Miljöforskningsnämnden
Ansökan om projektbidrag inom Naturvårdsverkets forskningsprogram

Forskningsprogram
SNAP X **REPROSAFE** ☐ **FLIPP** Inriktning: Ekonomiska styrmedel ☐
Inriktning: Informationssystem och indikatorer IPP ☐

Projekttitel (svensk):
Hälsoeffekter orsakade av exponering för vedrök och deponering av partiklar i andningsvägarna.

Projekttitel (engelsk):
Health effects induced by exposure to wood smoke and particle deposition in the human respiratory system.

Huvudsökande

Efternamn:	Förnamn:	Födelseår:	Kvinna ☐
Swietlicki	Erik	1958	Man X

Organisation:	Institution:
Lunds tekniska högskola, Lunds universitet	Avd för kärnfysik, Fysiska institutionen

Adress:	Postnr:	Ort:
Box 118	221 00	Lund

Telefon:	E-post:	Tjänst:
046-222 96 80	Erik.Swietlicki@nuclear.lu.se	Professor

Medsökande

Efternamn, förnamn, tjänst, organisation, institution:
Nordin, Anders, professor, Energiteknik och termisk processteknik, Umeå universitet, 901 87 Umeå

Telefon:	E-post:	Kvinna ☐
090-786 52 64	anders.nordin@chem.umu.se	Man X

Projektet utgör starten för ett nytt tvärvetenskapligt samarbete mellan grupper specialiserade inom aerosolteknologi, lungimmunologi, förbränningsteknologi och kemi. Metoden för snabba (minuter) och storleksuppdelade lungdepositionsmätningar är världsunik och utvecklad av de medverkande LTH-grupperna, och har inte tidigare använts inom större exponeringsstudier. Gruppen vid Umeå universitetssjukhus står för den medicinska kompetensen och har under åren byggt upp en mångårig erfarenhet rörande exponeringsförsök med dieselavgaser och hälsoeffektstudier. Gruppen vid Energiteknik och termisk processteknik, Umeå universitet har specialiserat sig på systematiska förbränningsstudier och detaljerad kemisk partikelkarakterisering.
Vid kall väderlek och ogynnsamma meteorologiska förhållanden (dålig omblandning) ger småskalig vedeldning upphov till kraftigt försämrad luftkvalitet i bostadsområden där vedeldning används som värmekälla. De största hälsoeffekterna antas främst härröra från utsläppen av partiklar. Inom detta projekt kommer friska försökspersoner att exponeras för vedrök under kontrollerade betingelser. Sådana exponeringsstudier har inte tidigare rapporterats, vare sig i Sverige eller internationellt. Vedeldningsaerosolen kommer att karakteriseras med avseende på storleksfördelning, hygroskopiska egenskaper och kemisk sammansättning. Aerosol från både befintlig småskalig vedeldningsteknik och modern teknik resulterande i mer optimerade förbränningsförhållanden kommer att studeras. Partikeldepositionen (dosen) till andningsvägarna kommer att mätas på varje försöksperson under exponeringen, och användas för att vidareutveckla och validera lungdepositionsmodeller. Effekten av vedeldningsexponeringen på försökspersonerna kommer att uppmätas, däribland ett flertal fysiologiska responser och symptom, såsom lungfunktion och inflammatoriska reaktioner i andningsvägarna. Förhållandet mellan exponering för vedrök, dos till andningsvägarna, och hälsoeffekter kommer att användas för att utröna och belysa tänkbara immunologiska mekanismer. Resultaten kommer att ge underlag för att bedöma hälsoeffekter förknippade med småskalig vedeldning, och för att utföra en preliminär riskuppskattning för olika hälsoeffekter. Projektet kommer även att kvantifiera potentialen för en reduktion i vedeldningsrelaterad ohälsa genom införandet av modern småskalig förbränningsteknik. Projektets resultat kommer att redovisas för berörda myndigheter och SNAP genom rapporter och möten, presenteras vid nationella och internationella specialistkonferenser, samt publiceras i vetenskapliga tidskrifter.

	År 2004	År 2005
Summa sökta medel per år i kr:	920 643	792 071

Miljöforskningsnämnden
Ansökan om projektbidrag inom Naturvårdsverkets forskningsprogram

Sökta projektmedel fördelade på kostnadsslag	År 2004 (kr)	År 2005 (kr)
Personalkostnad inkl. soc. avgifter *		
Senior scientist: Swietlicki (2 months), Nordin (2 months)	115 900	115 900
PhD students: Boman (4 months), Pagels (6 months), Rissler (4 months), Törnqvist (6 months)	338 550	338 550
Övriga omkostn exkl moms (förbrukningsmtrl, analyser, resor etc)**		
Förbrukningsmtrl (service aerosolinstrument, anpassning till exponeringskammare, filter, rörkopplingar, kemikalier:	70 000	20 000
Analyser (medicinska, PIXE, SEM-EDS, jonkromatografi, OC/EC):	50 000	40 000
Resor (Lund – Umeå), boende och traktamente (i Umeå):	70 000	40 000
Delsumma av ovanstående poster:	644 450	554 450
Förvaltningspåslag: 42.86% (=30 % avdrag på anslaget)	276 193	237 621
Totalsumma per år: (införs sid. 1):	920 643	792 071

*) 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 kkr
Water-soluble organic aerosols	Vr	2002-2004		1 170
ASTA	MISTRA	2000-2005		2 700
LBA-SMOCC	EU	2001-2004		1 700
Forskarskola aerosoler	FORMAS	2003-2005		645
Aerosol formation in biomass comb.	STEM	2000-2004		930
Källor till PM10 i trafikmiljö	Vägverket	2002-2004		605
Generering av vägdamm	Vägverket	2003		100
Health effects of fine aerosol particles	FORMAS	2004-2006	2 005	
Aerosols clouds and climate (BACC-TO-BACC)	EU	2004-2006	3 000	

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

Projekttitel	Finansiär	Tidsperiod	Beviljat kkr
Emissions and air quality – Emissions	STEM	2000-2003	510
Emissions and air quality – Immissions	STEM	2000-2003	1 113
Arctic Ocean Expedition 2001	NMR/NARP	2000-2003	1 500
Secondary and semi-volatile aerosols	Nv	2000-2002	1 260

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:
Lund, 14/10 2003	Lund, 14/10 2003, Prof. Lars Montelius (prefekt)

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.

Health effects induced by controlled exposure to wood smoke and particle deposition in the human respiratory system

Project leader: Prof. Erik Swietlicki, Div. of Nuclear Physics, Lund Institute of Technology.
Co-applicants: Prof. Anders Nordin, Prof. Thomas Sandström, Prof. Mats Bohgard, MD PhD Anders Blomberg, PhL Christoffer Boman.

1. The projects role and significance for the programme

This proposal is submitted in response to Call 3 (15 Oct. 2003) of the Swedish National Air Pollution and Health Effects Programme (SNAP). It is a joint collaboration project based on the extensive earlier research carried out by the participants during the last decades within the fields of biomass combustion, emission characterization, aerosol science and technology and health effects of air pollution exposure. It establishes interaction, integration and training for national researchers in a novel interdisciplinary way that would otherwise not take place. The proposed work is in accordance with several of the objectives of the SNAP programme, first of all by adding exposure and health effects related to wood smoke as a new aspect to the program. This problem is typical for Swedish conditions and has not been extensively studied internationally. By introducing particle deposition to various parts of the human respiratory system as a new dose metric, and linking it to physiological and immunological responses, the project will elucidate biological mechanisms associating wood smoke exposure and health outcomes. The project will use the exposure studies to evaluate the health effects associated with wood smoke in urban air, and quantitatively assess the risk for various health outcomes, in time for the final report of 2006. The project will also quantify the potential for reduction in health outcomes brought about by the introduction of new biomass combustion technology for domestic use.

2. Environmental relevance and expected significance for environmental policy

Residential biomass combustion appliances emit mostly sub-micrometer particles (<1 μm), and there is an increasing interest in their characteristics and implications to human health [1]. Epidemiological studies have clearly shown that exposure to ambient PM in general and fine combustion related particles in particular are associated with cardiopulmonary disease and mortality [2-4]. The toxicological mechanisms are, however, only partly understood and it has been suggested that other particle properties than mass concentration, e.g. ultrafine particles, transition metals and polycyclic aromatic compounds might be involved in the mechanisms responsible for the effects [1,5]. Also synergistic effects between particles and gaseous pollutants may exist and have been discussed earlier in diesel exhaust studies. Beside epidemiological studies, also animal toxicology and controlled human studies contribute to the knowledge of the toxicity of different pollutants. A limited number of epidemiological studies in relation to ambient wood smoke have been performed and recently reviewed by Boman et al [6] as well as more numerous studies addressing animal toxicology of wood smoke exposure [7]. However, **controlled environmental chamber exposure studies with wood smoke in humans have been lacking prior to this SNAP project initiative.**

For a given exposure of PM10, the dose to the human respiratory tract (given as number of particles, particle mass and surface area) can vary quite substantially depending mainly on the physical and chemical properties of the aerosol, most importantly the aerosol particle size distribution and the hygroscopic properties (i.e. droplet growth in the humid respiratory tract). Available experimental data on respiratory deposition in humans of “real-world” complex aerosols are largely missing. Due to the present lack of knowledge as to the underlying physiological mechanisms responsible for the health effects, it is prudent at this stage not to focus all efforts on quantities such as PM10 and PM2.5 that contain little information as to the interaction between the inhaled aerosol particles and the respiratory system. Instead, controlled and well designed systematic exposure studies are needed to seek new understanding about exposure-dose and dose-effect relationships in a way that can be generalized to a wide variety of aerosols (primary-secondary, natural-anthropogenic). This knowledge can then be used to infer health effects from basic aerosol physical measurements or aerosol dispersion and transformation models, once more information will become available regarding the actual physiological mechanisms involved. This project proposes to establish such exposure-dose and dose-effect relationships, based on the combustion aerosol particle size distribution, chemical characteristics and hygroscopic properties. These are not only fundamental chemical and physical properties of the aerosol, but they are also largely responsible for controlling the deposition pattern of the aerosol particles in the human respiratory tract.

In light of the ongoing conversion of the energy system with biomass as a major renewable and CO_2-neutral energy source as well as the issue concerning present residential wood combustion, the proposed project will significantly enhance the possibilities to perform relevant health impact assessments, set appropriate regulatory standards and make accurate evaluations concerning future use of residential biomass combustion appliances.

3. Scientific background

3.1. Participating groups

This project is an inter-disciplinary collaboration between four research groups: Div. of Nuclear Physics, Lund Institute of Technology (LTH-KF); Div. of Ergonomics and Aerosol Technology, Lund Institute of Technology (LTH-EAT); Dept of Respiratory Medicine & Allergy, Umeå University Hospital (UMU-RMA) and Energy Technology and Thermal Process Chemistry (ETPC) at Umeå University (UMU-ETPCs). The main applicant and co-applicants are Prof. **Erik Swietlicki** (LTH-KF), Prof. **Anders Nordin** (UMU-ETPC), Prof. **Thomas Sandström** (UMU-RMA), Prof. **Mats Bohgard** (LTH-EAT), MD PhD **Anders Blomberg** (UMU-RMA) and PhL **Christoffer Boman** (UMU-ETPC). Involved PhD students are also MSc **Joakim Pagels** (LTH-EAT), PhL **Jenny Rissler** (LTH-KF) and MD **Håkan Törnqvist** (UMU-RMA). Furthermore, Dr. Bo Olsson, Experimental Medicine, AstraZeneca R&D Lund, provides access to computational lung deposition models.

LTH-KF has conducted research in the field of atmospheric aerosols for nearly 30 years, and their extensive work on aerosol-water vapour interactions is of particular relevance to this project. LTH-EAT focuses on indoor and workplace aerosols and lung deposition measurements, and has developed the novel particle deposition measurement method. UMU-RMA has extensive experience of conducting human exposure chamber studies and studying health effects of air pollution. UMU-ETPC has extensive experience of biomass combustion chemistry, aerosol formation mechanisms and characteristics as well as on the use of statistical experimental design in the experimental and modelling work, including studies of the effects of combustion and fuel variables on emission and aerosol characteristics. The group also houses unique facilities for conducting exposure experiments with traditional wood- and pellet-fired appliances, isothermal lab-reactors as well as with synthetic aerosol generators. Three of the partners (UMU-ETPC, LTH-KF and LTH-EAT) take part in the “Emission Cluster” within the research programme “Biofuel – Health – Environment” (*Biobränsle – Hälsa - Miljö*) funded by the Swedish National Energy Agency (*Energimyndigheten*). LTH-KF also participates in the “Immission Cluster”.

The lung deposition program is developed by **Dr. Bo Olsson** (Experimental Medicine, AstraZeneca R&D Lund, SE-221 87 Lund, Sweden, e-mail: Bo.L.Olsson@astrazeneca.com Tel: +46-46-338601). AstraZeneca (http://www.astrazeneca.se/iSverige/) is a multinational pharmaceutical company, and the branch of Experimental Medicine at AstraZeneca R&D Lund specializes in drug delivery via the human airways. The model development at AstraZeneca is motivated by the need for accurate drug administration to the human respiratory tract, regarding target region, delivered dose and repeatability. There is a strong need for model calibration and validation.

3.2 Introduction to the research field

An increasing interest for sustainable energy production can be seen globally and the potential for increased use of biomass fuels, as carbon dioxide (CO_2)-neutral energy, is significant [9]. In Sweden, it has been estimated that the present biomass supply of about 97 TWh_a can be increased up to maximum of 230 TWh_a [10,11]. Within the residential sector, the present biomass combustion (mainly wood logs) comprises 10-12 TWh_a although with a significant potential for conversion from oil or electricity to modern wood or pellet combustion technology.

However, the present residential wood combustion is a major source of ambient local air pollutants, especially for hydrocarbons and particulate matter (PM). In many residential areas and smaller communities, there can be severe air quality problems especially during wintertime, which may periodically clearly exceed 100 $\mu g/m^3$ for PM_{10}. Wood smoke mainly consists of a complex mixture of gases (e.g. CO, NO and SO_2), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH) and PM. The PM is composed of inorganic ash material (including metals), soot and condensed organic material. CO, soot and organic compounds are products of incomplete combustion (PIC) and the amounts are strongly dependent on combustion efficiency. The majority of the presently used residential wood appliances suffer from poorly optimized combustion conditions compared to modern wood and pellets technology. This often results in situations with considerable emissions of PIC. The potential for new biomass technology using up-graded fuels, like pellets, is significant with drastically decreased

emissions of PIC´s [12]. During "optimized" combustion, the particulate matter mainly consists of alkali salts (e.g. KCl, K_2SO_4 and $K_3Na(SO_4)_2$) and particulate associated trace metals (e.g. zinc) [13]. Accordingly, the emission characteristics from residential biomass combustion can vary significantly depending on fuel properties and combustion conditions.

Particle deposition of monodisperse hydrophobic model aerosol to various parts of the human respiratory tract has been extensively studied and successfully modelled. According to these models, particles in the size range 200-600 nm where most of the mass is found, have a low deposition probability (~10-15%) and are to a large extent exhaled. However, particles smaller than 100 nm, mainly of anthropogenic origin, have a significantly higher deposition probability (~25-80%). Most of these ultrafine particles deposit in the alveolar region. Real-world aerosols often grow considerably in the humid (RH~99.5%) respiratory tract due to water uptake [22]. This has a large effect on the respiratory deposition especially for particles smaller than 200 nm and larger than 500 nm, as the particles deposit according to the altered diameter. Most of the particles from biomass combustion have a diameter of 50-150 nm and especially under favourable combustion conditions they show significant particle growth at RH=90% [23], almost as high as for pure potassium salts. Other uncertainties arise from the fact that combustion particles often consist of highly irregular agglomerated structures.

The few available studies of respiratory deposition of combustion particles (environmental tobacco smoke and vehicle emissions) shows a 1.5 to 3-fold higher deposition experimentally, compared to model predictions [33]. Hygroscopic laboratory (NaCl) aerosols have been studied in very few test subjects, and there is a disagreement between different data sets [34]. The reasons for these discrepancies are currently unknown. To our knowledge, no measurements of respiratory deposition in humans have been performed on wood combustion aerosols.

Since the emissions from biomass combustion comprise a complex mixture of different pollution components, it can be assumed that exposure to wood smoke is potentially harmful to human health. A relative extensive amount of work have been performed concerning adverse biological effects and toxicity of both individual gaseous combustion by-products, e.g. CO [14], NO_x [15,16] and SO_2 [17], as well as particulate air pollution [18-20]. However, very few studies have dealt with effects of exposure to wood smoke as a complex mixture of gaseous and particulate pollutants and no controlled human exposure studies have been reported dealing with wood smoke, see Boman et al. [6]. In the few epidemiological studies performed, substantial quantitative information was found only for acute asthma in relation to PM_{10}, with stronger relative risks compared to the general estimations (e.g WHO). Thus, there seemed to be no reason to assume that the effects of particulate matter in areas polluted by wood smoke are weaker than elsewhere. There is therefore an evident need today to elucidate the mechanism that links different biological effects with specific emission components or aerosol properties.

4. Objective and hypothesis

Overall objective:

To characterize the symptoms, respiratory and cardiovascular effects and changes in lung function induced by controlled exposure to biomass combustion emissions in healthy adults, and relate these to the physical and chemical properties of the combustion aerosol, the size-resolved dose of aerosol particles to various parts of the human respiratory system, and the wood combustion efficiency.

Hypotheses:

- Exposure to wood smoke will lead to pulmonary function changes, cardiovascular effects, and inflammatory respiratory and systemic effects, similar to those observed in humans exposed to diesel exhaust aerosols.
- The pollutant mixture produced under poor combustion conditions have stronger adverse health effects compared to the emissions deriving from an optimized and near-complete combustion.
- The dry particle size distribution in combination with the hygroscopic properties of the particles can account for the main features of respiratory particle deposition, for a given breathing pattern and dimensions of respiratory tract.

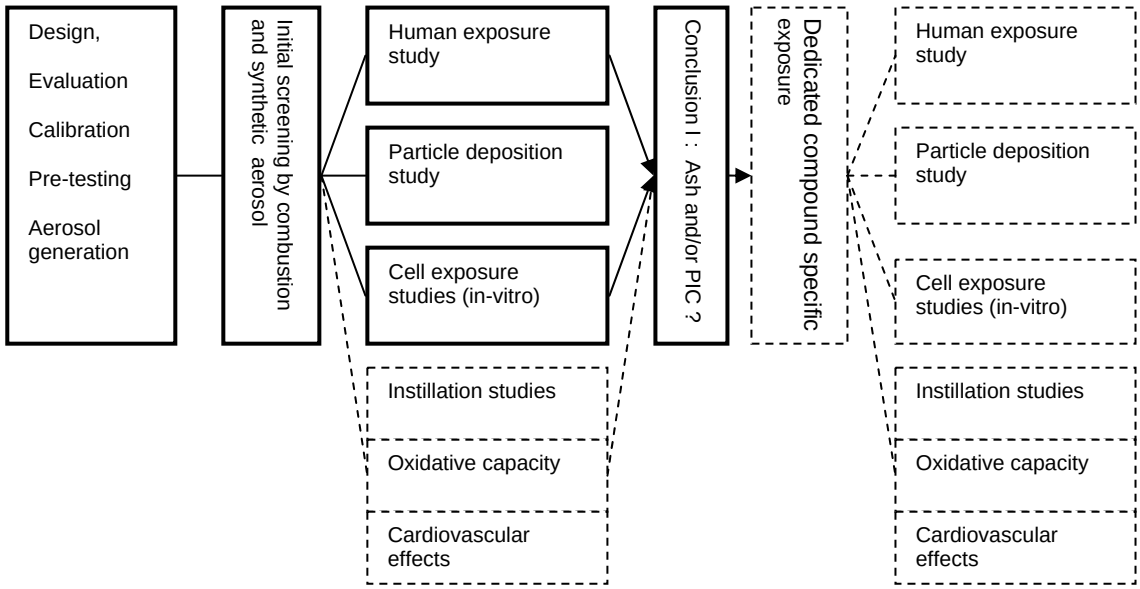
Specific scientific objectives:

1. To characterize the diluted biomass combustion generated emissions in the exposure chamber set-up during poor and optimized combustion respectively.
2. To establish the applicability of the new particle respiratory deposition measurement method to the diluted biomass combustion aerosol.

3. To expose healthy adult subjects to the well-characterised diluted biomass combustion emissions during ordinary old standard combustion vs. novel optimized technique (without PIC) combustion respectively, and to an artificial hygroscopic salt aerosol, and perform concurrent measurements of the particle deposition in the respiratory tract for each of these aerosols.
4. To study the effects of exposure to different kinds of biomass combustion emissions in healthy adult subjects in terms of experienced symptoms, pulmonary function changes, and inflammatory respiratory and systemic effects.
5. To model the particle deposition in the respiratory tract using the measured fundamental aerosol physical properties as input, and to compare the model predictions with the actual deposition measurements.
6. To establish exposure-dose-effect relationships and elucidate biological mechanisms.
7. To evaluate the health effects associated with wood smoke in urban air, and perform a preliminary risk assessment for various health outcomes.

5. Methods and implementation

The present proposal constitutes a continuation of a large number of well recognized UMU-RMA exposure studies on diesel exhaust, now followed by an extensive and dedicated program for biomass combustion emissions. The different planned work packages can be illustrated with the following schematic box diagram:



The presently proposed initiation study will include an extensive experimental matrix (solid boxes), which will significantly contribute to the quantification of health effects from wood smoke. It will first of all conclude the relative importance of combustion quality (i.e. PIC versus inorganic ash aerosols) on different health responses and in comparison with other air pollution (e.g. diesel exhaust). The specific effects of some aerosol components will also be included in the two year period. However, to fully link all emission components and aerosol properties with specific biological responses, extended dedicated component specific studies are needed and planned for. Based on the results from the above studies, the following work will be focused on specific PIC- and/or inorganic aerosol components or mixtures.

5.1 The biomass combustion aerosol exposure chamber

The UMU-RMA exposure chamber has been carefully evaluated and validated by Rudell et al 1994 [21] and extensively used in numerous diesel exhaust studies [24-29]. A corresponding design has been used to integrate a new on-campus exposure chamber with synthetic aerosol generators and wood fired combustion appliances, facilitating systematic variable studies.

5.2 Characterisation of the diluted biomass combustion aerosol in the exposure chamber

The wood smoke will be designed to consist of emissions from combustion of pelletized woody raw materials under both traditionally poor and incomplete conditions as well as optimized conditions

representing future best available residential technology (BAT), i.e. no PIC. The combustion will be performed in an experimental pellet stove where the combustion conditions easily can be controlled and adjusted. Approximately 90% of the exhaust is shunted away and the remaining part diluted with filtered air and fed into the chamber at a steady-state concentration. During the exposures, air is sampled in the breathing zone of the subjects and continuously analyzed for the traditional combustion by-products O_2, CO_2, CO, NO/NO_2, THC (total gaseous hydrocarbons), total PM and aerosol particle properties (see below). The wood smoke entering the environmental chamber is tuned to give realistic ambient exposure concentrations based on previous research results within BHM (e.g. PM_{10} ~100 μg /m^3). Care is taken to ensure that no concentration gradients occur in the chamber. Dry number particle size distributions (0.007-10 μm) will be measured in near real-time using an electrical mobility spectrometer (SMPS), and a time of flight instrument (APS). The volatility of sub-micrometer particles will be studied by heating the particles in a thermodenuder before entering the SMPS. From these measurements the vapour pressures and thereby information of the chemical composition can be inferred for different size fractions. A Diffusion Charger (DC) measures the total active particle surface area, which is an important exposure metric for agglomerated particles. The time resolution of these instruments is on the order of seconds to minutes. The hygroscopic properties of the particles as a function of particle dry size (20-500 nm) will be measured by a Humidity Tandem Differential Mobility Analyzer (H-TDMA), an instrument developed in Lund. Size distributions for mass, elemental and inorganic phase compositions will be measured by gravimetry, PIXE/SEM-EDS and XRD analysis on samples collected with a Dekati Low Pressure Impactor. A carbon analyzer will determine the mass of both organic and elemental carbon. In addition, 50 specific PAH components will be analysed in accordance with previous work within STEM-BHM [30,31]. The influence of changing the dilution temperature and dilution ratio will be examined, since it has been shown previously that these play a vital role in the formation of nucleation mode particles (<20 nm). The full characterization will result in an optimised set of chamber operational parameters so that a diluted biomass combustion aerosol representative for the exposure taking place in a residential wood-burning urban area can be produced. Comprehensive experience of the air quality in such areas was achieved through measurements performed by LTH-KF and others within "*Biobränsle – Hälsa – Miljö"* in Lycksele and Växjö (http://www.itm.su.se/BHM/rapporter.html).

5.3 Novel aerosol respiratory deposition method

The Lund groups have developed a new method to determine size-fractionated respiratory deposition of fine and ultrafine aerosol particles [8]. The system has been tested for both hydrophobic and hygroscopic aerosols in an exposure chamber in Lund similar to the one described above.

The basis of the method is the conservation of the dehydrated particle diameter in inhaled and exhaled air. The system utilizes a combination of two near real-time aerosol size spectrometers (SMPS and APS), sampling alternatively in inhaled and exhaled air. The deposition in the respiratory tract is determined by comparing the particle size distributions (at RH<15%) in inhaled and exhaled air. Previous studies have shown that the system can produce fast (~5-10 min) and reliable data in the size range 15 nm - 2.5 μm. In this project we will extend the method to diluted biomass combustion aerosol. The inhalation and exhalation flow is determined by a pneumotachograph. The test subjects can continuously follow their breathing pattern via a Video Display Unit and compare it to the suggested pattern. Particle number size-distributions 0.007-10 μm and hygroscopic properties will be measured throughout the entire exposure study. The TDMA is capable of measuring the increase in particle diameter at a high RH (~95%). From this value extrapolations are made to estimate the growth factors found in the respiratory tract (RH~99.5%). Such extrapolations, even to water vapour supersaturations (RH>100%), have been proven to produce accurate results in numerous previous studies.

5.4 Study design and methods

15 healthy adult subjects will be included in the study. Individual breathing patterns of the test subjects will be determined prior to the experiments using inductive plethysmography [32]. The geometrical dimensions of the lungs of each test subject is estimated from spirometry (vital capacity, peak expiratory flow, forced expiratory volume in the first second). The spirometric data will also be used to establish the representativeness of the group of selected persons. The test subjects will undergo a medical examination.

In the newly developed wood smoke exposure chamber, the subjects will first inhale 1) a hydrophobic oil aerosol and 2) a hygroscopic potassium salt aerosol, while measuring the particle deposition in the human respiratory tract. These measurements span the range of hygroscopicity found in real biomass combustion aerosols, and establish the influence of the hygroscopic particle growth on the

deposition pattern. Subjects are then exposed in blinded and randomised sequence to filtered air and biomass combustion aerosol with a PM_{10} concentration of ~100 μg /m^3. All individuals are pre-screened and tested for accurate lung function and induced sputum production performance as well as minute ventilation during exercise and rest.

The exposure time is two hours with subjects alternating rest with exercise on a bicycle ergometer (V_E = 20 L/min/m^2 body surface). Mucosal and airway symptoms are scored according to a modified Borg scale before, during and after exposures [21].

Lung function test including static and dynamic spirometry with measurements of airway resistance (sRaw and sGaw) will be performed before and after exposure. Nitric oxide (NO) measurements will be performed as a marker for airway inflammation, together with breath condensate for measurements of pH, nitrothyrosine, nitrate, hydrogen peroxide and malondialdehyde. Induced sputum is performed six hours after exposures with hypertonic saline according to Pizzicine for differential cells, methyl-histamine, myeloperoxidase, IL-6, IL-8, IL-10, ECP, ascorbic acid, gluthathione, uric acid, alpha tocopherol Peripheral blood samples will be collected before, directly after, 6, and 24 after exposure for measurements of cell differential counts, CRP, s-ICAM-1, s-P-selectin, IL-6, IL-8 and fibrinogen. Nasal lavages are performed according to lab routines before, directly after and 6 hours after exposure for antioxidant determination as given above. Cell exposure studies will be performed by well established techniques in used in the EU supported HEPMEAP-project (www.hepmeap.org).

6. How results will be presented in accordance with the programme

The results from the project will be well documented and disseminated in terms of a concluding report to the funding body, as well as international publications in peer review journals, PhD-theses, international seminars and conferences, as well as to the university and national and international authorities.

7. Time schedule

The table below outlines the project time plan for the period 1 January 2004 and 31 December 2005.

Activity	**2004**	**2005**
Proposed project time frame	|----------	----------
	--	--|
Recruitement of human test subjects	|---------|	
Calibration of exposure chamber and measurement techniques	|----------|	
Diluted wood smoke aerosol characterization	|-------|	
Wood smoke exposure studies	|--| |--|	|--|
Data evaluation and assimilation	|--------	----------|
Modelling of particle deposition	|----------	----------|
Establishing wood smoke exposure-dose-effect relationships	|-----	----------|
Quantitative wood smoke health risk assessment		|----------|
Project report		||
Dissemination of results and publication in scientific journals		|-- - - - - - - - - - -

8. References

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13. Boman C, Nordin A, Boström D, Öhman M. Characterization of inorganic particulate matter from residential combustion of pelletized biomass fuels. Accepted for publication in Energy and Fuels.
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17. Schlesinger RB. Toxicology of sulfur oxides. In: Holgate ST, Samet JM, Koren HS, Maynard R, editors. Air pollution and health. London: Academic Press; 1999. p. 585-602.
18. Ghio AJ, Samet JM. Metals and air pollution particles. In: Holgate ST, Samet JM, Koren HS, Maynard R, editors. Air pollution and health. London: Academic Press; 1999. p. 635-51.
19. MacNee W, Donaldson K. Particulate air pollution: injurious and protective mechanisms in the lungs. In: Holgate ST, Samet JM, Koren HS, Maynard R, editors. Air pollution and health. London: Academic Press; 1999. p. 653-72.
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21. Rudell B, Sandström T, Hammarström U, Ledin M-C, Hörstedt P, Stjernberg N. Evaluation of an exposure set-up for studying effects of diesel exhaust in humans. Int Arch Environ Health 1994, 66, 77-83.
22. D. M. Broday and P. G. Georgopolus Growth and Deposition of Hygroscopic Particulate Matter in the Human Lungs. 2001, Aerosol Science and Technology vol. 34 Pages: 144 – 159**.**
23. J. Pagels, M. Strand, J. Rissler, A. Szpila, A. Gudmundsson, E. Swietlicki, M. Bohgard, and M. Sanati. 2003. "Characteristics of aerosol particles formed during grate combustion of moist forest residue" *Journal of Aerosol Science*, **34**, 1043-1059.
24. Rudell B, Ledin MC, Hammarstrom U, Stjernberg N, Lundback B, Sandström T. Effects on symptoms and lung function in humans experimentally exposed to diesel exhaust. Occup Environ Med 1996 Oct;53(10):658-62
25. Salvi S, Blomberg A, Rudell B, Kelly FJ, Sandström T, Holgate ST, Frew AJ. Acute inflammatory response in the airways and peripheral blood following short term exposure to diesel exhaust in healthy human volunteers. Am J Respir Crit Care Med 1999;159:702-709.
26. Rudell B, Wass U, Hörstedt P, Levin JO, Lindahl R, Rannug U, Sunesson AL, Östberg Y, Sandström T. Efficiency of automotive cabin air filters to reduce acute health effects of diesel exhaust in human subjects. Occup Environ Med. 1999 Apr;56(4):222-31
27. Salvi SS, Nordenhäll C, Blomberg A, Rudell B, Pourazar J, Kelly FJ, Sandström T, Holgate ST, Frew AJ. Acute exposure to diesel exhaust increases IL-8 and GRO-α production inhealthy human airways. Am J Respir Crit Care Med, 2000;161:550.
28. Nordenhäll C, Pourazar J, Blomberg A, Sandström T, Ädelroth E. Airway inflammation following exposure to diesel exhaust: A study of time kinetics using induced sputum. Eur Respir J. 2001 May;17(5):909-15.
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30. Boman C, Nordin A, Westerholm R, Pettersson E. Influence of dilution sampling conditions on particulate and PAH characteristics from residential biomass fired appliances. Submitted to Biomass and Bioenergy
31. Christoffer Boman, Fredrik Lindmark, Marcus Öhman, Anders Nordin, Roger Westerholm Effects of temperature and residence time on emission characteristics from isothermal combustion of biomass pellets. Submitted to Energy & Fuels.
32. Bennett, W., D. and Zeman, K., L. (1998) Deposition of Fine Particles in Children Spontaneously Breathing at Rest. Inhalation Toxicol. 10:831-842.
33. W. Hofmann, L. Morawska, J. Hitchins and M. Ahmed 2003. Total Deposition of Combustion Aerosols in Human Respiratory Tract: Comparison Between Experimental Results and Model Predictions. Proceedings of the European Aerosol Conference 2003.
34. Ferron, G. A., Kreyling, W. G. and Haider, B (1988) Inhalation of salt aerosol-II. Growth and deposition in the human respiratory tract J. Aerosol Sci. 18:611–631.

Curriculum Vitae
Professor Erik Swietlicki

1. Personal information
Name: Erik Robert Swietlicki
Born: 20 November 1958 in Lund, Sweden
Nationality: Swedish (Swedish civic registration number: 581120-4030)
Civil status: Married 9 Aug. 1986 to Åse Gunilla, b. Holmberg, 8 July 1956
Children: Sara Madeleine Swietlicki, born 16 Oct. 1988 in Lund, Sweden
Daniel Sebastian Swietlicki, born 26 Jan. 1995 in Lund, Sweden
Sofie Helena Swietlicki, born 28 May 1997 in Lund, Sweden
Home address: Skallgången 18, S-226 52 Lund, tel: +46-46-211 05 35

2. Business address
Division of Nuclear Physics, Department of Physics, Lund University/Technical Faculty, P.O. Box 118, S-221 00 Lund, Sweden. (*Avd. för kärnfysik, Fysiska institutionen, Lunds universitet/LTH, Box 118, 221 00 Lund*)

3. Present position
- Professor from 1 July 2002 at the Division of Nuclear Physics, Lund University/LTH.

4. Previous academic positions (last ten years)
- Scientific visitor (Post-Doc) during the period 1 November 1989 - 31 October 1990 at the Central Bureau for Nuclear Measurements, Geel, Belgium. This institute is a Joint Research Centre run by the Commission of the European Communities.
- Assistant researcher (*forskningsassistent*) from 1 November 1990 to 31 June 1992 at the Division of Nuclear Physics, Lund University.
- Junior researcher (*forskarassistent*) from 1 July 1992 and limited to 31 Dec. 1998 at the Division of Nuclear Physics, Lund University. This position was to a large extent funded by the Swedish Natural Science Research Council (NFR).
- Senior lecturer (*universitetslektor*) from 1 Jan. 1999 at the Division of Nuclear Physics, Lund University/LTH.

5. Degrees
- Master of Science in Engineering Physics, May 1983, Lund University/Technical Faculty, Sweden (*Civilingenjör Teknisk Fysik, LTH*)
- Doctor of Philosophy in Engineering, Nuclear Physics, September 1989, Lund University/Technical Faculty, Physics Dept., Lund, Sweden (*Tekn. dr. i kärnfysik, Fysiska institutionen, LU/LTH*)
- Docent at the Dept. of Physics, Lund, Sweden, June 1994 (*Docent i Fysik, Fysiska institutionen, LU/LTH*)
- Professor at the Dept. of Physics, Lund University/LTH, July 2002

6. PhD student supervisor
At present, I am acting as supervisor for four PhD students (Arash Gharibi, Adam Kristensson, Matthias Ketzel and Jenny Rissler). Gharibi, Kristensson, Ketzel and Rissler started their PhD studies in December 1999, February 2000, July 2000 and November 2000 respectively. I am also acting as co-supervisor for two PhD students at the Div. of Ergonomics and Aerosol Technology, Lund Institute of Technology; Joakim Pagels and Aneta Szpila.

Olle Berg, whom I supervised since 1 Sept. 1994, defended his licentiate thesis entitled "Measurements and modelling of hygroscopic properties of atmospheric particles" in October 1997. Jingchuan Zhou, whom I supervised since 1 Oct. 1996, presented his thesis entitled "Hygroscopic properties of atmospheric particles in various environments" successfully on April 19, 2001. Adam Kristensson presented his licentiate thesis entitled "Characterization of sources of aerosol particles affecting the Swedish air quality" in January 2003. Matthias Ketzel presented his licentiate thesis entitled "Experimental and modelling studies of particle and gaseous pollutants in urban street environments" in January 2003.

7. Current project responsibility (acting as Principal Investigator or Coordinator)
- Water-soluble organic compounds in the atmospheric aerosol – Effects on cloud droplet formation, hygroscopic properties and climate – Swedish VR
- Aerosol monitoring at a background station in southern Sweden - Swedish EPA (Environmental Monitoring)
- ASTA: International and national abatement strategies for transboundary air pollution; Particulate air pollution – Concentrations, transport and sources – Swedish MISTRA
- Biomass combustion aerosol formation and effects - Swedish STEM
- Emissions and air quality - Emission cluster - Swedish STEM
- Emissions and air quality - Air quality cluster - Swedish STEM
- Sources of airborne particles over the remote Arctic Ocean and their climatic impact – NMR/NARP (Nordic)
- LBA-SMOCC (Smoke aerosols, clouds, rainfall and climate: Aerosols from biomass burning perturb global and regional climate) – EU

In total, I have secured external funding for the Lund Aerosol Group amounting to 2.7 MSEK for the year 2001, 3.1 MSEK for the year 2002, and 3.1 MSEK for 2003.

8. Course responsibilities

I am responsible for courses in "Environmental Measurement Technology" (5 credits) and "Atmospheric Chemistry" (3 credits) for students at the Lund Institute of Technology (LTH).

9. Boards and committees

- Since October 2000, I am *chairman of the Nordic Society for Aerosol Research* (Nordiska Aerosolsällskapet, NOSA; member of the board since November 1998).
- Since 15 October 1998, I am a member of the *board of the Swedish Clean Air Society* (Svenska Luftvårdsföreningen).
- Since 1 January 2003, I am a member of the *board of the Centre for Environmental Studies at Lund University* (Miljövetenskpaligt Centrum, Lunds universitet).
- I served on the *Scientific Steering Committee for LBA*, The Large Scale Biosphere-Atmosphere Experiment in Amazonia, 1999-2001.
- I servced on the *committee for ACAPS* (Aerosol Characterization and Process Studies) within IGAC (International Global Atmospheric Chemistry Project), which in turn forms a part of IGBP (International Geosphere-Biosphere Program), 1996-2001.

10. Referee

I have served as referee for papers submitted to the following journals: Atmospheric Chemistry and Physics, Atmospheric Environment, Atmospheric Research, Boreal Environment Research, Chemometrics and Intelligent Laboratory Systems, Environmental Science and Technology, International Journal of PIXE, Journal of Aerosol Science, Journal of Geophysical Research - Atmospheres, Nuclear Instruments and Methods in Physics Research, Physics and Chemistry of the Earth, The Quarterly Journal of the Royal Meteorological Society, Scanning Microscopy, Tellus, Water Soil and Air Pollution, and finally X-ray Spectrometry.

12. External examiner of research proposals

I have served as an external examiner of research proposals for the Swedish MISTRA and KK foundations, and for the research councils of German BMBF and the British NERC.

13. Duties as opponent and member of examination board

I have served as faculty opponent and member of the examination board at the following occasions:

- *Faculty opponent* on Licentiate thesis entitled "Scattering of light by small droplets in sprays" presented by Fredrik Ossler, Div. of Combustion Physics, Physics Dept., Lund University/LTH, 26 March 1997.
- *Member of examination board* during the presentation of the PhD thesis entitled "Atmospheric transport of persistent organic pollutants to aquatic ecosystems" defended by Cecilia Agrell, Div. of Chemical Ecology and Ecotoxicoloy, Dept. of Ecology, Lund University, 21 May 1999.
- *Member of examination board* during the presentation of the PhD thesis entitled "Laser diagnostics in combustion – Elastic scattering and picosecond laser-induced fluorescence" defended by Fredrik Ossler, Div. of Combustion Physics, Physics Dept., Lund University/LTH, 4 June 1999.
- *Faculty opponent* on PhD thesis entitled "Variation of aerosol concentration in ambient air" presented by Gintautas Buzorius, Physics Dept., Helsinki University, 31 May 2000.
- *Faculty opponent* on PhD thesis entitled "Properties of air pollutants in Botswana: Sources, concentration and dispersion of aerosol particles" presented by Kgakgamatso Moloi, Dept. of Experimental Physics, Chalmers Univeristy of Technology and Gothenburg University, 14 February 2001.
- *Member of examination board* during the presentation of the PhD thesis entitled "Persistent organic pollutants in the atmosphere" defended by Cecilia Backe, Div. of Chemical Ecology and Ecotoxicoloy, Dept. of Ecology, Lund University, 4 May 2001.

14. Originality and development ability

Quotation taken from the March 2001 VR evaluation report within the area of "Exogenic Processes 3 – Geosphere Dynamics": "The measurement techniques, in which he has had a major development role, have been copied by many other groups. The field is rapidly expanding, and is one where technical developments are paramount. New discoveries are being made at a rapid rate, and Erik Swietlicki is well positioned to become a world-leader."

15. Scientific productivity

Quotations taken from the March 2001 VR evaluation report within the area of "Exogenic Processes 3 – Geosphere Dynamics": "Erik Swietlicki has published at a high rate over the period 1995-2000, and the publications are virtually all in high-quality journals." … "Erik Swietlicki has developed an international reputation as one of the most

active and productive scientists in his research area, and his papers are well cited." … "His talents are considerable, and his efforts are enhancing the international reputation of the university in which he works.

En Techn & Thermal Proc Chem
Umeå University
S-901 87 Umeå
anders.nordin@chem.umu.se
-90-7865264 (tel.)
-90-7869195 (fax.)

Anders Nordin

Title

Prof. Energy Engineering January, 2003
Ass.Prof. (Docent) Energy and Recovery Processes, December 2000
PhD (Inorganic Chemistry, UmU), June 1993MSc (Engineering Physics, UmU), 1988

Summary of qualifications

Degrees in engineering physics and inorganic/combustion chemistry. Twelve years experience of research work in the area of inorganic chemistry, especially process modelling and optimization in combustion and gasification of biomass fuels, both at the Department of Inorganic Chemistry at Umeå University (presently 8 PhD students) and Energy Technology Center in Piteå (Managing Director/Director of research 1995-2000). From 1996 to 1999, Adj. Professor at the division of Energy Engineering, Luleå Technical University (Two licentiate degrees (-99), presently one PhD student). Extensive and close collaboration with industry, especially ASSI Domän, ÅF and regional enteprizes. Received the Swedish Steam Users Associations Technology Transfer Prize in 1997. Post Doc scholar, visiting dept. Chem. Eng. at Åbo Akademi University (autumn 1994) and one year (1997/1998) as
a visiting scientist at National Renewable Energy Laboratory, Golden, Colorado. Appointed strategic Energy Engineering professor at UmU in January 2003.

Professional experience

2003-	Full Professor Energy Eng. Head of Energy & Process Technology
2001-	Ass. Prof. Inorganic Chemistry -Energy and recovery processes
1999 -	University Lecturer, Umeå University
1997 - 1998	Visiting Scientist National Renewable Energy Laboratory, USA
1996 - 1999	Adj. Prof., Energy Engineering, Luleå Technical University
1995 - 2000	Managing Director/Director of Research, Energy Technology Center
1994	Post Doc scholar Åbo Akademi University, Finland
1993 -	University Lecturer, Inorganic Chemistry, Umeå University
1989 -	Managing Director of a small company (ProcessOMetri AB)

Additional professional activities

Engaged as reviewer by seven journals and books (Environ. Sci. Technol., Environ. Eng. Sci., Scand. J. Forrest. Res., Haz. Waste Haz. Mtrls., Energy & Fuels, Energy, Impact of mineral impurities in solid fuel combustion). Session chairman at the EF International Ash Conference and conference chairman of the International Flame Research Foundations (IFRF) biomass conference. Conference chairman of the IFRF Biomass Combustion Technical Oriented Meeting 1999. Member of the IFRF scientific and technology advisory group.

Awards received

1997	Swedish Steam Users Associations Technology Transfer Price
1989	The Swedish State Power Boards Energy Award

Professional memberships

American Chem. Soc.; Combustion Inst.; International Flame Research Fondation

Research interest	Inorganic high-temperature chemistry, chemical engineering, process chemistry, process closure, pollution control, biomass combustion and gasification, black liqour combustion and gasification, high temperature processes, thermochemistry, ash related problems, alkali and heavy metal speciation in high temperature processes, fate of non-process elements, chemical equilibrium modelling, chemometrics.
Supports - principal investigators	Swedish National Energy Administration, US DOE through NREL, Swedish Research Council for Engineering Research, ASSI Domän AB and several other industrial partners, EC Regional Funds, EC DG XII, Swedish National Board for Ind. and Techn. Dev., Swedish National Energy Administration, Kempe Foundation, Swedish State Power Board, Swedish Steam Users Ass., Thermal Engineering Foundation, Center for Environmental Research (CMF), Umeå University, Kempe Fondation.
Publications	Totally 35 papers in refereed journals, 25 conference papers and 30 technical reports. Some examples:

1. Nordin, A. **Chemical elemental characteristics of biomass fuels.** *Biomass & Bioenergy* **6(5),** 339-347, 1994.

2. Nordin, A. Eriksson, L. Öhman, M. **NO reduction in a fluidized bed combustor with primary measures and selective non-catalytic reduction; A screening study using statistical experimental designs.** *FUEL*, **74,** 128-135, 1995.

3. Nordin, A. **Optimization of sulphur capture when co-firing peat and biomass in a bench scaled fluidized bed reactor.** *FUEL* **74**, 615-622, 1995

4. Öhman, M. and Nordin, A**. A new method for quantification of agglomeration tendencies - a sensitivity study.** *Energy & Fuels* 12, 90-94, 1998

5. Ljung, A. and Nordin, A. **Theoretical feasibility for ecological ash recirculation; chemical equilibrium behaviour of nutrient elements and heavy metals during combustion.** *Environ. Sci. Technol.* 31, 2499-2503, 1997

6. Ljung, A., Nordin, A. **Effects of fuel characteristics, combustion conditions and inaccuracies in thermochemical data on trace element equilibrium behavior**, Submitted to *Environ. Sci. Technol.*

7. Skrifvars, B-J., Öhman, M., Nordin, A., Hupa, M. **Predicting bed agglomeration tendencies for biomass fuels fired in FBC boilers a comparison of three different methods.** *Energy & Fuels* 13, 2, pp 359-363, 1999

8. Natarajan, E., Nordin, A., Rao, A. N. **Overview of gasification of rice husk in fluidized bed reactors.** *Biomass & Bioenergy,* 14, 533-546

9. Natarajan, E., Öhman, M., Gabra, M., Nordin, A., Liljedahl, T., Rao, A. N. **Experimental determination of bed agglomeration tendencies of some common agricultural residues in fluidized bed combustion and gasification.** *Biomass & Bioenergy* 15, 163-169, 1998

10. Latva-Somppi, J., Kauppinen, E. I., Kurkela, J., Tapper, U., Öhman, M., Nordin, A., Johanson, B. **Ultrafine ash particle formation during waste sludge incineration in fluidized bed reactors.** *Combust. Sci. Technol.* 134, 433-456, 1998

11. Öhman, M., Nordin, A., Skrifvars, B-J., Backman, R., Hupa, M. **Bed agglomeration characteristics during fluidized bed combustion of biomass fuels.** *Energy & Fuels,* 14:1, 169-178

12. Dayton, D., Bell D., Nordin, A. **Effect of coal minerals on chlorine and alkali metals released during biomass/coal cofiring**. *Energy & Fuels* 13, 6, pp 1203-1211, 1999

13. Desroches-Ducarne, E., Marty, E., Martin, G., Delfosse, L., Nordin, A. Effect of operating conditions on HCl emissions from municipal solid waste combustion in a laboratory-scale fluidized bed incinerator. *Environ. Eng. Sci*. 15: (4), pp 279-289, 1998

14. Öhman, M., Nordin, A. **The role of kaolin in prevention of fluidized bed agglomeration.** *Energy & Fuels*. 14:3, pp 618-624

15. Gabra, M. Nordin, A. Öhman, M. Kjellström, B. **Alkali retention/separation during Bagasse gasification – A comparison between a fluidised bed and a cyclone gasifier.** *Biomass & Bioenergy* 21, 461-476, 2001.

16. Blander, M., Milne, T. A., Dayton, D. C., Backman, R., Blake, D., Kuhnel, V., Linak, W., Nordin, W., Nordin, A., Ljung, A. **Equilibrium chemistry of biomass combustion: A round-robin set of calculations**

using available computer programs and databases. *Energy & Fuels*, 15, 244-349, 2001.

17. Nordin, A. Sundqvist, T. Ljung, A. Backman, R. Lind, T. Kauppinen, E. **Heavy metal behaviour during isothermal bench-scale fluidized bed combustion of Salix and forest residues**. To be submitted *Biomass & Bioenergy*. (In Sundqvists thesis)
18. Sundqvist, T. Nordin, A. Backman, R. **A new high temperature process for ecological biomass ash recirculation – Heavy metal separation**. Submitted to Environ. Sci. Technol. (In Sundqvists thesis)
19. Hökfors, C. Nordin, A. Wallbäcks, L. **Effects of different additives on NOx reduction and production of NH3 and N2O.** Manuscript to be submitted (In Hökfors thesis)
20. Hökfors, C. Öhman, M. Nordin, A. Wallbäcks, L. **On-line multivariate statistical process control for emission minimization and process optimization.** Manuscript to be submitted (In Hökfors thesis)
21. Pettersson, E. Nordin, A. Öhman, M. **Effects of temperature and residence time on emissions of CO, total hydrocarbons tars and NOx during pellet combustion.** Manuscript to be submitted to *Biomass and Bioenergy*.
22. Mattsson, J. Nordin, A. Backeström, M. **Minimization of NOx emissions from a full-scale recovery boiler.** Manuscript to be submitted to TAPPI Journal.
23. Zevenhoven, M. Öhman, M. Skrifvars, B-J. Backman, R. Nordin, A. Hupa, M. **Bed agglomeration in a biomass fired fluidised bed furnace – a chemical approach**. Submitted to Fuel.
24. Brus, E. Nordin, A. Kassman, H. Kallner, P. **Fate of potassium and other salt forming elements during combustion of high-chlorine biomass fuels – chemical equilibrium sensitivity analysis.** Submitted to the Combustion Journal.
25. Boman, C. Nordin, A. Boström, D. Öhman, M. **Characterisation of inorganic particulate matter from residential combustion of pelletised biomass fuels.** Accepted to Energy and Fuels.
26. Sandelin, C. Backman, R. Nordin, A. **Equilibrium distribution of Arsenic, Chromium and Copper in the burning of impregnated wood.** Submitted to Environ. Sci. Technol.
27. Byström, M. Nordin, A. **Thermal separation of radioactive Cesium from biomass ash.** Submitted to Environmental Science and Technology
28. Byström, M. Nordin, A. **Effects of high-temperature treatment on leaching properties of biomass ash granules aimed at recirculation to forest and farmlands** Manuscript to be submitted to Environmental Science and Technology
29. Byström, A. Nordin. **Thermal treatment of biomass ashes and sludges with the aim of recycling – separation of heavy metals and PAHs.** Manuscript to be submitted to Environmental Science and Technology
30. Öhman, M. Nordin, A. Lundholm, K. Boström, D. Hedman, H. Lundberg, M. **Ash transformations during combustion of meat-, bonemeal and RDF in fluidized bed combustion**. Energy & Fuels, .
31. Nordin, A. Öhman, M. Brus, E. Skrifvars, B-J. Backman, R. **Bed material consumption in biomass fired fluidised bed boilers due to risk for bed agglomeration - coating formation and possibilities for regeneration.** Combustion Journal 200302, June, 2003.
32. Boman, C., Nordin, A., Thaning, L. **Effects of increased biomass pellet combustion on ambient air quality in residential areas – a parametric dispersion modelling study.** Biomass & Bioenergy 24 (6), 2003, 465-474

CV for Project Leader Thomas Sandström

TS (born in 1957) received his MD in 1983 and presented his PhD thesis on Respiratory effects of the air pollutants sulfur dioxide and nitrogen dioxide at in 1989. Two years later in 1991 he was awarded an associate professorship at the Medical Faculty at Umeå University and become specialist in Respiratory Medicine the same year.

In 1992 TS received a Senior Lecturer/ Consultant position and in 1997 he was awarded the first Chair in Respiratory Medicine at Dept of Respiratory Medicine and Allergy at Umeå University Hospital

TS has tutored six fellows to PhD's (Five on air pollution and one on asthmatic airway inflammation) and currently tutors five more fellows. He has been examiner ("opponent") on eight PhD Thesises since 1997. He serves and has served on several Committees, Steering Groups and Boards nationally, in Europe and the US. He is currently engaged in WHO work groups on air pollution issues. In 2001 he was awarded the Swedish Royal Skytteanska Research Prize.

The applicant is co-ordinator for the EU FP5 supported project HEPMEAP and participant in the EU supported Thematic European Air Pollution Network (AIRNET) which is under final financial negotiation. Together with Prof G Viegi Pisa he did in 2001 arrange the EU sponsored AFORDEE meeting, an EU-US interactive meeting on "Air Pollution Effects in the Elderly".

TS is Associate Editor for European Respiratory Journal and European representative in the American Thoracic Society (ATS) Environmental-Occupational Health Program Planning Committee. He has repeatedly served as Chairman and invited speaker at European and American Respiratory, Allergy and Air pollution Meetings and during the last year in this respect been invited to the Fraunhofer Instutute 8th International Inhalation Symposium, , California Air Pollution Technology and Solutions Management Meeting, Ontario Air Pollution Control Meeting, Canada, and other meetings.

Scientific papers in peer review journals 2001- Sept 2003

1. Frew AJ, Salvi S, Holgate ST, Kelly F, Stenfors N, Nordenhäll C, Blomberg A, Sandström T. Low Concentrations of Diesel Exhaust Induce a Neutrophilic Response and Upregulate IL-8 mRNA in Healthy Subjects but Not in Asthmatic Volunteers. Int Arch Allergy Immunol 2001;124(1-3):324-5.
2. Mudway IS, Stenfors N, Blomberg A, Helleday R, Dunster C, Marklund SL, Frew AJ, Sandström T, Kelly FJ. Differences in basal airway antioxidant concentrations are not predictive of individual responsiveness to ozone: A comparison of healthy and mild asthmatic subjects. Free Rad Biol Med, 2001;31(8):962-74.
3. Midulla F, Strappini P, Sandström T, Bjermer L, Falasca C, Capocaccia P et al. Cellular and noncellular components of bronchoalveolar lavage fluid in HIV-1-infected children with radiological evidence of interstitial lung damage. Pediatr Pulmonol 2001;31(3):205-13.
4. Thoren P, Wallin A, Whitehead PJ, Sandström T. The effect of different concentrations of lactose powder on the airway functionof adult asthmatics. Respir Med. 2001 Nov;95(11):870-5.
5. O'Byrne PM, Barnes PJ, Rodriguez-Roisin R, Runnerström E, Sandström T, Svensson K, Tattersfield A. Low dose inhaled budesonide and formoterol in mild persistent asthma: the OPTIMA randomized trial. Am J Respir Crit Care Med. 2001 Oct 15;164(8 Pt 1):1392-7.
6. Nordenhäll C, Pourazar J, Ledin MC, Levin JO, Sandström T, Ädelroth E. Diesel exhaust enhances airway responsiveness in asthmatic subjects. Eur Respir J. 2001 May;17(5):909-15.
7. Olin A-C, Stenfors N, Torén K, Blomberg A, Helleday R, Ledin M-C, Ljungkvist G, Ekman A, Sandström T. Nitric oxide (NO) in exhaled air after experimental ozone exposure in humans. Resp Med 2001 Jun;95(6):491-5.
8. Wilson SJ, Wallin A, Della-Cioppa G, Sandström T, Holgate ST. Effects Of Formoterol, Budesonide and Placebo on NF-κB and NF-κB Regulated Adhesion Molecules and Cytokines. Am J Respir Crit Med, 2001 Sep 15;164(6):1047-52.
9. Larsson K, Larsson BM, Sandström T, Sundblad BM, Palmberg L. Sodium cromoglycate attenuates pulmonary inflammation without influencing bronchial responsiveness in healthy subjects exposed to organic dust.Clin Exp Allergy. 2001 Sep;31(9):1356-68.

10. Lundbäck B, Ronmark E, Jonsson E, Larsson K, Sandström T. Incidence of physician-diagnosed asthma in adults--a real incidence or a result of increased awareness? Report from The Obstructive Lung Disease in NorthernSweden Studies. Respir Med. 2001 Aug;95(8):685-92.
11. Carlsson L M, Marklund S L, Edlund T, Sandström T: Increased neutrophilic inflammation of the airways after ozone exposure in mice lacking extracellular-superoxide dismutase (EC-SOD). Respir Med 2002, Apr;96(4):209-14.
12. Stenfors N, Pourazar J, Blomberg A, Krishna MT, Mudway I, Helleday R, Kelly FJ, Frew AJ, Sandström T. Effects of ozone on bronchial mucosal inflammation in asthmatic and healthy subjects. Resp Med, 2002;96:352-8.
13. Holgate ST, Sandström T, Frew AJ, Stenfors N, Nordenhäll C, Salvi S, Blomberg A, Helleday R, Söderberg M. The health effects of acute exposure to diesel exhaust and concentrated ambient particles. Part 1: Exposure of normal and asthmatic subjects to fresh diesel exhaust. Health Eff Inst Res Rep, 2002, 112, 1-54.
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16. Plewako H, Arvidsson M, Petruson K, Oancea I, Holmberg K, Ädelroth E, Gustafsson H, Sandström T, Rak S. The effect of omalizumab on nasal allergic inflammation. J Allergy Clin Immunol. 2002; 110:68-71.
17. Lundback B, Lindberg A, Lindstrom M, Ronmark E, Jonsson AC, Jonsson E, Larsson LG, Andersson S, Sandström T, Larsson K. Not 15 but 50% of smokers develop COPD?--Report from the Obstructive Lung Disease in Northern Sweden Studies. Respir Med. 2003 ;97:115-22.
18. Pathmanathan S, Krishna MT, Blomberg A, Helleday R, Sandström T, Holgate ST, Frew AJ. Repeated daily exposure to 2 ppm nitrogen dioxide upregulates the expression of IL-5, IL-10, IL-13 and ICAM-1 in the bronchial epithelium of healthy human airways. Occup Environ Med, in press
19. Bosson J, Stenfors N, Bucht A, Helleday R, Pourazar J, Holgate ST, Kelly FJ, Sandström T, Wilson S, Frew AJ, Blomberg A. Ozone induced bronchial epithelial cytokine expression differs between healthy and asthmatic subjects. Clin Exp Allergy, 2003 Jun;33(6):777-82
20. Wallin A, Sue-Chu M, Bjermer L, Ward J, Sandström T, Lindberg A, Lundbäck B, Djukanović R, Holgate ST, Wilson S. Effect of inhaled fluticasone with and without salmeterol on airway inflammation in asthma. J Allergy Clin Immunol, 2003 Jul;112(1):72-8.
21. Stenfors N, Nordenhäll C, Salvi SS, Mudway I, Söderberg M, Blomberg A, Helleday R, Levin JO, Holgate ST, Kelly FJ, Frew AJ, Sandström T. Different airway inflammatory responses in asthmatic and healthy humans exposed to diesel exhaust, Eur Respir J, in press.
22. Stenfors N, Blomberg A, Helleday R, Levin J-O, Pourazar J, Mudway I, Törnqvist H, Kelly FJ, Frew AJ, Sandström T. Ozone exposure exacerbates inflammation in bronchial mucosa of subjects with persistent asthma. Submitted.
23. Brown JL, Behndig A, Pourazar J, Blomberg A, Kelly FJ, Sandström T, Wilson S, Frew AJ. Quantification of asymptomatic lower airways inflammation in subjects with allergic rhinitis: a comparison with moderate asthmatic subjects and healthy controls. Submitted.
24. Pourazar J, Frew AJ, Blomberg A, Helleday R, Kelly FJ, Wilson S, Sandström T. Diesel exhaust exposure enhances the expression of IL-13 in the bronchial epithelium of healthy subjects, submitted.
25. Hughes SJ, Founds H, Goldstein I, Sandström T, Howarth P, Holgate ST, Wilson SJ. Advanced glycation end-products in the pathogenesis of airway remodelling in asthma, submitted.
26. Hamilton LM, Puddicombe SM, Thornber MD, Steel MD, Dearman RJ, Kimber I, Sandström T, Wallin A, Howarth PH, Holgate ST, Wilson SJ, Davies DE. Altered protein tyrosin phosphorylation in asthmatic bronchial epithelium, submitted.
27. Andersen G, Nilsson K, Pourazar J, Mincheva-Nilsson L, Waldenström A, Rantapää-Dahlqvist S, Sandström T. Evidence of a role for MMP-9 and TIMP-1 in lungfibrosis in systemic sclerosis. submitted.
28. Pourazar J, Samet J, Blomberg A, Helleday R, Frew AJ, Kelly FJ, Wilson SJ, Sandström T. Evidence for translocation of MAP kinases and transcription factors NFκB and AP-1 in human bronchial epithelium in-vivo following exposure to diesel exhaust, submitted.

Curriculum Vitae – Mats Bohgard

PERSONAL DETAILS

Full Name:	Mats Bohgard.
Date and Place of Birth:	16 March 1950, Stockholm, Sweden
Nationality:	Swedish.
Address:	Ergonomics and Aerosol Technology *Department of Design Science* *Lund Institute of Technology/Lund University* *P.O. Box 118* *SE 221 00 LUND, SWEDEN*
Telephone(work):	+46 46 222 8016
FAX(work):	+46 46 222 4431
E-mail(work):	Mats.Bohgard@design.lth.se

EDUCATION AND ACADEMIC TRAINING

1976	MSc, Engineering Physics, Lund University (Civ ing)
1984	PhD, Nuclear Physics, Lund University (Tekn Dr)
1991	"Docent", Ergonomics and aerosol technology, Lund University

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EMPLOYMENT HISTORY

(in reverse chronological order)

1999-	Professor, Ergonomics and Aerosol Technology, Lund University
1995 - 1999:	Professor, (Swedish: biträdande professor), Lund Univesity
1984 -1995:	Senior lecturer/Associated professor, Department of Working Environment, Lund University
1983:	Department of Environmental Health, Lund University, School of Medicine, assistant professor
1981-1985:	Teaching at school of Safety Engineering, University college, Jönköping, Sweden, assistant professor (3 months)
1976-1983	Department of Nuclear Physics, Lund University: teaching assistant, research assistant and assistant professor

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RESEARCH, TEACHING AND INTERACTION WITH SOCIETY OUTSIDE UNIVERSITY

Scientific interests

Aerosol science and technology, Working environment, Industrial hygiene, Physical and chemical environment, Air pollution, Contamination control

Scientific papers - overview

Published articles in refereed journals: 42
Review articles: 1
Book chapters: 2
Conference proceedings: 65
Patents: 2
Public service publications: 10
Others: 27

Some significant scientific papers

1. Bohgard M, Jangida B L: Akselsson K R An Analytical Procedure for Determining Chromium in Samples of Airborne Dust, Ann Occup Hyg **22**(1979)241-251.
2. Bohgard M, Malmqvist K, Johansson GI, Akselsson KR A: Personal Aerosol Sampler with Size Fractionation and Time Resolution in Aerosols in the Mining and Industrial Work Environment **3** (eds V A Marple and B Y H Liu), Ann Arbor Publishers (1982)907-917.
3. Eklund, P, Bohgard M: An Experimental Facility to Simulate Radon-Progeny Behavior in Dwellings,in "Indoor radon and lung cancer - reality or myth" (ed. Fredick T. Cross), Battelle Press, Columbus, 1990
4. Schneider T, Bohgard M, Gudmundsson A: A Semiempirical model for Particle Deposition onto Facial Skin and Eyes. Role of Air Currents and Electric Fields, J. Aerosol Sci. **25**(1994)583-593.
5. J. Pagels, M. Strand, J. Rissler ,A. Szpila, A. Gudmundsson, M. Bohgard, L Lillieblad, M,Sanati E. Swietlicki, , Characteristiscs of Aerosol Particles Formed during Grate Combustion of Moist Forest Residue, J. Aersol Sci, **34**(2003)1043-1059 .

Teaching of undergraduate students and pedagogical qualifications

Have extensively been involved in undergraduate and graduate teaching continuously since 1975. (30-80%)

Example of courses for undergraduate students: Nuclear Physics, basic course, Nuclear Physics, advanced course, Safety Engineering, Environmental Hygiene, Working Environment, basic course, Aerosol Technology, Techniques for the Elimination of Chemical Health Hazards, Methods for Environmental Monitoring, Management and Working environment, Particle technology, The indoor environment, Risk analysis – Health •

Example of teaching activities for post-graduate and for PhD-students: Aerosol Technology, Aerosol Measurement Technology, Analytical Methods of Aerosols in Occupational and Environmental Hygiene, Supervision of MSc theses, Licentiate theses and PhD theses

Pedagogical education:

Courses (titles in Swedish*):* Presentationsteknik och undervisningsmetodik 2p, 1985; Forskarhandledningskurs - Lunds Tekniska Högskola, 1986; Pedagogisk inspirationskurs -Lunds Universitet, 1999, PBL introduktionskurs - Lunds universitet, 2000; PBL examination - Lunds universitet, 2001; Lunds universitets ledarskapskurs 2002

Interactions with society outside university

Have been active in various activities and together with industrial partners as well as public service organisations: research projects, courses, consultancy, lecturers.

Miscellaneous

Referee of Scientific papers and applications. Expert verdicts of applicants to academic positions, board member of various university and scientific committees. Member of examination committees/external examiner of more than 20 PhD theses.

Christoffer Boman

Title
PhD-student, Energy Technology and Thermal Process Chemistry, UmU
PhL, Inorganic Chemistry, UmU
B.Sc, Environmental Health, UmU

Personal information
Born: Mars 22, 1970 in Stockholm
Citizenship: Swedish
Marital status: Engaged

Education

1999-2004	Graduate studies, Inorganic Chemistry/Energy Technology and Thermal Process Chemistry, Umeå University
2003	Licentiate degree, Inorganic Chemistry, Umeå University
1994-1997	B.Sc., Environmental Health, Umeå University
1991-1992	Military service, Platoon Officer, Berga Naval Base
1990	Assistant Nurse Education (10 weeks)
1986-1989	Senior High School in Science

Other merits of relevance

1998-1999	Industry commission at Umeå School of Environmental Studies (3 months) *"Environmental assessment of a full-scale bio-ethanol production plant"*
1997-1998	Employed as Research Engineer at Energy Technology Centre in Piteå

Founding

2001-2003	Swedish National Energy Agency (STEM) - BHM, *"Emissions from small-scale biomass combustion - extensive systematic quantification and characterization*"
1999-2003	Center for Environmental Research in Umeå (CMF), *"Small-scale biomass combustion - emissions, air quality and health effects"*
2001	Kempe Foundation, Travel grant for an international conference
1999	UmU, Research preparatory scholarship (3 months)

Lic. Thesis June 2003 "Particulate matter and products of incomplete combustion from residential biomass pellet appliances - emissions and potential for future technology"

B.Sc. Thesis Mars 1997 "Effects of increased small-scale biomass combustion on local air quality - a theoretical dispersion modelling study"

Publications

1. Boman C, Nordin A, Thaning L. *Effects of increased small-scale biomass pellet combustion on ambient air quality in residential areas - A parametric dispersion modeling study.* Biomass and Bioenergy 2003;24(6):465-474.
2. Boman BC, Forsberg AB, Järvholm BG. *Adverse health effects from ambient air pollution in relation to residential wood combustion in modern society.* Scandinavian Journal of Work, Environment and Health 2003;29(4)251-260.
3. Boman C, Nordin A, Boström C, Öhman M. *Characterization of inorganic particulate matter from residential combustion of pelletized biomass fuels.* Accepted for publication in Energy and Fuels
4. Öhman M, Boman C, Hedman H, Nordin A, Boström D. *Slagging tendencies of wood pellet ash during combustion in residential pellet burners.* Accepted for publication in Biomass and Bioenergy.
5. Boman C, Nordin A, Westerholm R, Pettersson E. *Influence of dilution sampling conditions on particulate and PAH characteristics from residential biomass fired appliances.* Submitted to Biomass and Bioenergy
6. Boman C, Lindmark F, Nordin A, Westerholm R. *Effects of temperature and residence time on emission characteristics from isothermal combustion of biomass pellets.* Submitted to Energy and Fuels.

7. Öhman M, Boman C, Hedman H, Nordin A, Pettersson P, Lethikangas P, Boström D, Westerholm R. *Beläggnings-/slaggbildning och partikelutsläpp vid förbränning av olika pelletskvalitéer i pelletsbrännare (<20 kW).* STEM Report, Oct 2000.
8. Nordin A, Pettersson E, Öhman M, Boman C. *Systematisk emissionsminimering – småskaliga anläggningar*, STEM Report 2000.
9. Olsen A, Clausen S, Öhman M, Petersen T, Boman C. *Laboratory Fluid Bed Agglomeration Experiments Performed at Energitekniskt Centrum in Piteå*. Joule 3, Contract JOR3.95-0079, 1999.