK.
10. Tysklind M, Fängmark IE, Marklund S, Lindskog A, Thaning L, Rappe C. 1993. Atmospheric transport and transformation of polychlorinated dibenzo-p-dioxins and dibenzofurans. *Environ Sci Technol* 27:2190-2197.

CURRICULUM VITAE

WIBERG Karin
Department of Chemistry, Environmental Chemistry, Umeå University
SE-901 87 Umeå,Sweden
Phone: 090-786 5672, Fax: 090-128133, E-mail: karin.wiberg@chem.umu.se

UNIVERSITY EDUCATION

2002	Doctor of Philosophy, Faculty of Science and Technology, Environmental Chemistry, Umeå Univeristy.
1981	Bachelor of Science (BSc) in Public Health and Environmental Protection, Umeå University.

PROFESSIONAL EXPERIENCE

2002-	Assistant Professor, Department of Chemistry, Environmental Chemistry, Umeå University, Sweden.
1996-1997	Environmental chemist contractor at Atmospheric Environment Services, Downsview, ON, Canada (Sept. -96-Aug. -97).
1994-2002	PhD student, Department of Chemistry, Environmental Chemistry, Umeå University, Sweden.
1994-1995	Research engineer at the Mass Spectrometer Facility, Life Science, College of Pharmacy, University of Kentucky, Lexington, KY, USA Oct. -94-- July –95.
1986-	Research engineer at the Department of Chemistry, Environmental Chemistry, Umeå University.
1982-1985	Environmental health officer in Gothenburg, Svedala and Lomma communities.

TEACHING

Course coordinator/planning, lecturer, lab. assistant, supervisor/assistant supervisor Master/PhD students students

AWARDS

2003 Umeå community scientific award for young promising scientists within the field Environment.

2003 Otto Hutzinger Student Presentation Award (Conny Danielsson was awarded for extended abstract and oral presentation, I was co-author to the abstract).

LITERATURE LIST

Thesis: Enantiospecific analysis and environmental behavior of chiral persistent organic pollutants, Umeå University, 2002

Book chapters (co-author):	In total 2 chapters: 1988, 2002
In journals:	In total 24 papers from 1987 to 2003
In proceed., ext. abstract etc.:	In total 17 publications from 1990 to 2003

Publications of interest for the present project:

1. **Sundqvist K., Wingfors H., Brorström-Lundén E., Wiberg K.** Air-sea gas exchange of HCHs and PCBs and enantiomers of α–HCH in the Kattegat Sea. *Accepted for publication in Environ. Pollut.*
2. **Wiberg K., Brorström-Lundén E., Wängberg I., Bidleman T. F., Haglund P.** Concentrations and fluxes of hexachlorocyclohexanes (HCHs) and chiral composition of a-HCH in environmental samples from the southern Baltic Sea. *Environ. Sci. Technol.* 35 (24):4739-4746, **2001**.
3. **Bidleman, T.F., Leone, A.D., Falconer, R.F.,Harner, T., Jantunen, L.M.M., Wiberg, K.**, **Helm, P.A., Diamond, M.L. and Loo, B.** Air-soil and air-water exchange of chiral pesticides. Chapter 12 in: J.R. Coats and Hiroki Yamamoto (eds.), *Pesticide Science, American Chemical Society Books*, *Symposium Series No. 853/ Environmental Fate and Effects of Pesticides,3rd edition,* Washington DC, American Chemical Society, **2002**. ISBN 0-8412-3722-0.
4. **Wiberg, K.** Enantiospecific analysis and environmental behavior of chiral persistent organic pollutants (POPs), Thesis, Umeå University, Sweden. ISBN 91-7305-162-4, **2002.**
5. **Bidleman, T.F., Harner, T., Wiberg, K., Wideman, J.L., Brice, K., Su, K., Falconer, R.L., Aigner, E.J., Leone, A.D., Ridal, J.J., Kerman, B., Finizio, A., Alegria, H., Parkhurst, W.J. and Szeto, S.Y.** Chiral pesticides as tracers of air-surface exchange *Environ. Pollut.* 102:43-49, **1998.**
6. **Falconer, R.L., Leone, A.D., Bodnar, C.E, Ulrich, E.M., Hites, R.A, Wiberg, K., Bidleman, T.F., Jantunen, L.M.M. and harner, T.** Enantiomeric ratios as source tracers of chlordane in ambient air. *Div of Environ Chem Preprints of Ext Abstr* **1999.**
7. **Wiberg, K., Bergman, A., Olsson, M., Roos, A., Blomkvist, G., Haglund, P.** Concentrations and enantiomer fractions of organochlorine pesticide residues in Baltic species that were hit by reproductive impairment. *Environ.Toxicol.Chem.*, 21 (12) 2542-2551, **2002.**

CURRICULUM VITAE

GELADI Paul Louis Marie
Department of Biomass technology and chemistry, Swedish University of Agricultural Sciences, Box 4097, SE- 904 03 Umeå, Sweden
Phone: 090-7869473, E-mail: paul.geladi@btk.slu.se

EDUCATION

2003-	Docent (Associate Professor) Measurement and Automation Applications of Chemometrics and Near Infrared Spectroscopy, Vaasan Yliopisto.
1990-	Docent (Associate Professor) Chemometrics, Umeå.
1979	Ph.D. Thesis on measurement of solid air pollutants at the workplace, defended April 20, 1979
1974-1979	Doctorate (PhD) Chemistry, Universitaire Instelling Antwerpen (UIA) Universiteitsplein 1, B2610 Wilrijk, Belgium.
1972-1974	Licentiate Chemistry, Universitaire Instelling Antwerpen (UIA) Universiteitsplein 1, B2610 Wilrijk, Belgium. Major in general chemistry, minor in theoretical physics.

LATEST PROFESSIONAL ACTIVITIES

2002-	Head of Research NIRCE-Kvarken,
2002-2003	Docent, Dept. of Chemistry, University of Umeå, S90187 Umeå, Sweden.
1991-1992	Visiting professor for 3 months at Micro and Trace Analysis Center (MITAC), University of Antwerp, Belgium.
1997	Visiting professor, Dept. of Chemistry, Clarkson University, Potsdam, NY.
1988-90	Senior Lecturer, Dept. of Chemistry, University of Umeå, S90187 Umeå, Sweden.
1988	Research scientist, Dept. of chemistry, University of Umeå, S90187 Umeå, Sweden.

Several Administrative Chairs, Memberships of Professional Societies and Memberships of Scientific Committees for Conferences

AWARDS

2002. Eastern Analytical Symposium, Chemometrics award.

PATENTS

Britta Sethson & Paul Geladi. Anordning vid ickedestruktiva och ickeinvasiva kliniska mätningar 0100168-4.

TEACHING

Participation as teacher/organizer (including course development) in several undergraduate and graduate courses since 1983

LITERATURE LIST

Books

1. "Multivariate Image Analysis", P. Geladi and H. Grahn, Wiley, Chichester, 1996, ISBN 0-471-93001-6.

2. "Multi-way Data Analysis in the Chemical Sciences", A. Smilde, R. Bro & P. Geladi, 2003. Publisher: Wiley, Chichester

Other publications
Technical reports, in proceedings, course books, in journals, popular science publications, editorials, educational material: In total 157.

Latest papers reviewed by Referees (in total 22 from 1998-2003) and Publications of interest for the present project

3. **Geladi P., Hadjiiksi L. & Hopke P**., "Multiple regression for environmental data: nonlinearities and prediction bias", Chemometrics and Intelligent Laboratory Systems, 47,165-173, 1999.
4. **Geladi P**., "Some recent trends in the calibration literature", Chemometrics and Intelligent Laboratory Systems, 60, 211-224, 2002.
5. **Geladi P. & Forsström J**., "Monitoring of a batch organic synthesis by infrared spectroscopy: modeling and interpretation of three-way data", Journal of Chemometrics, 16, 329-338, 2002.
6. **Åberg P., Geladi P., Nicander I. & Ollmar S.,** "Variation of skin properties within humn forearms demonstrated by non-invasive detection and multi-way analysis", Skin Research Technology, 8, 194-201, 2002.
7. **Nyström J., Lindholm-Sethson B., Stenberg L., Ollmar S., Eriksson J., Geladi P**., "A combined near infrared spectroscopy and multifrequency bio-impedance investigation of skin alterations in diabetes patients based on multivariate analyses", Medical and Biological Engineering, in print
8. **Lestander T. & Geladi P**., "NIR spectroscopic measurement of mositure content in Scots pine seeds", the Analyst, 128, 389 - 396, 2003.
9. **Geladi P.**, "Chemometrics in spectroscopy. Part 1. Classical Chemometrics", Spectrochimica Acta B, in print.

Other publications 1998-2003
10. **Nilsson C., Magnusson R., Olsson R. & Geladi P**., "Perennial rhizomatous grass. Characterisation by NIR spectroscopy amd multivariate calibration", in N. El Bassam, R. Behl & B. Prochnow eds. "Sustainable Agriculture for Food, Energy and Industry", James & James, 1998, 964-966
11. **Martens H. & Geladi P**. , "Multivariate Calibration", in S Kotz, C. Read & D. Banks eds. "Encyclopedia of Statistical Sciences", Wiley, Chichester, Update vol 3, 483-495, 1999.
12. **Geladi P. & Dåbakk E**., "Computational methods of analysis and chemometrics in near-infrared spectroscopy", in eds J. Lindon, G. Tranter & J. Holmes "Encyclopedia of Spectroscopy and Spectrometry" , Academic Press, London, 1999, 343-349.
13. **Geladi P. & Grahn H**. , "Multivariate Image Analysis", in R. Meyers ed. , Encyclopedia of Analytical Chemistry, Wiley, Chichester, 2000, 13540-13562.
14. **Lestander T., Odén P.-C. & Geladi P**., "2- and 3-way Analysis of NIR Scans from Seed Crossings", in A. Davies & R. Cho eds "Near Infrared Spectroscopy. Proceedings of the 10th International Conference, NIR Publications, Chichester, 2002, 385-388.