



Bulletin

January 2005



CONTENTS

ECG Bulletin – January 2005

Chairman's report.....	2
Harry Shalgosky, 1928-2004.....	2
2005 Distinguished Guest Lecture.....	3
Profile of Professor Jane Plant.....	4
Endocrine disruptors and UK river fish.....	4
Ferric iron remediation and stabilisation.....	7
Urban soils.....	9
Health Protection Agency.....	11
News of the ESEF.....	13
Probing the troposphere from space.....	14
Monitoring atmospheric composition from space.....	15
CASIX and CO ₂ air-sea fluxes.....	17
European Association for Chemical and Molecular Sciences.....	21
Book review: <i>Handbook of Atmospheric Science</i>	22
Journal of Environmental Monitoring.....	23
New books on the environment from the RSC.....	23
New book: <i>Organic Phosphorus in the Environment</i>	24
Monitoring ambient air.....	25
AIRNET 2004.....	26
Correction: British Geological Survey.....	26
Recent acquisitions by the RSC library.....	26
Forthcoming meeting: Pharma- ceuticals in the Environment.....	27

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[http://www.rsc.org/lap/rsccom/dab/
scaf003newsletter.htm](http://www.rsc.org/lap/rsccom/dab/scaf003newsletter.htm)



The Gudgeon (*Gobio gobio*)

The gudgeon is a small freshwater fish rarely exceeding 15 cm in length. It possesses a distinctive pair of barbels at the corner of the mouth. It is widely distributed in temperate waters in Europe and Asia, and generally lives in running water in small streams, although it is also occasionally found in lakes. The eggs are normally released over gravel and amongst plants. It is sexually mature at about 12 cm in length in the third year of life and will live for 4 or 5 years. The females will produce a number of batches of eggs each year. It feeds on a wide range of small invertebrates particularly small fly larvae and crustaceans. Endocrine disruptors threaten the stocks of this species (p 4)

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Chairman's report for 2004

Following what seemed like a long period of discussions, canvassing support and planning, the Environment, Sustainability and Energy Forum (ESEF) finally began its work in 2003. For many of us who had supported the creation of the forum this brought to an end a period of uncertainty as to the way in which the various groups would be represented and interact through the forum. The ECG has been fortunate in that our past Chair, Andrea Jackson, was asked to become Vice-Chair of ESEF and, as the current Chair of the Environmental Chemistry Group, I also joined the Executive Committee. Thus, the ECG has a good level of representation in the forum. Now that the forum has had time to formulate its role and functions, it seems an opportune moment to report back to you on how the activities and interactions within ESEF are developing.

The ECG, along with the Environmental, Health and Safety Committee, the Occupational, Environmental and Toxicology Group and the Water Science Forum form the core members of ESEF: the subject groups now report to ESEF.

Activities of the forum are being developed under the areas of Sustainable Energy, Green Chemical Technologies and Chemistry of the Natural Environment and include development of position papers and organisation of workshops and meetings. Several successful activities have been organised so far and the forum also produces a newsletter

Over the last couple of years the ECG committee has examined the way it works and we are now in a position where each of the committee members has a particular role. The changes have been effected with a view to increasing the effectiveness of the committee. An impact of this should soon be evident to those of you who visit the group web pages. Chris Harrington is now regularly checking and revising the links, and we are considering introducing some new functionality in the near future.

Regrettably, due to lack of numbers, we had to cancel the Young Environmental Chemists meeting that Kim Cooke had planned for June. Difficulty in

generating good attendance at meetings has been an on-going issue for the committee for a number of years. Presently, we have plans for collaborative meetings with other groups and organisations as well as participating in meeting organisation through ESEF. Hopefully these collaborative ventures will be well attended.

Finally, on the subject of meetings, I would like to recommend that you put two dates in your new 2005 diary. The first is for the *Pharmaceuticals in the Environment* meeting on the 1st March and the second is the AGM and Distinguished Guest Lecture and symposium on the 2nd March. The topic of the meeting is *Metals in the Environment: Estimation, Health Impacts and Toxicology* and the main speaker will be Professor Jane Plant CBE.

Wishing you all a happy and prosperous 2005.

BRENDAN KEELY
University of York,
December 2004

Obituary

Harry Shalgosky

15 December 1928 –
16 August 2004

Harry Shalgosky is remembered for his RSC work as a highly effective committee member of the Environment Group, for which he served as Chairman from 1986 to 1987, and for his long-standing commitment to the Analytical Division. This summary of Harry's career, which was spent in the service of the AEA, is based on two obituaries which were published in the October 2004 issues of the *Analytical Division Newsletter* and the *Harwell Chilton Campus and*

Culham Science Centre Newsletter, respectively.

Harry Shalgosky was a Vice-President of the Analytical Division (AD) during 1990-92, having previously served as Chairman of the RSC's Analytical Abstracts Editorial Committee between 1984 and 1990. He became South-East Region Chairman in 1984, and had been active in interest groups, having served on the committees of the Physical Methods, Special Techniques and Microchemical Methods Groups of the AD and of the Environment Group of the Industrial Division. Harry was awarded the AD's Distinguished Service Award in 1995.

Harry was educated in Riley and Kingston High Schools, Hull during 1939-1946. He studied at Hull Technical College and was awarded a BSc (London) in August 1949, and in October

1949 he passed the ARIC examination. His working life was in Atomic Energy, initially in the Royal Arsenal at Woolwich where he was engaged on developing analytical methods to the stringent demands and new materials of the infant nuclear power industry. He enjoyed developing polarographic methods, first using classical d.c. instruments and later the new 'cathode-ray' polarographs developed in-house by H. M. Davis and Joyce Seaborn. (For example, *Analyst*, 1956, pp 506-512; 512-518).

When the UK Atomic Energy Authority was formed in 1954, the Woolwich laboratory became part of Dr Albert Smales's Analytical Branch at Harwell. Harry began work on X-ray fluorescence spectrometry, and in 1962 took charge of the Chatham Outstation of Woolwich. Both Woolwich laboratories moved into

the new, purpose-built accommodation at Harwell in 1966, where Harry successively became leader of the Chemical Analysis and Environmental Safety Groups, Project Manager of the Physico-Chemical Measurements Unit (PCMU), and Head of the Environmental and Medical Sciences Division.

The PCMU provided a high quality analytical service for universities who hired the Harwell facilities. By 1978 his environmental safety group was providing government advice on landfill gas generation and control and decontamination of land. He was responsible for setting up the Chemical

Emergency Centre, now at Culham, and became a Harwell division head in 1981 where he took over additional responsibility for health physics and medical services. Much of the research and advice of his teams regarding non-radioactive waste disposal and emergency procedures was incorporated into UK legislation. His division responded to such international events as the Seveso and Chernobyl disasters. He never gave up his love for experimental work and was highly regarded by his staff as a skilful man manager and project manager. Harry retired from AERE Harwell in December 1988.

A fair minded, modest and cool individual, Harry was a role model and took an interest in helping and guiding colleagues. In retirement, as AD Vice-President, Harry and his wife Sheila, an art teacher, helped organise the SAC 92 Conference at Reading University. They enjoyed their home in the Berkshire Downs close to the ancient monument of the White Horse of Uffington. They had two daughters.

The Environmental Chemistry Group thanks Professor J. D. R. Thomas of the Analytical Division for the details of Mr. Shalgosky's career.

Forthcoming symposium

Metals in the environment: estimation, health impacts and toxicology

Royal Society of Chemistry Environmental Chemistry Group

2005 Distinguished Guest Lecture & Symposium

To be held in the **Council Room of the Royal Society of Chemistry on Wednesday 2nd March 2005.**

The 2005 Distinguished Guest Lecturer will be **Professor Jane Plant CBE**, Chief Scientist, British Geological Society.

Venue: Royal Society of Chemistry, Burlington House, Piccadilly, London, W1J 0BA

The nearest tube stations are Green Park and Piccadilly Circus

Metals in the environment: estimation, health impacts and toxicology.

PROGRAMME

- 13.30 Chairman's Introduction: Dr Brendan Keely (Chairman, RSC Environmental Chemistry Group)
- 13.35 Dr Jörg Feldmann, University of Aberdeen
Arsenic metabolism – Follow the transition from Dr Jekyll to Mr Hyde
- 14.20 Dr A. G. Smith, MRC Toxicology Unit, University of Leicester
Toxicogenomic approaches to determine consequences of metal exposure
- 15.05 Tea and **RSC Environmental Chemistry Group Annual**

General Meeting

- 15.30 Introduction to the 2005 Distinguished Guest Lecture
- 15.35 **2005 RSC Environmental Chemistry Group Distinguished Guest Lecture:** Professor Jane Plant CBE, The British Geological Survey
Metals, the environment and human and animal health
- 16.35 Open Forum
- 17.00 Close

There are no registration formalities associated with this meeting and guests are welcome, but in order to assist the organisers it would be appreciated if those intending to be present would notify Dr Michael Leggett by means of the slip below, or by email. There will be a charge of £10 for non-members of the Environmental Chemistry Group, which should be returned with the slip (cheques made payable to RSC Environmental Chemistry Group).

ROYAL SOCIETY OF CHEMISTRY ENVIRONMENTAL CHEMISTRY GROUP

Thirty Second Annual General Meeting, 2nd March 2005 and Distinguished Guest Lecture & Symposium, **Metals in the environment: estimation, health impacts and toxicology**

Please tick the item(s) below as appropriate

I would like to attend: The AGM The Symposium
I enclose a cheque for: _____ £10 registration fee (non-members of the ECG only)

Name: _____

Address: _____

Please send to: Dr Michael Leggett (Mike.leggett@bsi-global.com)
British Standards Institution, 389 Chiswick High Road, London W4 4AL

Profile of Professor Jane A. Plant CBE

2005 ECG Distinguished Guest Lecturer

Professor Jane Plant CBE, DSc, FRSE, FRSA, FIMM, CEng, FGS, CGeol is Professor of Applied Geochemistry in the Department of Earth Science & Engineering, Imperial College, London and Chief Scientist of the British Geological Survey (Natural Environment Research Council). Her research interests centre on economic and environmental geochemistry. She has particular expertise in baseline geochemical mapping, monitoring and modelling. She is an expert on uranium geochemistry

and natural radioactivity, and the geochemistry of arsenic and selenium. Jane Plant has published widely on a variety of topics, including geochemistry and human health in more than 250 academic books and papers in learned journals. She is chairman of the Government's Advisory Committee on Hazardous Substances and a member of the Chemical Stakeholders Forum. She is also a member of the Royal Commission on Environmental Pollution. She has served as a member of the CBI Minerals Committee and MIRO Council, and is presently on the Council of the Parliamentary Science & Technology Committee. In 1997 she was

awarded the CBE for services to earth sciences and has Honorary Doctorates from the Open University, Exeter University and Kingston University (for academic and scholarly distinction) and has been appointed as a Senior Academic Visitor to the Macaulay Institute, Aberdeen.

In 1999 Jane Plant was elected a Freeman of the City of London and a member of the Society of Water Conservators. She was also awarded the Lord Lloyd of Kilgerran Award from the Foundation of Science & Technology, in recognition of her contribution to the application of fundamental geochemical modelling.

Endocrine disruption and UK river fish stocks

Dr Elizabeth Hill, Senior Lecturer in Chemical Ecology, University of Sussex and **Professor C. R. Tyler**, School of Biological Sciences, University of Exeter, describe their research on the identification of endocrine disruptors in wastewater outlets.

Intersex fish

A wide variety of man-made chemicals present in the environment are capable of modulating and/or disrupting the endocrine system. Examples include organochlorine pesticides, polychlorinated biphenyls and their hydroxylated metabolites, dioxin-like chemicals, bisphenol-A, alkylphenolic chemicals (products of the degradation of industrial surfactants and antioxidants), tributyl tin, and some phthalate plasticisers. Sex hormones such as the natural oestrogens, 17 β -oestradiol, oestrone and oestriol, and the synthetic steroid hormone ethinyl-oestradiol (the main active ingredient of the oral contraceptive pill) also enter the aquatic environment.

Adverse physiological effects, which are indicative of exposure to endocrine disrupting chemicals, have been observed in mammals, birds, reptiles, amphibians, fish and invertebrates. A

well-publicised example of endocrine disruption in the UK is the oestrogenic effect of effluent from wastewater treatment works (WwTWs) on fish. The discharge of these effluents into UK rivers results in feminisation of wild fish, including roach (*Rutilus rutilus*) and gudgeon (*Gobio gobio*) (Jobling *et al.*, 1998). Feminisation of male roach disrupts the development of the gonad, and in severe cases results in intersex, where eggs develop in the testis (Figure 1). The reproductive capability of these intersex fish is also compromised, and this could have detrimental effects on fish populations in UK rivers. A recent study of 50 river sites by the Environment Agency, in collaboration with researchers at the Universities of Brunel

and Exeter, shows that signs of intersex in wild fish are widespread in the UK.

Although intersex in fish populations has been reported in other European countries and in the US, the incidence appears to be significantly worse in the UK. This is probably as a consequence of the low dilution rates of WwTWs effluents in many receiving rivers. Future pressure on water resources from climate change and increased water abstraction (UK demands increase by approx 2% per annum) is likely to result in even lower dilution rates of WwTW effluents and an increased problem from this type of pollution, with potentially serious consequences for aquatic organisms living in UK waters.

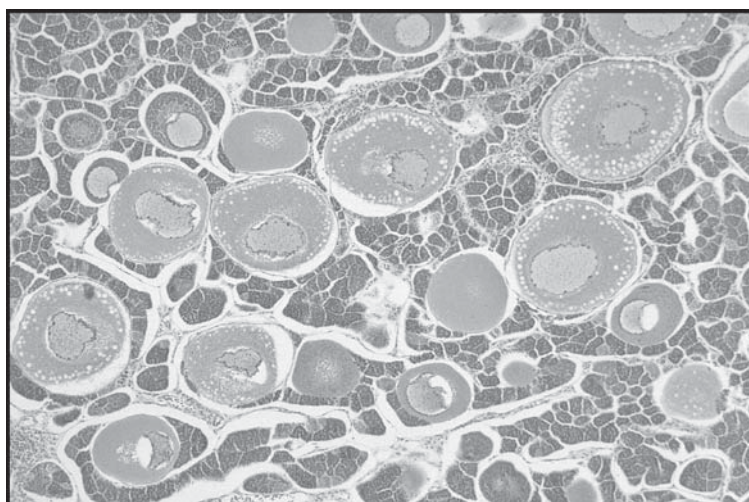


Figure 1: Section of a gonad from an intersex fish showing round eggs (oocytes) interspersed within the darker testicular tissue

Which are the chemicals causing intersex in fish?

Given that intersex in wild fish has resulted from the feminisation of males, the hunt to track down the causative chemical agents has focused on oestrogens. One of the challenges of studying this type of pollution was to identify and quantify low levels of oestrogenic chemicals in complex matrices such as effluent extracts. The use of a bioassay-directed fractionation study to analyse WwTWs effluents has been highly effective in the identification of these contaminants (Desbrow *et al.*, 1998). Effluents were extracted using solid phase extraction, and fractionated on reverse-phase high performance liquid chromatography (HPLC). The HPLC fractions were assayed for oestrogenic activity using biological screening – specifically, a yeast recombinant oestrogen receptor screen (YES assay) – and active fractions were analysed for oestrogenic chemicals using mass spectrometry. Using these techniques, three steroidal oestrogens

were identified in effluents: 17 β -oestradiol (E2) and oestrone (E1) – the natural oestrogens excreted by men and women, and 17 α -ethinyloestradiol (EE2) – a synthetic oestrogen used for birth control (Figure 2).

These oestrogens are excreted as inactive conjugates, but they are hydrolysed back to the parent molecule. Although a significant proportion of the oestrogens are degraded during the sewage treatment process, sufficient amounts are often still present in the final effluents (at ng/L concentrations) to cause oestrogenic responses in fish. In fact the most potent of these oestrogens, EE2, can cause feminised responses in fish at 0.1ng/L in water, a concentration that is extremely difficult to quantify accurately in complex effluent extracts, even using tandem mass spectrometry techniques. Additionally, most effluents contain alkylphenolic chemicals. These phenols are used in a wide range of industrial processes and are oestrogen mimics, often referred to as xenoestrogens. They can be present at μ g/L concentrations but

are considerably less potent than the steroidal oestrogens.

We have little knowledge as to the relative importance of these individual chemicals in inducing intersex in wild fish. Furthermore, we know that the oestrogenic contaminants identified in effluents can have additive effects in inducing feminised responses in fish (Thorpe *et al.*, 2003). Laboratory based studies, in which fish have been exposed to *environmentally relevant* concentrations of these chemicals individually (e.g. ethinyloestradiol and nonylphenol), have induced feminised responses but have not resulted in induction of the full intersex condition i.e. oocytes in testis. It is still very unclear, therefore, what the causative agents in the induction of intersexuality in males in wild fish in UK rivers is (are).

In order to identify the causative agent(s) of intersexuality in wild fish in UK rivers, we need to establish what chemicals accumulate in the fish and at what concentrations. We (EMH, University of Sussex and CRT, University of Exeter) have collaborated in work funded by the EPSRC to determine the identity of oestrogenic chemicals accumulating in fish exposed to a range of WwTWs effluents. We analysed the bile of fish, as many contaminants (and their conjugates) can accumulate in bile at concentrations between 10,000-100,000 times greater than that of the concentration of the parent compound in the water or effluent. We used the bioassay-directed HPLC fractionation approach previously applied to effluents to analyse the bile. HPLC fractions showing oestrogenic activity in the YES assay were analysed by mass spectrometry to determine the nature and quantity of chemicals in the bile fractions. We found that a complex mixture of E2, E1, EE2, nonylphenol and nonylphenol mono-, di-, tri- and tetra-ethoxylates (NP+NPEOs) (Figure 2) accumulated in fish bile (Figure 3). Although these compounds have been identified as oestrogenic contaminants in WwTWs effluents, our work showed that they bioconcentrated in fish bile as a complex mixture with concentration factors of between 16,000 - 46,000 depending on the effluent.

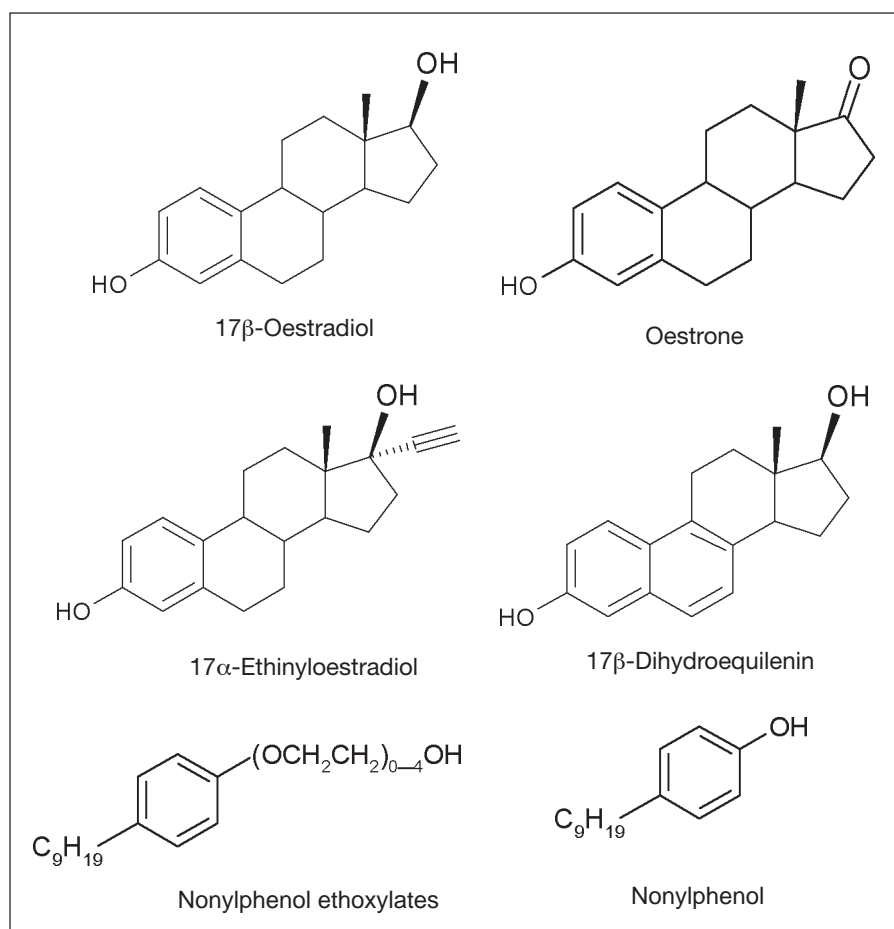


Figure 2: Structures of some oestrogenic endocrine disruptors detected in WwTWs effluents

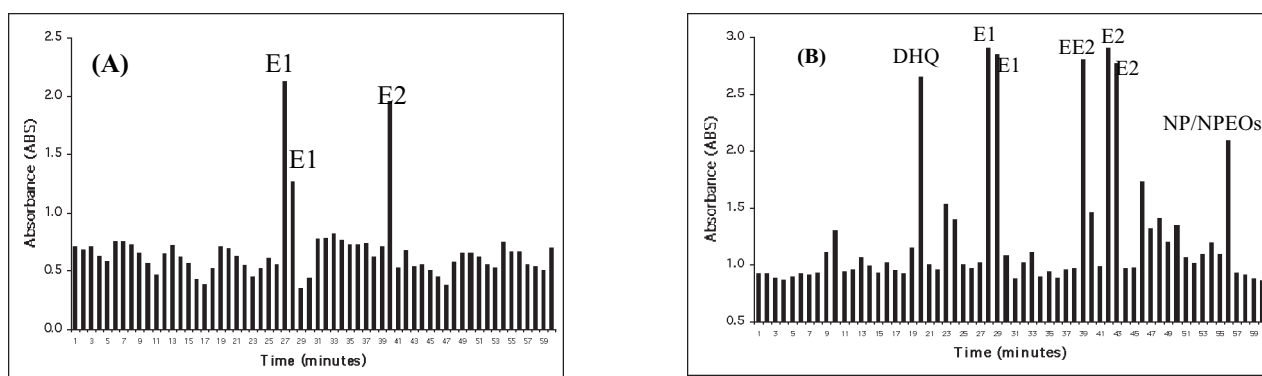


Figure 3: Oestrogenic profiles of bile from immature rainbow trout exposed to (A) tap water (B) effluent. Extracts of hydrolysed bile were fractionated by reverse phase high performance liquid chromatography, and fractions were analysed for oestrogenic activity by measuring the response (absorbance) in the YES assay

A new discovery in this work was that an additional oestrogen was detected in bile from effluent-exposed fish, namely 17 β -dihydroequilenin (DHQ) (Figure 2). DHQ had not been previously recognised as an environmental oestrogen and its source, as well as its potency as a feminising agent in fish, is now being currently investigated.

Are there other endocrine disrupting chemicals present in WwTWs effluents?

We are confident that we have identified all the major oestrogen receptor-active contaminants in WwTWs effluents that are likely to contribute to the feminisation of fish. However, sex changes in fish and other vertebrates are mediated by other sex hormones in addition to oestrogens – notably androgens – and these effects are signalled *via* specific receptors. Thus, disruptions in sexual development can potentially occur *via* either the oestrogen receptor(s) or the androgen receptor(s). Therefore, we have also attempted to identify bioavailable (anti-)androgen receptor-active contaminants in effluents that could contribute to endocrine disruption and feminisation of fish. Based on our work with oestrogens, we collected bile from fish that had been caged below a WwTWs effluent and analysed the bile extracts for anti-(androgenic) activity using a recombinant yeast androgen receptor screen (YAS). The receptor activity of total and HPLC fractionated bile extracts from these fish were compared with fish held in tap water.

The anti-androgenic activity of effluent-exposed fish was 28-fold higher than that from reference fish. In contrast, the oestrogenic activity was 12-fold higher

in bile from effluent-exposed fish compared with bile in reference fish. This work suggests that a number of other bioavailable androgen antagonists are present in effluents from WwTWs, and their presence in bile of exposed fish has opened up a new dimension in this work. Anti-androgens can induce similar feminising effects as oestrogens. We are currently trying to identify these chemicals and to establish their relative contribution to the feminised responses in fish. The recent survey of 50 effluents from WwTWs, mentioned above, found that most contained anti-androgenic activity, emphasising the potential significance of the finding of anti-androgens in the environment.

A variety of other biologically active pharmaceuticals including analgesics, antidepressants, lipid lowering drugs, antibiotics, anti-cancer agents, caffeine and musks are present in wastewater effluents of many countries including the UK, and their impact on organisms living in the aquatic environment has not been established. The research from this project illustrates that bile acts as an excellent tissue for concentrating chemicals in effluents, and that combining biological screening with high quality analytical chemistry is a highly successful approach for identifying chemicals with endocrine disrupting activity, an approach that could equally be applied to chemicals with other modes of action in organisms.

References

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Web links

US EPA Endocrine Disruptor Screening Program <http://www.epa.gov/scipoly/oscpendo/>

EU Endocrine Disruptors Website http://europa.eu.int/comm/environment/endocrine/index_en.htm

WHO International Programme on Chemical Safety Global Assessment of the State-of-the-Science of Endocrine Disruptors http://www.who.int/ipcs/publications/new_issues/endocrine_disruptors/en/

FIRS (Ferric Iron Remediation and Stabilisation)

A new low-cost method for cleaning up contaminated land

Andrew Cundy, from the Centre for Environmental Research, University of Sussex, and **Laurence Hopkinson** and **David Faulkner**, from the Division of Civil Engineering at the University of Brighton, discuss the development of a new, low-energy, electrical technique for the clean-up of contaminated land and the protection of groundwater.

Introduction

Contaminated soils and groundwater at industrial, waste disposal and waste spillage sites are serious environmental problems. The clay and silt-rich soils present at many of these sites tend to sequester large quantities of heavy metals, radionuclides, and selected organic pollutants, but are relatively resistant to clean-up (or remediation) by traditional technologies (e.g. pump and treat, soil washing) because of their low hydraulic conductivities. This, coupled with more stringent regulatory restrictions on “dig and dump” (removal to landfill) disposal methods, has stimulated a considerable amount of research into cost-effective *in situ* techniques that can be used to remediate contaminated soils with a high clay content.

One such technique that has received much attention, particularly in the U.S.A., is **electrokinetic remediation** [1]. Electrokinetic remediation separates and extracts organic, inorganic, and radioactive contaminants from saturated or unsaturated clay-rich soils, sludges and sediments under the influence of an applied electrical field [2, 3]. The electrokinetic process involves the application of a low intensity direct current across two or more electrodes that have been implanted in the ground on each side of a contaminated soil mass.

Groundwater is dissociated at the electrodes (*via* the reactions shown in Figure 1), producing an acid front (due to excess H^+ ions) around the anode and an alkaline front (due to excess OH^- ions) at the cathode. The electric current causes **electro-osmosis** and **ion migration**, which move both water and aqueous phase contaminants in the subsurface from one electrode to the other, and **electrophoresis**, which results in migration of colloidal fractions. Aqueous phase contaminants and contaminants desorbed from soil particles are transported towards the anode or cathode, depending on their charge.

In existing commercial electrokinetic land remediation systems, contaminants are commonly extracted by a secondary recovery system or deposited/isolated at the electrode. Surfactants, complexing agents, and other reagents are frequently used to assist contaminant desorption and movement, and various membranes and/or chemical additives employed to restrict the development of the alkaline zone and so avoid reprecipitation of some acid-mobilised contaminants (and large-scale precipitation of hydroxide and carbonate cements) in the treated soil.

Many of the current commercial technologies, however, are technically complex and extremely energy intensive, and operate only under very specific field or laboratory-based conditions, which has tended to limit their widespread

adoption by the contaminated-land industry.

Recent research at the Universities of Sussex and Brighton (funded by EPSRC and industrial partners) has attempted to address this problem through the development of a novel, low-energy and ‘low-tech’, natural analogue-based electrokinetic process for contaminant removal and confinement at contaminated sites.

The FIRS (Ferric Iron Remediation and Stabilisation) technique

Unlike existing electrokinetic techniques, FIRS provides a robust, non-selective and ‘low-tech’ approach to contaminant reduction and containment, and is based on natural iron mineralisation processes that occur in the near-surface environment.

The technique involves the application of a low magnitude (typically less than 0.2V/cm) direct electric potential between two or more sacrificial, iron-rich, electrodes emplaced in, or either side of, a contaminated soil or sediment. The electric potential is used to generate a strong pH/Eh gradient within the soil column, and force the precipitation of an iron-rich barrier in the soil between the electrodes at the boundary between the acid and alkaline “fronts” (Figures 1 & 2).

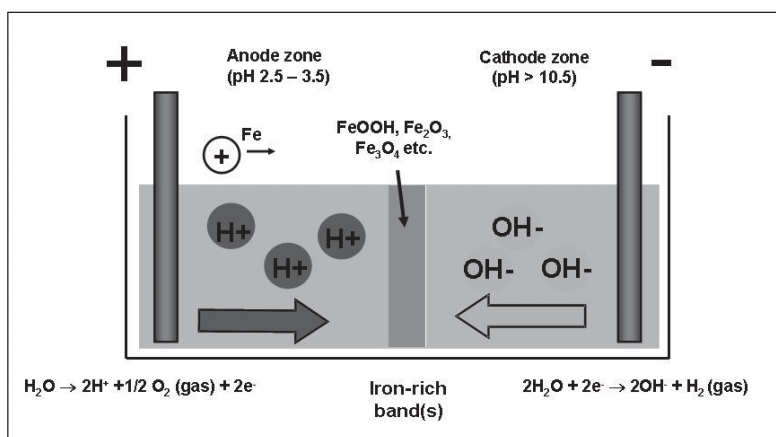


Figure 1: Schematic diagram of the FIRS technique. The system generates a highly acidic zone around the anode electrode, and a highly alkaline zone around the cathode. Iron, dissolved from the sacrificial anode (and the anode zone sediment) migrates towards the cathode, and on encountering the abrupt pH “jump” between the acid and alkaline fronts precipitates as oxide and oxyhydroxide mineral phases, e.g. $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$

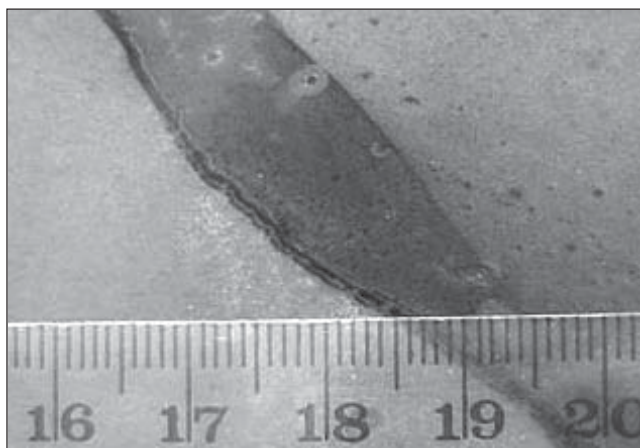


Figure 2: Sub-vertical, 1cm thick, Fe-rich band generated by the FIRS technique in water-saturated sands after 30 hours application of a 1.5V potential difference between cast iron electrodes.

The iron in this barrier is derived from the cast iron sacrificial anode, and the treated sediment itself. The acid front “acid-washes” the soil, while the precipitated iron band provides an impermeable barrier to contaminant migration, and, together with the pH gradient, provides a chemical trap for a range of inorganic, organic and radioactive contaminants remobilised from the treated soil. Essentially, in contaminated soils, the system remobilises contaminants and concentrates them on to the solid iron barrier, which can then be excavated. Alternatively, the precipitated iron band itself can be used as a reactive (i.e. sorptive) barrier for waste spillages and contaminated shallow groundwaters.

The system mimics natural mineralisation processes, where internal electric fields present in rock and soil bodies can generate multiple bands of ironstone *via* precipitation of iron oxides and hydroxides. In the FIRS technique, these iron-rich bands are grown over timescales of 3 - 400 hours, and consist of a series of amorphous (or micro-crystalline) iron “pans”, or, in sandy soils, a coating of the minerals goethite and magnetite which cements mineral grains. Freshly precipitated amorphous or poorly crystalline Fe-rich solids, of the type generated by the FIRS technique, are extremely effective scavengers of a range of radioactive, inorganic and organic pollutants in a variety of environments.

In terms of its physical structure, the iron barrier itself is comparable in strength to

a moderately lithified sandstone (or to the strongest chalks in southern England), and can be generated in a variety of geometries (both vertical and horizontal), depending on the placement of the electrodes. It is also possible to rapidly generate a dispersed sorptive coating of iron on a pre-defined area of soil without significant loss of porosity, simply by switching off the current before the Fe-band fully develops. Such an approach may be desirable in situations where the sorptive properties of iron can be harnessed to reduce the concentration of specific contaminants (e.g. arsenic) in groundwater. This has the added benefit of strengthening the soil for subsequent building use, with the iron acting as a cement, promoting an order of magnitude scale increase in the measured shear strength of the soil [4].

Developmental work

Bench-scale studies: Pilot studies on the FIRS technique have been applied at laboratory scales, in a variety of sands and contaminated muds, with groundwater and seawater interstitial porewaters [4, 5]. Despite the differing mineralogical characteristics of the soils tested in these pilot studies, in every case a strongly acidic zone was generated around the anode (approx. pH 2), and an alkaline zone around the cathode (approx. pH 13). At the point of abrupt pH change, approximately equidistant between cathode and anode, a 1-4 cm thick continuous barrier of iron was precipitated.

Bench-scale studies on contaminated

clay-rich sediments from a variety of radionuclide and heavy metal-rich sites, and on waste spoils, indicate that FIRS can remobilise and concentrate a range of contaminants, including copper, lead, zinc and arsenic. It is also possible to use the technique to strategically dewater parcels of soil or waste slurries, due to the electro-osmotic water flow induced between the anode(s) and the cathode(s).

Current work is aimed at assessing the use of FIRS in the remediation of sites contaminated with organic pollutants (e.g. chlorinated hydrocarbons), and particularly in addressing the key problem encountered by many electrokinetic techniques of effectively scaling up from the laboratory to the field (i.e. the contaminated site).

Larger scale trials: In order to examine the larger scale application of FIRS, a series of experiments are underway using large (>2 m long) treatment cells. These cells contain unsorted, slag-rich material from contaminated land sites. The slag is designed to mimic the so-called “made ground” found at many former industrial sites.

Although this work is still in progress, preliminary results are extremely promising. Application of the FIRS technology produces a pH gradient similar to that observed in the bench-scale studies. This gradient forms at voltages too low to produce soil heating, despite the increased distance between the electrodes and the extremely heterogeneous soil material. The potential for scaling-up the technique is good, since FIRS mimics a natural mineralization system that operates over scales in excess of 100 m in geological structures.

Applying the FIRS technique

The FIRS technology, while still at prototype laboratory scale, shows considerable promise as a technique for soil engineering, groundwater protection, and contaminated site remediation. The technique generates a resealable iron-rich barrier, which can be remotely placed (without engineering) to physically inhibit (or redirect) subsurface pollutant migration, and adsorb contaminants from ground or soil water.

The FIRS technology is also capable of significantly reducing contaminant concentrations in treated soil, and can also improve the mechanical properties of soils (contaminated or otherwise) for civil engineering purposes, *via* iron cementation and/or strategic electro-osmotic dewatering or rewatering.

The FIRS system has significantly lower energy requirements than commercial electrokinetic remediation techniques, uses low cost sacrificial (scrap iron) electrodes, and does not involve the use of potentially toxic conditioning solutions. The technique is applicable to small sites, as well as to larger areas of contaminated land, and the flexibility provided by the use of multiple, low cost electrodes, means that contaminated land could be sequentially treated with a series of electrode arrays (wired to car batteries or a similar current source), placed to avoid (or work around) site infrastructure, where the distance between individual electrodes does not exceed a few metres.

Following a successful scaling-up, the

system could be operated in combination with, or as an alternative to, existing land remediation technologies, although laboratory data indicate that it will probably best be applied as a low-energy, non-selective, preliminary contaminant reduction/containment technique (particularly in cleaning up more localised “hot-spots” of contamination) before the application (if necessary) of more specialist (and expensive) techniques.

Note: The technique and ideas described here are the subject of a patent application filed in September 2002 by the Universities of Sussex and Brighton. Part of this work was completed under funding provided by EPSRC (grant number GR/S27924/01).

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Raising the profile of urban soil in Europe

Christine Davidson and **Graham Urquhart** from the Department of Pure and Applied Chemistry, University of Strathclyde, describe collaborative research on the analysis and environmental management of urban soils.

Introduction

Urban soils are less studied than their agricultural equivalents. However, these are the types of soil most people have direct contact with – whether walking their dog in an urban park or growing vegetables in a suburban garden.¹ The EU URBSOIL project (“Urban soils as a source or sink for pollution: towards a common European methodology for the evaluation of their environmental quality as a tool for sustainable resource management”) aims to improve knowledge about the general status of urban soils in public-access areas such as parks, ornamental gardens, roadsides

and riverbanks in European cities.

Key objectives are:

- To collate existing information on soil quality.
- To generate a unique data set of new analytical results covering a range of soil quality indicators, from simple bulk parameters such as pH and CEC to specific analytes such as potentially toxic elements (“heavy metals”).
- To cross-validate analytical methods.
- To develop a web-GIS based decision support tool (DST) to assist urban planners.

The project is co-ordinated by Professor Franco Ajmone-Marsan from the Università di Torino (Italy) and involves partners from six countries: Universidade de Aveiro (Portugal), Univerza v Ljubljani (Slovenia), University of Paisley (UK), Instituto de Recursos Naturales y Agrobiología de Sevilla (Spain), University of Strathclyde (UK), and the Swedish University of

Agricultural Sciences. Participants come from a range of disciplines, including environmental and analytical chemists, soil scientists and experts in environmental management.

Preliminary results

Early URBSOIL work focused on a single land use: a visually homogeneous area of parkland close to the centre of each city. Each area was sampled in a regular 50 m grid to assess variability in soil quality indicators within each site and between sites in different cities. As expected, considerable differences were found in heavy metal concentrations in the different parks (Table 1). This reflects both history and geology. Soils obtained from parks in older, industrialised cities such as Glasgow and Torino generally contained higher metal concentrations than those from relatively modern cities with little industrial legacy, such as Aveiro. However, the relatively high chromium and nickel levels in Torino may include a geochemical component (from ultramafic rocks in the surrounding

TABLE 1: Heavy metal content in city centre parks in six European cities (mg kg⁻¹)

City	Cr	Cu	Hg	Ni	Pb	Zn
Aveiro	10 ± 2	18 ± 11	0.058 ± 0.021	11 ± 6	20 ± 7	46 ± 15
Glasgow	29 ± 4	85 ± 23	1.55 ± 1.24	35 ± 8	307 ± 146	199 ± 81
Ljubljana	21 ± 6	33 ± 12	0.41 ± 0.18	22 ± 6	78 ± 37	114 ± 42
Sevilla	36 ± 7	48 ± 11	0.41 ± 0.30	29 ± 4	107 ± 48	107 ± 29
Torino	188 ± 42	87 ± 20	0.48 ± 0.19	207 ± 43	144 ± 50	225 ± 57
Uppsala	36 ± 10	36 ± 17	0.35 ± 0.29	22 ± 7	47 ± 24	112 ± 36

Results are mean values ± one standard deviation (in general n=25) for samples taken from a depth of 0-10 cm. Cr, Cu, Ni, Pb and Zn were measured by flame atomic absorption spectrometry or inductively-coupled plasma atomic emission spectrometry following aqua regia digestion. Hg was determined by direct pyrolysis atomic absorption spectrometry with gold amalgamation.

catchments) as well as an association with manufacturing (Torino is the home of FIAT). Notably, the mercury content in soil from the Glasgow park was more than three times higher than that in any other city and over 26 times the level in Aveiro.² Further useful information was gained from application of chemometric procedures to the data set. For example, rotated principle components analysis allowed differentiation between the so called “urban metals” (copper, lead and zinc) and other analytes.³

Assessing inter-laboratory comparability

A research project that involves the collection of several hundred soil samples, their transport across Europe, and analysis in different laboratories requires the definition and implementation of adequate QC/QA procedures. Few urban soil certified reference materials exist for use in method validation and so

partners prepared a suite of project-specific reference soils, one from each city. These were exchanged and analysed to assess comparability of the results obtained in different countries. Despite the fact that different laboratories used different analytical methods (e.g. microwave vs. reflux digestion, FAAS vs. ICPOES analysis) and some determinations were carried out by laboratories not specialising in analytical chemistry, agreement between results for heavy metal analysis was generally good with few analytes showing overall variability of > 15%. An example of the results obtained is shown in Figure 1.

The URBSOIL DST

Interfacing science with wider social, economic and policy issues is both challenging and topical.⁴ The URBSOIL DST, development of which is being led by Professor Andrew Hursthouse and colleagues at the University of Paisley,

incorporates databases, a data handling and display tool and an electronic conferencing resource based on e-Delphi. Its purpose is not risk assessment, as in, for example, the UK CLEA model, but to facilitate consultation and integrate information on soil into urban decision making processes. The concept is as follows. When a planning decision is to be made, information is solicited from a wide range of “stakeholders”. As well as scientific experts, these will include local special interest groups, legislators, environmental authorities and other interested parties. The information obtained is collated and disseminated, anonymously, back to the stakeholders who then have the option to refine their input in a subsequent round of information gathering. The process is iterated until consensus is achieved (or areas of non-consensus become clearly defined) thus guiding the planner towards an “optimal” solution. Recent tests on the prototype DST, to support a hypothetical planning decision on placement of a city farm in Glasgow, indicated that reproducible results could be obtained.

Continuing developments

In addition to further refinement and testing of the DST, current research within URBSOIL is focused on soil obtained from different types of urban land surface (roadsides, riverbanks etc) and on more specialised investigations such as the measurement of polycyclic aromatic hydrocarbons; heavy metal fractionation using the BCR sequential extraction protocol, and column leaching experiments to assess the mobilisation of metals under reducing conditions. Information on the URBSOIL project can be obtained at <http://URBSOIL.paisley.ac.uk/>

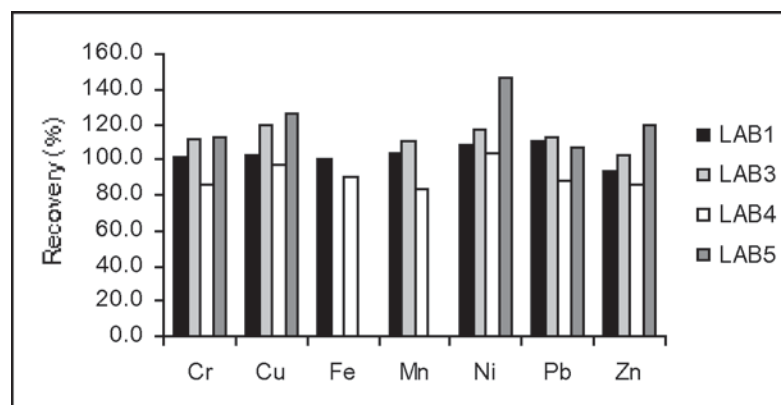


FIGURE 1: Inter-laboratory comparison for measurement of heavy metals in the Glasgow URBSOIL reference material

The figure shows values reported by URBSOIL partners in Aveiro, Ljubljana, Sevilla and Torino expressed as percentages of the “target values” established by workers in Glasgow.

Acknowledgements

The URBSOIL project is supported by the EU FP5, Energy, Environment and Sustainable Development Program under contract EVK4-CT-2001-00053. The authors gratefully acknowledge the contribution of all members of the URBSOIL team to the contents of this article.

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[Ultramafic Rock: The class of rock which crystallizes from silicate minerals at the highest temperatures is sometimes referred to as "ultramafic" rock. It includes peridotite and komatiite. It is in the highest temperature range of the Bowen reaction series].

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November 2004

The UK's Health Protection Agency

In 2003, **George Kowalczyk** was transferred from the Department of Health to the newly-formed Health Protection Agency (HPA). In this article, George, a stalwart of the RSC's OETG, describes the multifarious roles of this new organisation.

What is the HPA?

Although I came from the Department of Health, my new HPA associates – some 2,700 in total – were assembled from over 80 different other organisations. Needless to say, even after a year together we are still establishing our working relationships and our public profile. So, what is the HPA, and what does it do?

The Health Protection Agency is a new national organisation for England and Wales, which was established on 1st April 2003. It is dedicated to protecting people's health and reducing the health impact of:

- Infectious diseases
- Chemical hazards
- Radiation hazards.

The HPA brings together the expertise of health and scientific professionals working in public health, communicable disease, emergency planning, infection

control, chemical and radiation hazards. This expertise was previously located in a number of organisations which have now been incorporated into the HPA, and they include:

- The Public Health Laboratory Service (PHLS), including the Communicable Disease Surveillance Centre and Central Public Health Laboratory at Colindale.
- The Centre for Applied Microbiology and Research (CAMR) at Porton Down.
- The National Focus for Chemical Incidents in Cardiff and the four Regional Service Provider Units that support the management of chemical incidents – e.g. the Chemical Incidents Response Service (CIRS) based at Guys Hospital, London.
- The National Poisons Information Service (NPIS).
- NHS and Department of Health public health staff responsible for infectious disease control, emergency planning, and other protection support.

The HPA currently works in partnership with the National Radiological Protection Board. (NRPB), which is expected to become incorporated into the HPA later in 2004.

What does the HPA do?

The HPA

- Provides impartial authoritative information and advice to professionals and the public, and independent advice to the Government on public health protection policies and programmes.
- Delivers services and supports the NHS and other organisations to protect people's health from infectious diseases, chemical hazards, poisons, and radiation hazards.
- Monitors and responds to new threats to public health, and provide a rapid response to health protection emergencies, including the deliberate release of poisons, chemicals, or microbiological substances.
- Seeks to improve knowledge about health protection through research, development, education and training.

What is HPA's role with regard to chemical hazards?

The Agency has six main Divisions, three of which have roles in provision of advice on chemical hazards and assisting in the response to chemical incidents. The relevant parts of the HPA dealing with toxicological issues are:

- Chemical Hazards and Poisons Division (DCHaP)
- Emergency Response Division (ERD)
- Local and Regional Services (LARS).

Chemical Hazards and Poisons Division (DCHaP)

The Chemical Hazards and Poisons Division of the Health Protection Agency provides comprehensive expert advice and support for chemical incidents across England and Wales. Such potential health threats might involve chemical fires, chemical contamination of the environment, or the deliberate or accidental release of chemicals and poisons. It provides information and support to the NHS and health professionals on toxicology and is developing a national programme for the surveillance of chemical hazards and their health effects, along with a national poisons information databases, and a database of laboratories.

DCHaP also provides advice on a wide range of issues including:

- Personal protective equipment
- Decontamination and evacuation following a chemical incident
- Toxicological and epidemiological advice on likely health effects of chemicals
- The appropriateness of industrial operational conditions (i.e. IPPC applications for which NHS Primary Care Trusts are a statutory consultees)
- Clinical advice on antidotes and medical treatment.

The Director of DCHaP is Professor Stephen Palmer who is based in the Division's National Headquarters in Didcot, Oxfordshire. Operationally, most of the staff of the Division work at four regional centres:

LONDON – located within the Medical Toxicology Unit at Guy's and St Thomas's NHS Trust and headed by Professor Virginia Murray.

CARDIFF – based at the University of Wales Institute and headed by Professor Gary Coleman, who is also interim Deputy Director of DCHaP.

BIRMINGHAM – based at Birmingham University and headed by Pat Saunders.

NEWCASTLE – based at Newcastle University and headed by Professor Peter Blain.

Each regional centre comprises small teams of scientists and administrative staff (each ranging in size from 6 to 12 staff) with expertise in a range of relevant disciplines including toxicology, environmental epidemiology, public health medicine, and information science.

Local and Regional Services (LARS)

LARS provides the HPA field teams and is spread around the country in nine Regional Centres, each with a Regional Director, Regional Epidemiologists, Health Emergency Planners, Laboratory and Health Surveillance facilities. Each Regional Centre also runs specialist Health Protection Units (there are 42 of these across the country) with medical specialists in infection control, chemical and radiation hazards. In respect of chemical incidents LARS staff are involved in the following ways:

- Assisting the front line NHS response to chemical incidents, such as industrial accidents, fires, chemical spillages etc which might affect public health.
- Investigating and monitoring the health of the local population in respect of possible long term consequences of environmental exposures to chemicals (e.g. contaminated land, factory emissions).
- Assisting NHS Primary Care Trusts in their role as statutory health consultees for IPPC applications.
- Ensuring that the NHS has planned and is prepared to deal with a range of chemical (and other) incidents and emergencies, including deliberate release by terrorists.

LARS staff receive specialist toxicological assistance from colleagues in DCHaPs.

Emergency Response Division (ERD)

ERD is a headquarters based function

providing specialist advice on the response to emergencies. Its focus is currently on so called "CBRN" incidents (i.e. deliberate release of chemical, biological, nuclear or radiological agents, such as sarin, anthrax or ricin). ERD works closely with medical toxicologists at Porton Down in providing advice and training programmes in the following areas:

- Advice on the symptoms and effects of chemicals likely to be involved in CBRN incidents.
- Personal protective equipment and chemical decontamination procedures.
- Antidotes and prophylactic measures.

The work of ERD is facilitated through the HPA's teams of regional Health Emergency Planning Advisers who support the emergency planning and response function of the NHS.

Case studies of toxicological assistance

A few examples of how toxicologists in the HPA assist in the health response to chemical incidents and other aspects of chemical health risks are given below.

Mercury exposures

In 2003, the Greater Manchester area experienced three separate mercury incidents in Trafford (29 children and 3 adults exposed), Rochdale (22 children) and Salford (10 children and 1 adult). These were possibly a result of waste mercury being found by groups of youngsters which was then circulated among local friends and households – although the source of mercury from a scrap yard was confirmed in only one of the three incidents mentioned above. Ultimately mercury spillages arose and these were brought to the attention of Local Authority Environmental Health Officers. The local HPA Health Protection Units were asked to advise on possible significance of the exposures and possible health risks. After liaising with toxicologists in DCHaP, the local HPA teams provided information on possible health effects to residents and local media, arranged for blood and urine monitoring and follow-up, and proposed

a multi-agency approach to dealing with abandoned waste mercury to reduce the chances of such incidents re-occurring.

Ammonia spill

A spill by a workman working on a refrigeration unit on the roof of a large department store in Wilmslow, led to ammonia entering the store's air conditioning system and spreading throughout the building. Eleven people were affected and transported to hospitals in the locality. The local HPA and DCHaP were alerted and provided advice to A&E staff about the need to decontaminate casualties before admission (A&E units in the past have become contaminated and needed to be shut down after receiving chemical casualties) and on the needs for monitoring and possible longer term surveillance.

IPPC applications

IPPC (Integrated Pollution Prevention and Control) is a regulatory system to ensure that industry adopts an integrated approach to pollution control to achieve a high level of protection for the environment and human health. Operators of new or proposed installations must apply for a permit from the Regulator (either the Environment Agency or the Local Authority) and part of the process involves consultation with nominated health organisations, principally NHS Primary Care Trusts (PCTs). The HPA, through its specialists in DCHaP and LARS has drafted guidance for NHS to respond to consultation process and in many cases has conducted the IPPC assessment on behalf of the PCTs.

The addition of landfill sites to the IPPC process has placed an additional burden on the NHS, and since its inception in April 2003, the HPA has responded to over 400 applications, and the workload is expected to increase during 2004.

Further information

Further information about the HPA can be found on the its web site on www.hpa.org.uk, and in particular for ECG and OETG members on the Chemical Hazards and Poisons section of this site.

Additionally, information on deliberate release of chemical agents may be found on the DH web site (www.dh.gov.uk)

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News of the RSC's Environment, Sustainability and Energy Forum

The Environment, Sustainability and Energy Forum (ESEF) had a busy year in 2004, expanding our portfolio of activities, key initiatives and projects. As reported in previous bulletins, ESEF's interest are wide-ranging and we are developing our activities under three key initiatives:

- Sustainable Energy
- Green Chemical Technologies
- Chemistry of the Natural Environment.

We are also expanding our portfolio of activities to include Sustainable Water – an area where chemists and the chemical sciences will play a major role in improving our understanding of water science and developing technologies for water treatment.

During 2004, we organised a number of workshops and meetings. Our first, held in April 2004, was on the commercialisation of ionic liquids which was a great success, attracting nearly 100 delegates from industry and academia. Ionic liquids have received a tremendous amount of interest over the last decade as non-volatile, recyclable alternatives to conventional solvents. The speakers and delegates represented the chemicals industry, petroleum industry,

pharmaceuticals, manufacturers and specialised equipment. The meeting was very timely and complemented the publication of the technology road-map from QUILL (Queen's University Ionic Liquids Laboratory) on the future of ionic liquids.

A major piece of work which will outline the priority areas for chemistry and the chemical sciences in the context of energy is nearing completion. The expert group, coordinated under the auspices of ESEF, is near to finalising the report which looks across the energy distribution system and all major energy sources and highlights where chemistry and chemists will play a critical role in achieving major breakthroughs. The document will be made available in early 2005.

The Forum is also developing activities with other RSC Fora; we organised a workshop on November 15th in London on *Materials for Sustainable Chemical Technologies* with the RSC's Material Chemistry Forum. The workshop aimed to bring together materials chemists working on different sustainable energy technologies. The key points to arise from this workshop included the lack of materials chemists in the UK who apply their research to sustainable energy

technologies and the need for more funding to support academic research as its moves from lab-based research into technology development. To download the presentations from this event, visit <http://www.rsc.org/science/esef.htm>.

ESEF also organised a workshop on *Nanotechnology in Land and Natural Water Remediation* on December 6th in London in association with FIRSTFARADAY and CL:AIRE. The emerging fields of nanoscience and nanoengineering provide new and novel tools for environmental technologies. This workshop focused on the application of nanoscience in land and natural water remediation and brought together those working in this field to assess current progress and discuss opportunities for future developments. Many participants agreed that the potential benefits of nanoscience in environmental technologies were tremendous with considerable increased efficiency in, for example, the remediation of contaminated sites and groundwater. However, many noted the potential environment, health and safety impacts associated with the introduction of nanoparticles into the environment by means of environmental technologies. They called for more research to understand how these nanoparticles

could potentially impact the natural balance of human health, animal and plant ecosystems. To access the presentations from this workshop visit <http://www.rsc.org/science/esef.htm>.

In relation to green chemistry, ESEF is organising an international conference *Catalysis and Biocatalysis in Green Chemistry* in December 2005 in Cambridge which is attracting attention from an international audience. Confirmed speakers include Paul Anastas, Green Chemistry Institute, ACS; Alfons Baiker, ETH, Switzerland; John Frost, Michigan State University; Klavs Jensen, MIT; Shu Kobayashi, University of Tokyo; Isao Noda, The Proctor and Gamble Company, USA; John Pierce, Dupont and Roger Sheldon,

Delft University of Technology, The Netherlands. This conference will provide a strategic response to the recommendations in the International Assessment of UK Chemistry Research and the follow-on Benign and Sustainable Chemical Technologies report which recommends providing a forum to bring various catalysis communities together. This conference is supported by the RSC's journal Green Chemistry, the ACS Green Chemistry Institute and IChemE. For more details click on <http://www.rsc.org/lap/confs/green.htm>.

In addition to organising focussed workshops and events, ESEF is also becoming very active in developing RSC policy on environment, sustainability and

energy matters. We have responded to two Government consultations over the summer – Defra's Draft Strategy for Non-food Crops and Uses in England and the Government's Approach to Sustainable Development. See <http://www.rsc.org/lap/polacts/polindex.htm> for a full copy of the RSC response.

For more information about the Environment, Sustainability and Energy Forum, please go to www.rsc.org/science/esef.htm or contact Eimear Cotter at cottere@rsc.org or call 020 7440 3333.

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Probing the troposphere from space

Dr. Peter Borrell summarises **Professor John Burrows'** lecture presented last March as part of the ECG symposium *Environmental chemistry from space*.

Professor Burrows first drew attention to the environmental problems in the atmosphere and the effects of the continuous increase in human population and activity, which have resulted in a variety of remarkable changes since the start of the industrial revolution in the 19th century. Among these changes are:

- The global decrease in stratospheric ozone
- The occurrence of summer smog over most cities in the world
- The increase in greenhouse gases and aerosols in the atmosphere and associated climate change
- Acid rain and the eutrophication of surface waters and other natural ecosystems by atmospheric deposition
- Enhanced aerosol and photo-oxidant levels
- The increase in fine particles in regions of industrial development and population growth, and
- The long range transport of air pollution to regions far from the industrial activity.

Through the efforts of European scientists, it has become possible to measure concentrations of tropospheric trace gases and pollutants from space. For example, using a spectrometer mounted on low earth orbit (LEO) satellite, 800 km above the earth and orbiting the earth every 100 minutes, it is possible to determine concentrations of NO₂ in the atmospheric boundary layer at mixing ratios of the order of parts per billion. Other species observable in this way are O₃, HCHO, SO₂, BrO and aerosols.

At the moment the nadir looking instruments determine only total column densities of the species of interest, but much progress is being made with a variety of techniques to obtain rough height profile information as well. It is hoped that in the not too distant future, such retrievals will become automatic.

Some of the applications of these measurements include the determination of NO₂ budgets from lightning, the detection of HCHO and NO₂ from biomass burning with subsequent photochemical formation of a vast pool of O₃ over the South Atlantic, and the intercontinental transport of NO₂ from Africa to Australasia and of aerosol from forest fires in North America to Europe.

One of the major needs in the field is information on a chemical timescales,

rather than the present three-day scale offered by LEO satellites. This could be provided by a geostationary satellite situated 36000 km above the Earth. The measurements would yield concentration fields on a roughly 30 minute basis. The project is technically feasible but requires some political will on the part of the space agencies and the governments that must fund it.

Integrated Global Atmospheric Chemistry Observations (IGACO) is a global observation system proposed for the long term by a team of scientists working under the auspices of the WMO, ESA and NASA. There would be four essential components of IGACO:

- **Networks of ground-based instrumentation**, including balloon sondes, millimetre wave radiometers, lidars, UV-Visible and FTIR spectrometers.
- **Regular aircraft-based measurements** for chemical and aerosol measurements in the troposphere and particularly in the upper troposphere and lower stratosphere (UT/LS), which is sensitive to chemical and climate changes.
- **Satellite-based instrumentation**, preferably mounted on a combination of geostationary (GEO) and Low Earth Orbit (LEO) satellites to provide measurements with the temporal and spatial

resolution needed for sufficient coverage.

- **A comprehensive data modelling system** capable of combining the data for the chemical species, aerosols and ancillary parameters, obtained from the three measurement components, into a comprehensive global picture.

The aim would be to produce a comprehensive picture of the state of the atmosphere on a nearly daily basis in

order to provide information on long terms trends, as well as providing a tool to tackle the scientific challenges presented by the chemical reactor which is our atmosphere.

For some further information and images see http://www.iup.physik.uni-bremen.de/index_e.html and <http://troposat.iup.uni-heidelberg.de/>

Dr PETER BORRELL is deputy coordinator of two ACCENT themes

concerned with the use of satellite instrumentation to monitor the troposphere and the transport and transformation of pollutants in the troposphere. He is also co-editor of the newly published IGACO report promoting the establishment of a global observation system for the atmosphere. Previously, he was Executive Secretary of the EUREKA environmental project EUROTRAC. See: <http://www.luna.co.uk/~pborrell/>.

A new paradigm for monitoring atmospheric composition from space

Ambient air quality remains a matter of high public concern. The impacts of primary and secondary pollutants on human health are numerous, causing, for example, eye irritation, coughing and breathing difficulties (O_3 , NO_2 , SO_2), heart disease (CO and PM_{10}) and lung disease (PM_{10}). Pollutants emitted within urban and near-urban areas are dispersed over the surrounding countryside and, depending on the atmospheric lifetime of the pollutant or its secondary reaction product(s), are dispersed globally. Indeed, long-range transport of pollutants throughout the atmosphere underlies many of the environmental problems, which have arisen over the last 50 years. Thus, the effect of emitted pollutants does not stop at the local level.

One of the major challenges facing atmospheric science is to assess, understand and quantify the impact of natural and anthropogenic pollution on the quality of life on Earth on a local, regional and global scale. It has become apparent that pollution originating from local/regional events can have serious effects on the composition of the lower atmosphere on a global scale. However, to understand the effects of regional pollution on a global scale there is a requirement to transcend traditional atmospheric spatial and temporal scales and attempt to monitor the entire atmosphere at the same time. For example, current observing limitations dictate that *the troposphere is significantly under sampled*.

The role that satellites may play in this scenario is important, as they have the ability to view large areas of the

atmosphere simultaneously.

Traditionally used polar-orbiting satellites can provide high-quality measurements of atmospheric parameters, but a combination of low spatial resolution, non-contiguous data images (normally single swath) and poor revisit times (global coverage is usually achieved in one to three days in mid-to-low latitudes) does not allow the smaller scale events to be studied satisfactorily. An important step towards monitoring atmospheric processes occurring over a local/regional scale can be gained by utilising the observation advantages of the geostationary orbit, which so far has only been exploited by series of meteorological satellites. Geostationary observations of atmospheric composition could provide a unique insight into the interaction between the small-scale changes in composition and global pollution problems.

The geostationary orbit is commonly used today for both telecommunication and weather satellites. The use of geostationary orbits for telecommunications was first suggested by Arthur C. Clarke in 1945. A typical geostationary orbit requires a satellite to be at the geostationary radius of 42,165 km, with zero eccentricity and inclination, thus ensuring that the satellite remains at zero latitude and a constant, selected longitude. The advantages of the application of geostationary observations clearly stem from the nearly stationary location of the satellite with respect to the Earth. This permits, for instance, continuous observation of the same region, and thereby allows

addressing research issues that require *e.g.* monitoring of the diurnal cycle.

For atmospheric composition monitoring in relation to the common pollutants, UV-VIS-NIR spectroscopy presents itself as a sensitive, proven and flexible technique for remote sensing, in that many of the major pollutants have significant absorptions in these spectral regions. For example, a mission concept comprising a UV-VIS-NIR spectrometer (better than 0.5 nm resolution) mounted on a geostationary platform (see Figure

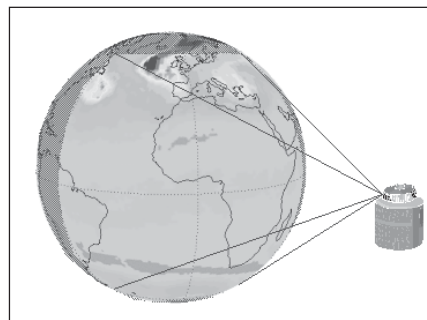


Figure 1 Artist's impression of a geostationary satellite measuring atmospheric composition.

1) positioned nominally at 0° longitude, the attendant launcher, ground segment, mission control and scientific support would be required. The spectrometer would measure the top of atmosphere radiance over Europe and its surrounding areas at high spatial ($< 10 \times 10$ km over Europe) and temporal (< 60 min) resolution and the solar spectral irradiance. From these measurements (see Figure 2) the following atmospheric parameters could be retrieved:

- Total column and tropospheric column of O₃, NO₂, SO₂, HCHO, H₂O & BrO
- Vertical Profiles of O₃
- Cloud cover, top height and cloud optical thickness, aerosol optical thickness.

Figure 3 shows the current state of the art from the SCIAMACHY instrument on Envisat for NO₂ measurements. The data in Figure 3 illustrate that urban pollution sources can be identified from space, but shows the relative paucity of data from current low earth orbit satellites. The satellite will next revisit Birmingham in six days time at 10.00am in the morning.

A new scientific imperative is emerging to understand atmospheric processes, their development and evolution, and their effects on air quality and human health. It is argued that the chemistry and dynamics of trace gases and pollutants in the troposphere and lower atmosphere are highly significant factors in determining long-term trends in air quality. Key issues emerge on local, regional and global scales. Geostationary observations of atmospheric composition offer a totally new approach to the scientific study of atmospheric composition and pollution monitoring, through its capability to provide comprehensive data sets of atmospheric trace constituents with high temporal and spatial resolution on scales ranging from local to continental.

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(This article is based on a presentation by Dr Monks at the ECG symposium *Environmental chemistry from space* held in London in March 2004).

Web link: Techniques for determining tropospheric composition http://troposat.iup.uni-heidelberg.de/AT2/PIs/TG_3/Monks.htm

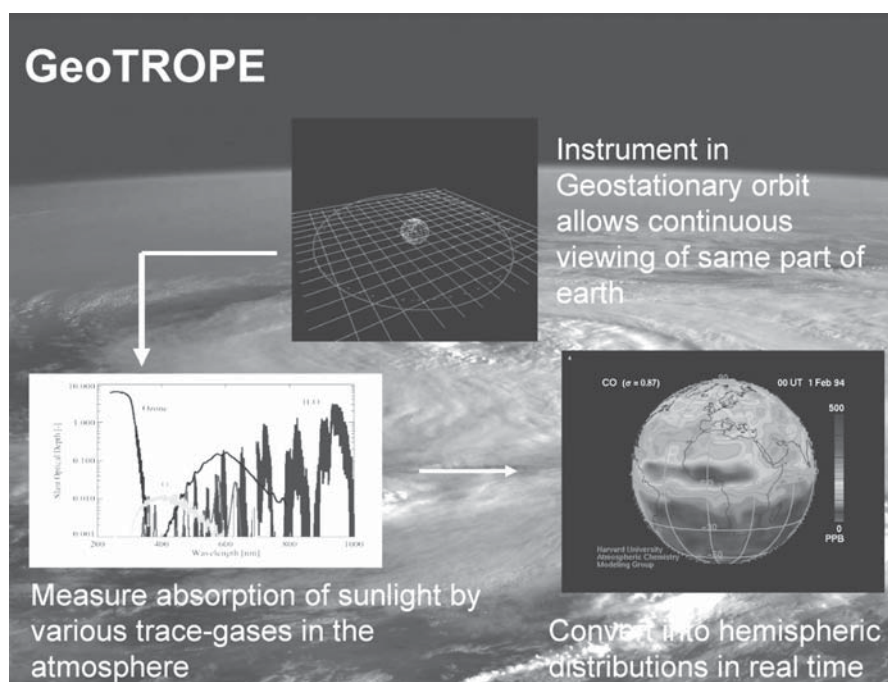


Figure 2 Schematic representation of elements of geostationary observations of atmospheric composition.

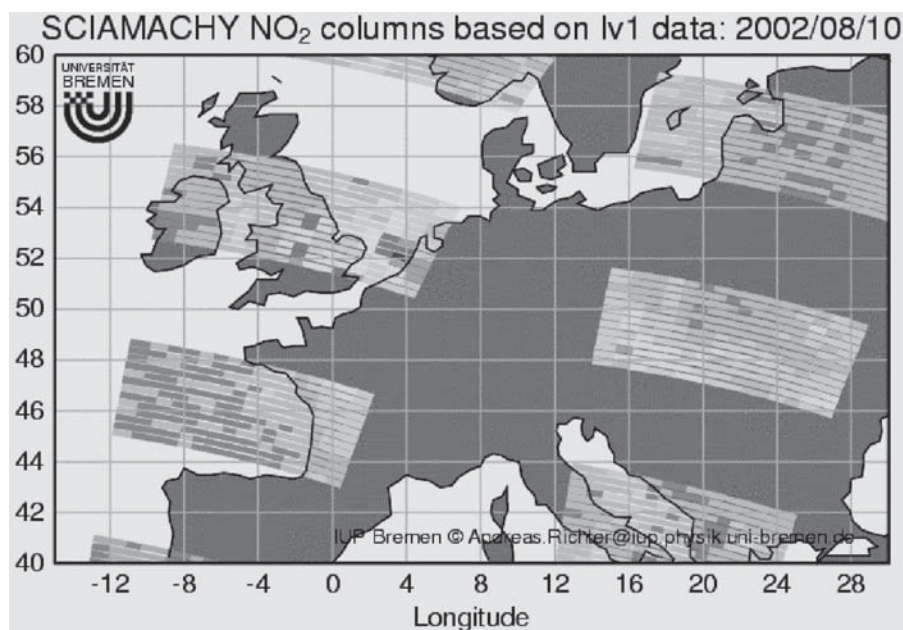


Figure 3 NO₂ column data from the SCIAMACHY instrument on ENVISAT showing the ability to pick up urban pollution from space. (Courtesy of Andreas Richter, University of Bremen, Germany)

CASIX and CO₂ air-sea fluxes

Established in 2003, CASIX is a collaborative centre hosted by the Plymouth Marine Laboratory, with partners at the Plymouth Marine Laboratory, the Southampton Oceanography Centre, the Proudman Oceanographic Laboratory and the Met Office. CASIX studies the interactions between the sea and the atmosphere and aims to make climate change predictions as precise as possible. The primary goal is to accurately measure the transport of carbon dioxide between the sea and the air on a global scale. CASIX will accelerate the use of new Earth Observation satellite data to further the understanding of marine biogeochemistry in the Earth System. The Director of CASIX, **Professor Jim Aiken**, describes some of the work of the centre.

CASIX: objectives and strategy

The acronyms used in this article are listed in the Appendix.

CASIX: The Centre for Observation of Air-Sea Interactions and fluXes (CASIX) is an Earth Observation Centre of Excellence funded by the NERC. The purpose of CASIX is to exploit new-generation Earth Observation (EO) data in order to understand the science of air-sea interactions and to reduce the errors in the prediction of climate change.

CASIX is linked to the Atlantic-basin pCO₂ measuring programmes (AMT & CAVASSOO) and will exploit pCO₂ and AMT bio-optical databases for the study of air-sea fluxes. CASIX combines the work of three NERC centres (PML, SOC-SOES and POL), six universities,

and the Met Office ocean modelling team with international links and direct Space Agency support.

The primary goal of CASIX is to quantify accurately the global air-sea fluxes of CO₂, other gases (CH₄, DMS *etc.*), and particles. Sea surface properties are acquired by remote sensing at CASIX. This information is used to derive air-sea interactions and CO₂ fluxes.

CO₂ air-sea fluxes: The flux of CO₂ is the major component of the oceanic contribution to the global carbon cycle. The air-sea fluxes of CO₂ are driven by physical, chemical and biological processes, often separated in time and space. The solubility and ecological conversion of CO₂ into the ocean is a rapid process (time scale of a few days), but the re-equilibration (time scale ~100 days) may be displaced several hundred kilometres from the sink because of ocean circulation.

High-resolution 3D circulation models with coupled biological processes (carbon cycle) are needed to compute CO₂ fluxes over ocean basins and shelf seas. With a severe paucity of CO₂ data and no seasonal studies, modelling is currently the best method to derive global air-sea fluxes.

CASIX is timely. New sensors in new satellites (Terra, Envisat, Aqua) are giving high precision, high resolution data of the atmosphere, ocean boundary layer properties, and ocean biogeochemical variables - both globally, daily and long term (>5 years). These sensors supplement existing established satellite sensors (NOAA-AVHRR, TOPEX-Poseidon, ERS-1, ERS-2, SeaWiFS *etc.*).

Modelling CO₂ air-sea fluxes: A major component of CASIX is the incorporation of data from models. CASIX uses 3-D general circulation models coupled with the biology (NPZD) of the deep ocean and shelf seas. New EO algorithms of CO₂ using SST, SSS (climatological data) and photosynthetic quantum efficiency (proxy from ocean colour data), are being developed. Novel EO data for sea surface properties (SAR,

ASAR) will be used to determine gas transfer velocities with higher precision.

Global CO₂ budgets and air-sea fluxes

The current assumption of a passive ocean biosphere in assessments of global change is not tenable [as hypothesised by IGBP (SOLAS) and other programmes (EDOCC, OCTET)]. For a warming Earth, with changing atmospheric and oceanic, circulation, thermal structure, albedo, ecosystem functioning and acidity, there is a need for precise data, globally, to constrain the fluxes of CO₂ and other climatically active gases.^{1,2,3,4} [Albedo is the proportion of incident radiation reflected by a surface, especially of a planet or moon].

Ocean surface physics, biogeochemistry and coupled atmospheric properties, regulate the exchanges of heat, momentum, particles and gases at this boundary.⁵ By reducing errors in estimating the marine carbon cycle, quantification of the total Earth CO₂ budget will be improved.

The shelf seas are 10% of the ocean area, but contribute 30% to global biological production and are crucially important for accurate quantification of CO₂ and other gas fluxes in global budgets. With few measurements (and no time series), it is not known if the shelf seas are a net source or a net sink of CO₂.

Studies of the oceans and shelf seas use diverse EO sensors. New EO methods can address flux uncertainties,⁶ as already demonstrated for hydrological fluxes.⁷ A goal of CASIX is to deliver precise, quality-assured, EO data for use in models of Earth system science. The initial focus will be on the North Atlantic and the adjacent European shelf seas. The short-term focus will be on CO₂ and the ocean carbon cycle, which should improve our understanding of air-sea interactions and fluxes in general.

For important practical reasons, better knowledge of the air-sea flux of CO₂ is needed to quantify the fluxes at sub-basin

scales and sub-seasonal (monthly) time scales. Both terrestrial and marine sinks for anthropogenic CO₂ vary greatly from year to year⁸ and are changing substantially on decadal time scales. As part of the post-Kyoto carbon accounting, changes in these natural sinks must be tracked and if possible predicted. Terrestrial carbon sinks at the continental scale can be tracked, but the results are reliable only if the intervening oceanic sinks are constrained independently.⁹ Thus, improved estimates of oceanic fluxes will lead to better estimates of the land-atmosphere components of the global carbon cycle. On decadal to centennial scales, substantial changes in both marine and terrestrial components of the carbon cycle are expected in response to global climate change. Current predictions range from the modest to near-catastrophic.¹⁰ It is likely, in a warming Earth, that the land 'sink' will become a 'source' within 20 years. In the marine realm, we expect that increasing CO₂ concentrations, temperatures and an intensifying hydrological cycle will affect ocean circulation, ventilation and ecosystem structure. Currently we have little knowledge of the impact of these changes on the capacity of the oceans to take up atmospheric CO₂, and no methods to monitor the extent of their occurrence now or in the future. EO data, combined with models and *in situ* observations offer the best prospects of a quantitative solution.

Currently, our knowledge of air-sea CO₂ fluxes is based on models,¹¹ atmospheric measurements of CO₂ and O₂/N₂ ratios¹² or climatologies compiled from decades of sea-surface observations.¹³ None of these techniques provides the space and time resolutions needed to constrain calculations of sources or sinks on an annual and regional basis.

Estimating air-sea gas fluxes at regional, sub-seasonal resolution and global coverage, requires calculation at the appropriate resolution by a Fickian flux equation.^{14, 15}

$$\text{Flux} = -K S [p_{\text{atm}} \{1 + \Delta\} - p_{\text{occe}}]$$

Where K is the transfer velocity, S is the solubility of the gas in the upper ocean, p_{atm} and p_{occe} are the partial pressures of the gas in the lower atmosphere and

upper ocean respectively; Δ is a modification of the standard 'Fickian' equation to incorporate small but important anomalies.^{14,16} Each term in the flux equation relates to diverse strands of science that must be integrated to achieve the primary objective.

Most of the errors in computed CO₂ fluxes arise from uncertainties for the coefficients K and p_{occe} , and their determination is the highest priority. K is the primary 'rate constant' and depends on turbulent and molecular transport near the surface of the ocean. The partial pressure (or fugacity) of the dissolved gas, p_{occe} , varies on the scale of ocean gyres and seasonally, but also at shorter space and time scales. This is due to mesoscale biophysical dynamics, and creates a difficult sampling problem. EO data will play a major role in estimating fluxes. EO data of surface roughness are the key to estimating K accurately with high resolution, while EO colour and SST will be used to interpolate the sparse measurements of CO₂ in the upper ocean. Estimating CO₂ fluxes globally requires continuous data, which ships and buoys alone cannot provide. EO data are the only global sources of data, and these are exploited by CASIX in concert with *in situ* data and models. One approach uses EO and *in situ* data to derive improved parameterisations of the air-sea gas fluxes, including analysis of the importance of processes not presently considered in predictions of future oceanic carbon uptake. These include the complex cycling of carbon in the shelf seas, the impact of white-capping, and the role of surface films in inhibiting air-sea gas exchange. A second approach is developing methods for data assimilation of carbon and ecosystem variables into 3-D ocean circulation models, using EO colour data to interpolate the oceanic ecosystem

between sparse *in situ* measurements. This will provide coherent, self-consistent and time evolving maps of the pCO₂ distributions, and using the improved CASIX parameterisations, accurate maps of air-sea fluxes of CO₂.

The different processes of carbon uptake in shelf seas and the open ocean are handled in separate models, with careful attention to the links between these at the shelf edge. CASIX will use the new models and archived EO data to produce a 10-year climatology of air-sea gas fluxes, primarily CO₂, over the North Atlantic and where possible the globe. Analysis of these and comparison with climatologies derived from a less comprehensive approach, will provide the knowledge needed to parameterise gas fluxes more robustly in global climate models. Finally, remote sensing of atmospheric concentrations of CO₂ are now available from SCIAMACHY on Envisat and CASIX will both utilise and evaluate these measurements.

The scientific structure of CASIX

Figure 1 shows the scientific elements of CASIX and their interconnections, which defines the scientific work programme.

Element 1 (E1) is concerned with improving the parameterisation of air-sea exchange of materials, primarily CO₂, in relation to the physical state of the sea surface. Hitherto, only wind speed and SST have been used as drivers, but the impact of other factors such as the wind stress, sea state, wave breaking and surface films can now be quantified using EO data. A fundamental scientific study of these issues will lead to a better understanding of the physical controls on

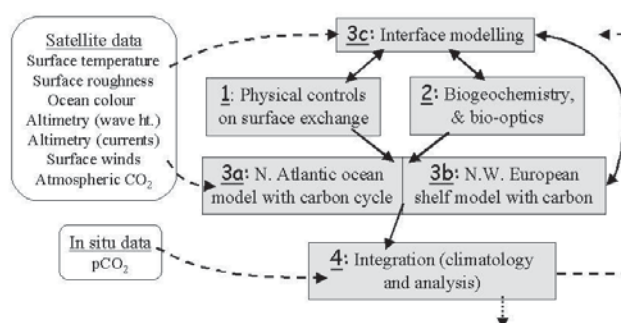


Figure 1: The Elements (1 to 4) of CASIX and their interconnections

air-sea exchange. New parameterisations will be evaluated in the 1-D model (E3c). The final parameterisation will be incorporated into the 3-D models (E3a and E3b) to produce a new flux-climatology (E4).

Element 2 (E2) is concerned with improved understanding of upper ocean biogeochemical processes using bio-optical data derived from satellite observations. A priority task is to provide accurate, quality-assured satellite-derived chlorophyll data, to be assimilated into the 3-D models, to reduce the errors in carbon modelling. Another major task is to parameterise the role of particulates in the carbon budget in shelf-sea models, using ocean colour data linked to *in situ* samples and develop new algorithms for the shelf seas. CASIX is exploring the derivation of photosynthetic rates directly from EO colour data. The results from E2 will be tested in a 1-D model to assess the impact on integrated CO₂ fluxes and a new parameterisation applied to the 3-D models.

Element 3a will significantly improve the capability to numerically model air-sea fluxes of CO₂ by embedding the Hadley Ocean Carbon Cycle (HadOCC) model in the Met Office Forecasting Ocean Atmosphere Model (FOAM). As FOAM is a nested model, concerns about boundary conditions and linking to the shelf sea model (E3b) will be minimised. Data will be assimilated simultaneously into the three nested resolutions, thus

increasing understanding of the effect of model resolution on flux estimates.

The task for **Element 3b** is to model the 3-D shelf seas circulation (POLCOMS) incorporating the ERSEM ecosystem model, building on experience with existing 3-D shelf models^{17,18} and drawing new knowledge from E2 on the effect of biological activity on surface CO₂ concentrations.

Element 3c is developing, an ocean interface model of the response to physical forcing (including resulting fluxes), starting from a 1-D model of the physical structure of the upper ocean and heat fluxes and extended to include coupled biology and radiative transfer. Its purpose is to provide a test facility to explore the sensitivity of the integrated gas flux through the surface to different oceanic and atmospheric forcing and to different parameterisations of physical and biogeochemical processes. It will not represent any advective processes, but it will explicitly represent processes at short depth and time scales, that must be parameterised in the 3-D models.

Thus it is at the heart of CASIX, serving as a tool for the scientific studies in E1 and E2, and providing a route for the results from E1 and E2 to be incorporated into the 3-D models. Together, **Element 3** provides a robust modelling capability for predicting the distribution of CO₂ in the surface ocean, driven by a variety of EO data inputs. From this, air sea gas fluxes can be calculated using EO-

derived surface roughness and surface exchange parameterisations informed by E1. The models will be tools for understanding linkages between physical forcing, biogeochemistry and air-sea fluxes, and ultimately for prediction.

Many groups worldwide are striving to derive air-sea CO₂ flux climatologies from coupled 3-D circulation and ecosystem models, but CASIX is unique in combining Open ocean models (FOAM-HadOCC) and shelf sea models (POLCOMS-ERSEM) that are nested (solving many boundary problems) and very high resolution: FOAM is 1 deg globally, 1/3 deg Atlantic Ocean, 1/9 deg (~12 km) N Atlantic; POLCOMS is down to 1.8 km for the N.W. European shelf seas. Both FOAM-HadOCC and POLCOMS-ERSEM are operational and can provide simulations for annual seasonal cycles of their spatial domains. Again the major task in the near term is validation.

Element 4 (E4) is concerned with the creation of climatologies of gas fluxes and their relationship to other climate variables. CASIX is focused on the N Atlantic and this area will produce the best climatologies. However, CO₂ fluxes are a global problem and we will strive to produce global climatologies. Though these will have less accuracy, they may still be the best produced globally. Initially we will use empirical algorithms to produce a statistical relationship between the *in situ* flux data and satellite observations. Using results from the 3-

Element	Main Task	Goal
E1	Study of physical controls on air-sea gas flux	Improved parameterisation of exchange coefficients using EO data Algorithms for material exchange in Met Office operational models
	Quantifying surface films effect on gas transfer	
	Exploitation of EO measurements of surface roughness and atmospheric CO ₂	
E2	Biogeochemistry of the upper ocean	Improved process models of BGC fluxes and exchange. New methods to estimate production rates from EO
	Biogeochemistry specific to shelf seas	
E3	(a) Modelling the ocean carbon cycle and air-sea gas fluxes in the deep ocean	Achieve operational Ocean Carbon Model. 10 Year hind-cast for FOAM and POLCOMS domains Assessment of systematic uncertainty in carbon fluxes from use of competing parameterisations
	(b) Shelf seas modelling with biogeochemistry and air-sea gas flux	
	(c) Ocean-atmosphere interface modelling (1-D)	
E4	Climatology and analysis	Climatologies of air sea gas fluxes over the 10-year period 1997-2007. Relationships between CO ₂ fluxes and other climate indicators
	Data management	
	Scientific co-ordination	

Table 1: The tasks and goals associated with each of the Science Elements of CASIX

D models, we will produce new climatologies, combining modelled $p\text{CO}_2$ with the improved air-sea exchange parameterisations from Element 1. Finally we will analyse the relationships between the observed fluxes and other climate indicators such as ENSO and NAO.

Table 1 summarises the scientific elements of CASIX, involvement of the CASIX team, the main tasks to be performed and their principal deliverables. The table shows the interactions between several partners are needed within each science element as well as across the whole span of CASIX. This highlights the importance of establishing CASIX, since without it, the necessary collaborative research projects are unlikely to emerge. The management challenge is to ensure that CASIX fosters the fully integrated research that is needed to tackle the pressing problem of CO_2 fluxes and global budgets.

All science elements and sub-projects are making substantial progress and accomplished new developments in the first year of CASIX. Element 1 has produced new algorithms for the gas exchange coefficients using EO data of wind and waves and Element 2 has developed preliminary bio-optical algorithms for ocean biological properties that work in open ocean and shelf seas; validated, tested analyses will be released soon. Element 4 has produced the first new CO_2 flux climatology for the global oceans, combining historical $p\text{CO}_2$ data and new satellite remotely sensed data for wind and waves.

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Appendix

List of acronyms

- AIRS**
Atmospheric InfraRed Sounder (on NASA Aqua spacecraft)
- AMT**
Atlantic Meridional Transect
- ANIMATE**
Atlantic Network of Interdisciplinary Moorings And Time series for Europe
- ASAR**
Advanced Synthetic Aperture Radar
- BATS**
Bermuda Atlantic Time-series Station
- CASIX**
Centre for observation of Air-Sea Interactions and fluxes
- CAVASSOO**
CARbon VARIability Studies by Ships Of Opportunity
- CDOM**
Coloured Dissolved Organic Material
- CMG**
CASIX Management Group
- Coastfloc**
COAtal Surveillance Through Observation of Ocean Colour
- COLORS**
Coastal region LOnG-term measurements for colour Remote Sensing development and validation
- DMS**
Dimethyl sulphide
- ENVISAT**
ENVIronment SATellite
- ENSO**
El Nino/Southern Oscillation
- EO**
Earth Observation
- EOF**
Experimenters' Operations Facility (at NASA Goddard Space Flight Center)
- ERSEM**
European regional Sea Ecosystem Model
- FOAM**
Forecasting Ocean Atmosphere Model
- FRRF**
Fast Repetition Rate Fluorometer
- GCM**
General Circulation Model
- GMES**
Global Monitoring for Environment and Security
- GODIVA**
Grid for Environmental Systems Diagnostic and Visualisation
- HadOCC**
Hadley Ocean Carbon Cycle
- HOTS**
Hawaii Ocean Time Series
- IOP**

Inherent Optical Properties

JGOFS

Joint Global Ocean Flux Study

LISST

Laser

In-Situ Scattering and Transmissometry

MERIS

MEdium Resolution Imaging Spectrometer

MODIS

Moderate Resolution Imaging Spectroradiometer

MODIS-A

Moderate Resolution Imaging Spectroradiometer - Aqua

NAO

North Atlantic Oscillation

NASA-AMT

National Aeronautics and Space Administration - Atlantic Meridional Transect

NPZD

Nutrient - Phytoplankton - Zooplankton - Detritus

OCTET

Ocean Carbon Transport, Exchanges and Transformations

SAR

Synthetic Aperture Radar

SCIAMACHY

SCanning Imaging Absorption SpectroMeter for Atmospheric CHartography

SeaWiFS

Sea-viewing Wide Field-of-view Sensor

SOLAS

Surface Ocean-Lower Atmosphere Study

SPM

Suspended Particulate Material

SSH

Sea Surface

SSS

Sea Surface Salinity

SST

Sea Surface Temperature

TOPEX

TOPOgraphy EXperiment for Ocean Circulation

JIM AIKEN,

Director of CASIX, **NICK**

HARDMAN-MOUNTFORD and the

CASIX team

(This article is based on a presentation by Professor Aiken at the ECG symposium *Environmental chemistry from space* held in London in March 2004).

Web links

CASIX: <http://www.nerc.ac.uk/funding/earthobs/coex/casix.shtml>

'The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System', P. Falkowski *et al*, *Science*, 2000, **290**, 291-296 <http://www.globalcarbonproject.org/PRODUCTS/pre%20project%20products/Falkowski2000.pdf>

European Association for Chemical and Molecular Sciences

The new European Association for Chemical and Molecular Sciences, EuCheMS, will take over the role and responsibilities of the former Federation of European Chemical Societies (FECS) in 2005. The RSC is the largest member society of EuCheMS and will hold the Secretariat. **Sean McWhinnie** from the RSC reports.

At the 2004 Federation of European Chemical Societies (FECS) General Assembly meeting in Romania, the member societies approved an amended constitution and a new name. The European Association for Chemical and Molecular Sciences (EuCheMS) is a non-profit-making organisation. Its object is to promote co-operation in Europe between those non-profit-making scientific and technical societies in the field of chemistry whose membership consists largely of individual qualified chemical and molecular scientists and whose interests include the science and/or practice of chemistry. In the coming months, EuCheMS will become an 'Association Internationale Sans But Lucratif' (not-for-profit organisation) in Belgium.

The most vital aspect of the future

strategy of EuCheMS is political impact. With the new enlarged EU, it is even more important that EuCheMS provides a focus for discussion on chemical and molecular science issues in order to influence EU government and politicians on developments in European research. To do this, EuCheMS needs to obtain financial support. Under its new constitution, EuCheMS will be better able to enter into partnership with other science groups. The chemical and molecular sciences community needs to readjust in order to operate on equal terms with other science groups and to be welcomed as a partner in joint initiatives. EuCheMS is ready to take the lead. To succeed, EuCheMS must be visible to the decision makers, to other science groups and to its member societies and their members. EuCheMS aims to provide added value to the member societies in order to ensure their involvement in developing the new strategy.

Professor Giovanni Natile from the Italian Chemical Society will take over as President of EuCheMS from Professor Gábor Náray-Szabó of the Hungarian Chemical Society at the beginning of 2005.

EuCheMS, like FECS, promotes educational, professional and ethical matters, including the designation European Chemist (EurChem).

Scientific meetings, sponsored events and development of initiatives in specific areas are carried out by Divisions and Working Parties.

The former FECS Division for Chemistry and the Environment will continue to operate under the new constitution. The Division's main activities are centred on the arrangement of conferences, especially the Annual International Conferences on Chemistry and the Environment. However, in 2006 the Division will contribute to European Chemistry Congress which will take place in Budapest from 27th to 31st August 2006.

The Division also has a number of sub-committees which have their own activities and organise specialist meetings. These sub-committees are: Soil Chemistry; Cultural Heritage Chemistry; Environmental Chemistry Education; Green Chemistry; Atmospheric Chemistry; and Water Chemistry.

The current chairman of the Division is Philippe Garrigues from France, and John Holder from Centre for Environmental Research and Technology Transfer in Blackburn is secretary.

More details about EuCheMS and its activities may be found at <http://www.chemsoc.org/networks/enc/fecs.htm>

Book review

Handbook of Atmospheric Science: Principles and Applications

Edited by C.N. Hewitt and Andrea Jackson, Blackwell, Oxford, 2003

Contents

Part I: Principles of Atmospheric Science:

1. Chemical Evolution of The Atmosphere: Richard P. Wayne.
2. Atmospheric Energy and The Structure of The Atmosphere: Hugh Coe and Ann R. Webb.
3. The Earth's Climates: John G. Lockwood.
4. Biogeochemical Cycles and Residence Times: Dudley E. Shallcross, Kuo-Ying Wang and Claudia H. Dimmer.
5. Sources of Air Pollution: Andrea V. Jackson.
6. Tropospheric Photochemistry: Paul S. Monks.
7. Stratospheric Chemistry and Transport: A. Robert Mackenzie.
8. Aqueous Phase Chemistry of The Troposphere: Peter Brimblecombe.
9. Atmospheric Particulate Matter: Urs Baltensperger, Stephan Nyeki and Markus Kalberer.
10. Atmospheric Dispersion and Air Pollution Meteorology: David Carruthers.
11. Synoptic Scale Meteorology: Douglas J. Parker.
12. Atmospheric Removal Processes: Brad D. Hall.

Part II: Problems, Tools And Applications:

13. Global Air Pollution Problems: Atul K. Jain and Katharine A.S. Hayhoe.
 14. Regional Scale Pollution Problems: Crispin J. Halsall.
 15. Urban Scale Air Pollution: Jes Fenger.
 16. Measuring and Monitoring The Atmosphere: Rod Robinson.
 17. Emission Inventories: David Hutchinson.
 18. Pollutant Dispersal Modeling: Yasmin Vawda.
 19. Climate Modeling: William Lahoz.
 20. Critical Levels and Critical Loads as A Tool For Air Quality Management: Wim De Vries and Maximilian Posch.
 21. The Practice of Air Quality Management: Bernard E.A. Fisher.
- Index.

Atmospheric Science – yes – but a handbook?

This is a nicely produced collection of well-written essays by acknowledged experts, mainly on the varied aspects of atmospheric chemistry. However, it is disappointing as a handbook – and there is one serious omission from the topics covered.

The book, as the title suggests, should be a good desk book for a practitioner in the field, allowing him or her to check up on areas peripheral to his or her main

interest. It should also make a good reference work for someone on the periphery, or for a library. The first part of the book comprises twelve chapters on the principles of atmospheric science. The initial chapters set the scene, dealing with the evolution of the atmosphere (Wayne), the structure of the atmosphere and atmospheric energy (Coe and Webb), the Earth's climates (Lockwood), biogeochemical cycles and residence lifetimes (Shallcross, Wang and Dimmer) and sources of pollution (Jackson). Pollution is, as it should be, a recurring topic throughout the book.

Then come five more detailed chapters on tropospheric photochemistry (Monks), stratospheric chemistry and transport (Mackenzie), tropospheric aqueous phase chemistry (Brimblecombe) and on atmospheric particulate matter and aerosols (Baltensperger, Nyeki and Kalberer). The first section concludes with chapters on meteorological aspects: atmospheric dispersion and air pollution meteorology (Carruthers), synoptic scale meteorology (Parker) and wet and dry deposition (Hall). The text is copiously supported with clear diagrams and well set-out equations. It is nice to see a willingness to repeat chemical equations to avoid constant thumbing back and forth when trying to follow the argument over several pages. There are a few oddities such as the CLAW hypothesis and the QG theory and potential vorticity (PV) which are discussed at length but for which definitions are either not given or are hard to find.

The second part of the book is concerned with problems, tools and applications. It opens with three chapters on air pollution: on global (Jain and Hayhoe), regional (Halsall) and urban scales (Fenger). Two chapters follow on monitoring techniques (Robinson) and emission inventories (Hutchinson). There are then modelling chapters for each end of the scale – pollutant dispersion (Vawda) and climate (Lahoz). The book concludes with two chapters on management: critical levels and critical loads (de Vries and Posch) and air quality management (Fisher). An effort is made throughout to break away from the European bias and consider

problems in other regions. However the final management chapter is confined just to the UK, although summer smog episodes in south-eastern England almost always involve the whole of north-western Europe. Since the UK is a party to the CRTAP convention and adheres to EU directives, some mention of the EU directives and the CAFÉ initiatives would have been welcome, together with the role of the EEA and the interaction with EMEP.

The level of approach is reasonably uniform throughout and each chapter would provide a good start for a new research student. Each is self-contained with its own references and in some cases has a conclusion. Although the first chapter leaves the reader 300M years before the present, there are in fact references up to the year 2000.

So why the fuss about a handbook? In what is essentially a reference work, an excellent index, and cross referencing within chapters is needed to be able to find things easily, particularly in areas with which one is less familiar. The book has a nice contents list but a poor index; so, much of the book is inaccessible to all but those who know the areas well. For example, you won't find the ozone hole or summer smog or the QG theory or potential vorticity, even though they are dealt with at length in the text – or the weekend or titration effects or the CLRTAP, which perhaps ought to have been both discussed and mentioned. Initials and chemical formulae are eschewed, which is crippling in a field where they are common. Surely abbreviations and acronyms, such as IPCC, EMEP, NO_x, AOT40 and POPs, are part of the language of the field now – they are mentioned as such in the text. And if one insists on avoiding them in the index, then perhaps a comprehensive glossary would have helped, provided it was correlated with the index. As well as the omissions, it is hard to discern the philosophy behind the index: some section heads are included, some aren't; some items are included for one chapter but not for another. So following up ozone chemistry for example will take you to the nice discussion in chapter 14 but not to the definitive account in chapter 6. In short you cannot find all

the references to the subjects mentioned – essential where there is no internal cross-referencing. Having had to do such indexing myself, I realise that it costs a lot of effort – but it is essential to provide access for the potential users.

And what of the serious omission? Well apart from a brief section in chapter 14, there is nothing about regional and synoptic scale modelling. Chemical Transport Models (CTM) attempt to encapsulate our knowledge and understanding of the behaviour of trace substances in the atmosphere, and they provide the basis for the appreciation and regulation of tropospheric air pollution. But here we learn nothing about

distinctions between Lagrangian and Eulerian models, and their uses in interpreting data, or their support through the EMEP and RAINS models for the EU directives on ozone, NO_x, VOC and other pollutants. And there is no discussion of the problems of such models – the science and skill needed to construct spatial and temporal emission estimates; the parameterisation of turbulence and the necessary simplifications of the chemistry schemes. Nor is there any mention of the gradual progress in incorporating observations from disparate sources into model calculations on these scales which, many believe, will underpin future regional and global monitoring and forecasting.

In conclusion, although I liked the book and the presentation, there is a major omission and the book is not as useful as the content deserves. One final thought: if the editors commissioned a modelling chapter, encouraged the authors to include cross referencing in the individual chapters (easier now that it is written) and provided a first class index, they could make use of the present excellent material to produce a worthwhile second edition.

PETER BORRELL
P&PMB Consultants
Newcastle-under-Lyme
October 2004.

Journal of Environmental Monitoring

The following review articles were published in *J. Environ. Monit.* during 2004:

- Review of ozone and temperature lidar validations performed within the framework of the Network for the Detection of Stratospheric Change
- Electrochemical sensors for environmental monitoring: design, development and applications

- Advances in analytical technologies for environmental protection and public safety
- The biological behaviour and bioavailability of aluminium in man, with special reference to studies employing aluminium-26 as a tracer: review and study update
- Assessing workplace chemical exposures: the role of exposure monitoring
- Biosphere 2 Center as a unique tool

for environmental studies.

Reviews from the News Section of *J. Environ. Monit.* in 2004 included:

- Groundwater arsenic contamination and its health effects in the Ganga-Meghna-Brahmaputra Plain
- Safe as houses? Indoor air pollution and health
- Lead and public health: review of recent findings, re-evaluation of clinical risks.

New books on the environment from the RSC

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New book on organic phosphorus and the environment

Organic Phosphorus in the Environment

Edited by B. L. Turner, Smithsonian Tropical Research Institute, Republic of Panama, E. Frossard, ETH, Lindau, Switzerland, and D. S. Baldwin, Murray-Darling Freshwater Research Centre, Australia

December 2004, 432 pp, ISBN 0 85199 822 4

Special discount price for ECG members: £60.00 (US\$112.00) (Normal Price: £75.00/US\$140.00) Reference JBO20

Organic Phosphorus in the Environment brings together the latest research and opinion on the biogeochemistry of organic phosphorus from a wide range of disciplines and focuses specifically on the characterisation and transformations of organic phosphorus in terrestrial and aquatic systems. It examines analytical procedures for the chemical characterization of organic phosphorus in environmental samples, processes regulating organic phosphorus in the environment, and integration of the process at the ecosystem level. Ecological, chemical, microbiological and analytical aspects are explored. Written by a team of leading experts, the book will provide an invaluable reference for all those interested in organic phosphorus.

Contents

Preface: B. L. Turner, E. Frossard and D. S. Baldwin

SECTION A: Chemical characterization of organic phosphorus in environmental samples

- Separation, preconcentration and speciation of organic phosphorus in environmental samples
D. McKelvie, Monash University, Australia

- Using phosphorus-31 nuclear magnetic resonance spectroscopy to characterize organic phosphorus in environmental samples
B. J. Cade-Menun, Stanford University, USA

- Organic phosphorus speciation in natural waters by mass spectrometry
W. T. Cooper, J. M. Llewelyn, G. L. Bennett, A. C. Stenson and V. J. M. Salters, Florida State University, USA

SECTION B: Processes controlling the dynamics of organic phosphorus in the environment

- Abiotic degradation of organic phosphorus compounds in the environment

D. S. Baldwin, J. A. Howitt, Monash University, Australia, and J. K. Beattie, University of Sydney, Australia

- Enzymatic hydrolysis of organic phosphorus

H. Quiquampoix, and D. Mousain, INRA-ENSAM, France

- Abiotic stabilization of organic phosphorus in the environment

L. Celi and E. Barberis, University of Turin, Italy

- Microbial turnover of phosphorus in soil

Oberson, Institute of Plant Sciences, Switzerland, and E. J. Joner, Norwegian Forest Research Institute, Norway

- Utilization of soil organic phosphorus by higher plants

E. Richardson, T. S. George, M. Hens, and R. J. Simpson, CSIRO Plant Industry, Australia

- Microbial turnover of organic phosphorus in aquatic systems

R. T. Heath, Kent State University, USA

- Ecological aspects of phosphatase activities of algae and bryophytes

A. Whitton, University of Durham, UK, A. M. Al-Shehri, King Khalid University, Saudi Arabia, N. T. W. Ellwood, Universita Roma Tre,

Italy, and B. L. Turner

SECTION C: Integrating processes at the ecosystem level

- Organic phosphorus dynamics in tropical agroecosystems

G. Nziguheba, Generose, Belgium, and E. K. Buenemann, Institute of Plant Sciences, Switzerland

- Organic phosphorus transfer from terrestrial to aquatic environments

B. L. Turner

- Interactions of organic phosphorus in terrestrial ecosystems

L. M. Condon, Lincoln University, New Zealand, and H. Tiessen, Göttingen University, Germany

- Organic phosphorus in the aquatic environment: speciation, transformations and interactions with nutrient cycles

M. Mitchell and D. S. Baldwin, Murray-Darling Freshwater Research Centre, Australia

- Modelling phosphorus, carbon and nitrogen dynamics in terrestrial ecosystems

W. J. Parton, Colorado State University, USA, J. Neff, US Geological Survey, Denver, USA, and P. M. Vitousek, Stanford University, USA

- Modelling organic phosphorus transformations in aquatic systems

P. Reichert, Swiss Federal Institute for Environmental Science and Technology, Switzerland, and B. Wehrli, Swiss Federal Institute of Technology, Switzerland

- Synthesis and recommendations for future research

L. Turner



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Meeting report

Monitoring ambient air: implications and implementation of new Directives and standards

Organised by the National Physical Laboratory (NPL), the DTI Valid Analytical Measurement (VAM) programme, the Flemish Environmental Agency, and the RSC's AAMG Group

English Heritage Lecture Theatre, London, 15-16th December 2004

Topics for discussion at this two-day meeting, which was attended by over 100 delegates, included the EU's ambient air quality legislation, air monitoring techniques, measurement of particulate matter (PM), and pan-European air monitoring networks.

Stefan Jacobi from the DG Environment, Unit C1, European Commission, reviewed the Air Quality Framework and the 4th Daughter Directive. He described the legal background and legislative approach of Directive 96/62/EC on Ambient Air Quality (sulphur dioxide, nitrogen dioxide, PM₁₀, lead, carbon monoxide, benzene and ozone) and Annex 1 – which refers to arsenic, cadmium, nickel, PAHs (as B[a]P), and mercury. Annex 1 was adopted in November 2004 and an attainment date for the Annex 1 targets (e.g. arsenic: 6 ng m⁻³, cadmium: 5 ng m⁻³) is set for 2012). Sampling regimes and methods are being developed for the Annex 1 species.

Peter Bruckman (Landesumweltamt Nordrhein-Westfalen, Essen) spoke on “The Work of the CAFÉ (Clean Air for Europe) Steering Group” (<http://europa.eu.int/comm/environment/air/caf%C3%A9/index.htm>; http://www.europa.eu.int/comm/environment/air/caf%C3%A9/pdf/working_groups/2ndposition_paper_pm.pdf). CAFÉ was launched in June 2001 as a strategy to abate air pollution.

Professor Mike Pilling (University of Leeds) summarised the Air Quality Expert Group (AQEG) report on particulate matter <http://www.defra.gov.uk/corporate/consult/particulate-matter/index.htm>. Overall, the PM₁₀ emission

inventory shows a substantial decrease from 1970-2000 and this is mostly associated with a decrease in coal use. But PM resulting from road transport is becoming relatively more important – especially since particulate iron concentrations seem to be high, and inhaled iron has been linked to cellular oxidative stress. In both the UK and Europe the decrease in PM now seems to have declined, but it is not clear if this is associated with climate factors or due to some other reason.

In the final paper of the first session, **Peter Woods** (NPL) spoke on “The European Network of National Air Quality Reference Laboratories (AQUILA)” (<http://ies.jrc.cec.eu.int/Units/eh/Projects/Aquila/>). EC Directive 96/62/EC on Ambient Air Assessment requires member states to nominate National Reference Laboratories (NRL) to conduct quality assurance and quality control checks of both analytical methods and those who carry out the analyses. AQUILA is a network of European NRLs, with 38 representatives from 25 countries.

Thomas Kuhlbusch (University of Duisburg-Essen) opened the second session with a paper on “PM Source Apportionment Data” with results from North Rhine-Westphalia, Rhineland Palatinate and Berlin/Brandenburg. Sources of PM₁₀ are attributed to local traffic (26%), background (47%), and urban (27%). **Frank Kelly** (King's College, London) discussed the relationship between particulate metals (iron, copper, nickel and chromium), oxidative stress and health effects. **Anton Van der Meulen** (National Institute for Public Health and the Environment, Bilthoven) examined “PM₁₀ and the new PM_{2.5} Standard”, and focused on the need to select, validate, and assess PM_{2.5} measurement methods (working group CEN/TC264/WG15).

Natacha Claeys (Flemish Environmental Agency) spoke on “Monitoring Heavy Metals in Belgium” and focussed on local emissions from non-ferrous industrial plants and steel manufacturers. Further discussion concerning PM_{2.5} was covered in a paper “PM_{2.5} Measurements in Europe” by **Marina Froehlich** (Department of Air Quality Control,

Vienna). The first day ended with a presentation from **Rob Kinnersley** (Air Science Team, Ecosystem Science, EA) who argued succinctly that the attention given to nanoparticle technology suggested that a re-examination of the importance of particle number would be useful:

“... we need to look beyond the conventional metrics of mass and number in order to derive meaningful ambient measurements.”

The second day began with two papers (“Monitoring of Inorganic Gases” **Ente Sneek** (Convenor of WG12 CEN TC 264); “The New CEN Benzene Standards” **Ulrich Pfeffer** (WG13 CEN TC 264) (Landesumweltamt Nordrhein-Westfalen, Essen), which described the manner in which harmonisation of procedures for quality control and assurance are being undertaken in the laboratory and in the field. **Gary Fuller** (King's College, London) examined PM₁₀ in London during 2003 (www.londonair.org.uk). He discussed the effects of the several ‘regional’ episodes on monitored values (Fuller *et al.* (2002) *Atmos. Env.* **36**, 1431-1444). **Theo Hafkenscheid** (van Swinden Laboratory, Delft) spoke on the “Demonstration of Equivalence” (use of standardised methods). **Harald Creutzmacher** (UMEG) explained a method for particulate PAH (B[a]P) analysis.

In the final session, **Iain Marr** (University of Aberdeen) described the results of an air quality survey in a harbour. Results from pumped and passive sampling of priority air pollutants indicated that only nitrogen dioxide was likely to be a problem (ships in Aberdeen do not burn high sulphur content fuels). **Peter Woods** gave a second paper (“Type Approval of Automatic Instruments”), which was followed by “QA/QC of Ambient Air Measurements” (**Richard Brown**, NPL). **Don Munns** (EA) summed up the meeting with his presentation “Will it all have been worthwhile? – 2010 and beyond.”

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Meeting report

Third annual AIRNET conference

The 3rd, and final, AIRNET Annual Conference was held at the Movenpick Hotel, Prague, Czech Republic from 21st - 23rd October 2004, and was attended by approximately 150 delegates.

AIRNET is a thematic network project initiated to develop a European-wide framework for air pollution and health research. AIRNET collects, interprets and disseminates data from individual (EU funded) projects, in order to strengthen the relationship between science and policy and to draw policy-

relevant recommendations from air pollution and health research. AIRNET started in 2002 and is funded until the end of 2004. The first two years have focused on the collection and interpretation of air pollution and health data. The main aim of the 2004 AIRNET Conference was on communication between EU research and policy. The following topics were discussed:

- Role of EU research in policy development for air pollution and health.
- AIRNET and WHO reports on air pollution and health.
- Air pollution and health in Central and Eastern Europe – views from

science and policy.

- Air pollution and health issues and problems specific to European regions (North, West, Central/East, South).

Details of AIRNET conferences plus reports of various working parties may be seen at the AIRNET web site: <http://airnet.iras.uu.nl/>

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Recent books on the environment and on toxicology at the RSC library

The following books and monographs on environmental topics, toxicology, and health and safety have been acquired by the Royal Society of Chemistry library, Burlington House, during the period July to December 2004.

Agricultural Applications in Green Chemistry

(ACS Symposium Series No. 887)
Nelson, W.M. (Ed), ACS, Washington, 2004 ISBN/ISSN: 0841238286

Chemical Sciences in Changing Times: Visions, Challenges and Solutions

Vol. II (4th International Conference of the Chemical Societies of the South-east

European Countries, Belgrade July 18-21 2004)

Serbian Chemical Society, Belgrade, 2004 ISBN/ISSN: 8671320200

COSHH in Practice: Skin Management

2nd edition
Packham, C.L; Packham, H.E., Croner, Kingston, 2004 ISBN/ISSN: 1855246813

1,1-Difluoroethane (JFC-152a)

(Joint Assessment of Commodity Chemicals No. 45)

European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), Brussels, 2004

1,1,1,3,3-Pentafluoropropane (HFC-245fa)

(Joint Assessment of Commodity Chemicals No. 44)

European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), Brussels, 2004

Water Quality Assessments in the Mississippi Delta: Regional Solutions, National Scope

(ACS Symposium Series No. 877)
Nett, M.; Locke, M.A.; Pennington, D.A. (Eds.), ACS, Washington, 2004 ISBN/ISSN: 084123812X

THE ROYAL SOCIETY OF CHEMISTRY ENVIRONMENTAL CHEMISTRY GROUP

Bulletin

CORRECTION

In the July 2004 edition of the *ECG Bulletin*, The Royal Society of Chemistry Environmental Chemistry Group published an article by Mike Sharpe entitled "*Deadly waters run deep: the global arsenic crisis*".

That article stated that the Natural Environment Research Council ("NERC") and its research institute, the British Geological Survey ("BGS"), were being sued by 750 Bangladeshis in the High Court in London. It also stated that BGS had applied to have the claim struck out in May 2003, but that the application had been dismissed.

The article was correct in its summary of the status of the Court proceedings when it was first published in 2003. However, NERC has since appealed the High Court's decision to dismiss its application. The Court of Appeal agreed with NERC and struck the claim out in February 2004. The Claimants are currently applying to the House of Lords for permission to appeal the Court of Appeal's decision. NERC deny negligence.

Forthcoming symposium

Pharmaceuticals in the Environment: Fate, Effects and Regulation

Tuesday, 1st March 2005

Venue: The Society of Chemical Industry, 14/15 Belgrave Square, London

Organised by the SCI BioActive Sciences group in association with JPAG, RSC and SETAC-UK

Conference Aims

There is an increasing awareness of the presence and effects of pharmaceuticals in the environment – particularly in watercourses. Pharmaceuticals are present from veterinary and human use. This meeting, which is aimed at regulators, industry and academics, will address recent regulatory advances, and include talks on current research into the fate of pharmaceuticals in the environment and their potential impacts on environmental and human health.

Programme

Tuesday, 1st March 2005

- 09.15** Registration and coffee
09.55 Introduction
10.00 **Usage and input routes of pharmaceuticals into the environment**
 Emma Pemberton, Environment Agency, UK
10.35 **Environmental legislation for human and veterinary pharmaceuticals in Europe**
 Alex Tait, Veterinary Medicines Directorate, UK
11.10 **Fate of pharmaceuticals in the environment**
 Alistair Boxall, University of York/Central Science Laboratory, UK
11.45 **Occurrence of human pharmaceuticals in the UK aquatic environment**
 Kevin Thomas, CEFAS, UK
12.20 Lunch and Poster Exhibition
13.40 **Challenges in exposure modelling for pharmaceuticals**
 Kathrin Fenner, EAWAG, Switzerland

- 14.15** **Impacts of clinical and non-clinical usage of antibiotics and biocides on environmental reservoirs and mobility of resistance genes**
 Liz Wellington, University of Warwick, UK
14.50 Tea break
15.10 **Ecotoxicity testing of human pharmaceuticals: principles and practicalities**
 Tim Williams, AstraZeneca, UK
15.45 **Indirect effects of pharmaceuticals on consumers**
 Len Levy, IEH Leicester, UK
16.20 Closing remarks
16.30 Close of meeting

REGISTRATION FORM

To register, please fill in your details below and send with the appropriate remittance to:

Katherine Simpson, Society of Chemical Industry, 14/15 Belgrave Square, London, SW1X 8PS, UK
 Tel: +44 (0) 20 7598 1566,
 FAX: +44 (0) 20 7235 7743,
 E-mail: katherine.simpson@soci.org

Pharmaceuticals in the Environment: Fate, Effects and Regulation

Tuesday 1 March 2005, SCI, 14/15 Belgrave Square, London, SW1X 8PS, UK

Name:

Affiliation:

Address:

Special requirements: dietary/access/other

Please register me for the above conference

Signature Date

PLEASE NOTE THAT UNSIGNED FORMS CANNOT BE ACCEPTED

FEE: Includes refreshments as stated in the programme.

Non-members: £140 Member of SCI/JPAG/RSC/SETAC: £100 Retired member of SCI: £35

Non-member students: £35 Student member of SCI: £25

Register online at www.soci.org

Scientific Organisers: Alistair Boxall, University of York/CSL; Mark Cronin, Liverpool John Moores University; Roger Reeve, Sunderland University

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