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Practical Applications of Medical Geology, 19th to 20th March 2009: Book of Abstracts

Environmental Geochemical Baselines Programme

Internal Report OR/09/026

BRITISH GEOLOGICAL SURVEY

ENVIRONMENTAL GEOCHEMICAL BASELINES PROGRAMME

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Practical Applications of Medical Geology, 19th to 20th March 2009: Book of Abstracts

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Foreword

This report provides abstracts of the presentations given at the Practical Applications of Medical Geology held at the British Geological Survey Offices at Keyworth Nottinghamshire on the 19th and 20th March 2009.

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The authors would like to thank the following members of the British Geological Survey Staff who were instrumental in the successful organisation of the meeting:

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Karen Kennedy – Financial secretary

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Mark Button – General assistant

Amy Coleman - General assistant

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1 Introduction

"Medical Geology" is defined as the science dealing with the relationships between natural geological factors and health in man and animals, and understanding the influence of environmental factors on the geographical distribution of such health problems. This area of science is aimed at improving the interdisciplinary interactions between environmental and health scientists. The first British Geological Survey meeting concerning the 'Practical Applications of Medical Geology' was organised in order to provide a common platform for medical geology practitioners to present and highlight successful applications of interdisciplinary case studies. It facilitated professionals, from industry, regulatory authorities and academia, to discuss their findings and identify problems and scientific solutions to conducting such research.

Papers were invited on the following themes:

- Novel methods for assessing the impact of human and animal exposure to potentially harmful elements, organic contaminants and radionuclides.
- Chemical and mineral speciation controls on the bioaccessibility of potentially harmful substances in soil and particulates.
- Trace element deficiency problems in human health and agriculture.
- The relationships between hazard and risk.
- Geochemical spatial distribution from maps to microscopic scale.
- Climate change and its impacts on human health and agriculture.
- Water and air quality.

2 Meeting Programme

Day 1: Thursday 19th March

09:45 – 10.30 Coffee and registration

10:30 Welcome – Ben Klinck (Head of Science- Environment and Health) and Mark Cave (conference organiser)

Session 1: Bioaccessibility of harmful substances – Session Chair Mike Watts

10:45 Olle Selinus (Geological Survey of Sweden / Chair IMGA) – The International development of medical geology - what will happen now and in the future?

11:20 Sebastien Denys (INERIS) – In-vivo validation of the Unified Barge Method for the bioavailability of arsenic, cadmium and lead in soils

11:40 Mark Cave (British Geological Survey) – Measurement, modelling and mapping of the bioaccessibility of arsenic in the Tamar Catchment

12:00 Christine Davidson (University of Strathclyde) - Human bioaccessibility of potentially toxic elements in urban soils from two European cities

12.20 Tom Van de Wiele (University of Ghent) – Development of an in-vitro test for measuring the bioaccessibility of polyaromatic hydrocarbons in contaminated soils

12.40 Chris Collins (University of Reading) – Model human digestive system for the determination of bioaccessibility of environmental pollutants

13.10 Lunch

Session 2: Biomonitoring – Session Chair Mark Cave

14.10 Randal Parrish (BGS/ Leicester University) - Environmental and military depleted uranium aerosol pollution: health and exposure assessment in light of recent UK and US studies

14.40 David Large (University of Nottingham) – A Geological re-evaluation of the Xuan Wei lung cancer epidemic

15.00 Mark Button (Leicester University / BGS) – Human toenails as a biomarker of exposure to elevated environmental arsenic

15.20 Jenny O'Reilly (Surrey University / BGS) – Biomonitoring / arsenic speciation of human materials and environmental samples in arsenic affected regions of Argentina

15.40 Paul Wright (ICENS, Jamaica) – Beta-2 microglobulinuria in a Jamaican population exposed to cadmium through diet

16.00 Poster Mixer Session

17.30 Bus to centre of Nottingham for hotels

19.30 Conference Dinner at Las Iguanas in central Nottingham

Day 2: Friday 20th March

Bus to return delegates to BGS, leaving 8.45am from the Holiday Inn Express, pick up from Ibis (if staying at Jury's Inn please go to the Ibis for pick-up) on the way.

9.30 Opening address – Mark Cave

Session 3: Hazard and Risk Assessment – Session Chair Joanna Wragg

9.40 Paul Nathanail (University of Nottingham) – Bioaccessibility in human health risk assessment for regulatory purposes: Implications for the proposed Soil Framework Directive

10.10 Barry Smith (Intelliscience) - Risk assessment of technological materials:

the importance of medical geology in crossing disciplines

10.30 David Polya (University of Manchester) – Groundwater arsenic attributable health risks in West Bengal- Application of probabilistic risk assessment

10:50 Raquel Duarte-Davidson (HPA) - An overview of human health risk and exposure assessment training needs across the EU

11.10 Coffee

Session 4: Deficiency / Exposure Health Studies – Impact on Health – Session Chair Mark Cave

11.25 Andrew Hursthouse (University of the West of Scotland/ SEGH Chair) – Micronutrient deficiency in maternity and child health: exploring agricultural, medical and social influences on iron and zinc deficiencies.

11.55 Charles Shand (MacAuley Institute) – Could exposure to silt adversely affect early life respiratory health?

12.15 Shona Kelly (Division of Epidemiology and Public Health, University of Nottingham) – Is environmental arsenic associated with increasing basal cell carcinoma incidence in Britain?

12.40 Lunch

Session 5: Water, Air and Soil Quality – Session Chair Mike Watts

13.30 Mike Ellis (British Geological Survey) – Climate Change and its impact on Health

14.00 Alecos Demetriades (Institute of Geology and Mineral Exploration, Hellas) – Chemical speciation to assess bioaccessibility of potentially harmful elements in surface soil and house dust, Lavrion urban area, Attiki, Hellas

14.20 Nick Lloyd (Leicester University / BGS) – Environmental fate of depleted uranium particulates after 25 years: implications for bioaccessibility

14.40 Clemens Reimann (Geological Survey of Norway) – EGG: European groundwater geochemistry Part I: Mineral water

15:00 Coffee and general discussion – major themes

16.00 Close meeting

2.1 PLATFORM PRESENTATION ABSTRACTS

TC1 - The international development of medical geology - what will happen now and in the future?

Selinus O, Geological Survey of Sweden

KEYWORDS: Medical geology, metals, dust, education, diseases, earth and health

Medical Geology has grown rapidly in ten years. It brings together geoscientists and medical/public health researchers to address health problems caused by geological materials and processes. In January 2006 the International Medical Geology Association (IMGA) was established. Information can be found on the website http://www.medicalgeology.org. IMGA has organised itself in regional divisions all over the world and also chapters in several countries. Regular conferences have started, e.g. hemispheric conferences in South-Central America.

Medical geology is involved in promoting medical geology at meetings around the world by organizing and/or sponsoring special sessions or symposia on medical geology. Short courses have been presented in more than 40 countries and have been attended by thousands of students and professionals with backgrounds in geoscience, biomedical/public health science, environmental science, geography, engineering, chemistry, etc.

The lecture will bring to attention the activities going on now, e.g. local offices, new books and publications, international activities, education activities, new activities with ICSU etc. It will also analyse the future of medical geology.

TC2 - In-vivo validation of the Unified Barge Method for the bioavailability of arsenic, cadmium and lead in soils

Caboche J[1, 2] Feidt C[2], Tack K[1] and Denys S[1,*], [1] INERIS, Parc Technologique Alata, BP 2, F-60550 Verneuil-en-Halatte, France, sebastien.denys@ineris.fr, tel: 00-33-3-44-55-61-89; [2]INPL-ENSAIA-URAFPA, BP 172, F-54505 Vandoeuvre-lès-Nancy, FRANCE

KEYWORDS: Bioaccessibility, bioavailability, soils, arsenic, cadmium, lead

The Bioaccessibility Research Group, Europe (BARGE) has set up the unified Barge method (UBM) to assess the Human oral bioavailability of metals in contaminated soils. This protocol aims to measure the bioaccessibility using a two-step *in vitro* procedure. Acceptance of UBM by the regulators and the end-users should be based on three main criteria: repeatability, reproducibility and accuracy compared to the human physiology.

Here the last point was tested for two heavy metals (lead and cadmium) and one metalloid (arsenic). Fasted juvenile swine (human model regarding the digestion) were daily fed with 15 contaminated soils over 14 d. The swine were then slaughtered and hair, bone, liver and kidneys were sampled. Urine was also collected during the last two days of the exposure period. Concentrations of lead, cadmium and arsenic in the target organs and in the urine were measured to calculate the relative bioavailability (for a given target, soil: reference concentration ratio). For each element, the relative bioaccessibility (soil: reference concentration ratio in the digestive fluids) was also determined using the UBM.

For each element, significant relationships between relative bioavailability and relative bioaccessibility were obtained. This demonstrates the accuracy of the UBM to estimate the oral bioavailability of soil contaminants.

TC3 – Measurement, modelling and mapping of arsenic bioaccessibility in the Tamar Catchment

Cave M, Wragg J, Palumbo-Roe B and Klinck B, British Geological Survey, Keyworth, Nottingham UK m.cave@bgs.ac.uk

KEYWORDS: bioaccessibility, soil, arsenic, mapping, NIR, multiple linear regression model

Studies show that we ingest of the order 100 mg of soil per day from our local environment, maybe more for children playing in back gardens and playgrounds. In the UK, there are large areas that have relatively high concentrations of naturally occurring arsenic in the soil. Since arsenic is toxic to humans there is a potential risk to human health. Importantly, when a soil is ingested, only a fraction of the arsenic in the soil is mobilised in the human gut and passes into body (the bioavailable fraction). In order to assess the risk to human health we need to know the bioavailable fraction of arsenic in the soil. The Medical Geology Team has developed an informatic approach to measurement, mapping and modelling of arsenic bioaccessibility as a surrogate of bioavailability. The methodology has been demonstrated on the River Tamar catchment in the South West of the UK. Multi-variate statistical modelling of geochemical and near Infra-Red (NIR) data provided a robust model of arsenic bioaccessibility, which should be applicable to other geographical areas of the UK. A spin off of this methodology is that, using portable XRF and NIR instruments, there is the potential for real time on-site bioaccessibility screening.

TC4 - Human bioaccessibility of potentially toxic elements in urban soils from two European cities

Sialleli J and Davidson CM, WestCHEM, Department of Pure and Applied Chemistry, University of Strathclyde, 295 Cathedral Street, GLASGOW, G1 1XL, UK

KEYWORDS: potentially toxic elements, urban soils, bioaccessibility

Accidental soil ingestion can be an important route for exposure of humans, especially young children, to soil contaminants such as potentially toxic elements (PTE). In this study, a two-compartment physiologically based extraction test (PBET)[1] was used to estimate the human bioaccessibility of PTE in urban soils that had been previously collected from public-access areas in Glasgow, UK and Torino, Italy[2]. Soil extracts were analysed by inductively coupled plasma atomic emission spectrometry for chromium, copper, iron, lead, manganese, nickel and zinc.

Chromium, copper and iron showed generally greater bioaccessibility in the intestinal phase, whereas bioaccessible lead and zinc contents were usually higher in the stomach phase. Principal component analysis of data obtained for the Glasgow soils indicated that extractable concentrations of anthropogenic elements, i.e. chromium, copper, lead and zinc were highly correlated in the stomach phase, and to a lesser degree in the intestinal phase. Samples collected on roadsides exhibited generally higher bioaccessible PTE contents than those from parks and open spaces. The bioaccessibilities of copper, manganese and nickel were generally higher in the soils from Torino, whereas Glasgow samples exhibited higher concentrations of bioaccessible iron and lead. Bioaccessibilities for chromium and zinc were of the same order in both cities.

1. M V Ruby, A Davis, R Schoof, S Eberle, and C M Sellstone. *Environ. Sci. Technol.* 1996, **30**, 422-430

2. C M Davidson, G J Urquhart, F Ajmone-Marsan, M Biasioli, A C Duarte, E Díaz-Barrientos, H Grčman, I Hossack, A S Hursthouse, L Madrid, S A Rodrigues, and M Zupan. *Anal. Chim. Acta*, 2006, **565**, 63-72.

TC5 - Bioaccessibility of polyaromatic hydrocarbons from contaminated soils in a static and dynamic human gut in-vitro model

Van de Wiele T[1], De Groeve E[1], Harrison I[2], Vane C[2], Wragg J[2], Verstraete W[1], Cave M[2], Thomas R[3], Robinson J[3], Daly P[4], Nathanail P[5]. [1]University of Gent, Gent, Belgium; [2]British Geological Survey, Keyworth, UK; [3]Parsons Brinckerhoff, UK; [4]National Grid; UK, [5]Nottingham University/LQM, UK

KEYWORDS: Oral bioavailability, Aryl hydrocarbon bioassay, SHIME, FOREhST

Reliable bioaccessibility measurements may become important for risk evaluators when assessing the oral bioavailability of ingested soil-bound contaminants. Here, we describe bioaccessibility data for 11 polycyclic aromatic hydrocarbon (PAH) contaminated soils, as obtained from a static and dynamic *in vitro* digestion system of the human gut. PAH bioaccessibility showed a moderate to good correlation between both systems. Simulating a gradual gastric pH decrease and gradual intestinal delivery, the dynamic *in vitro* system generally (9 out of 11 soils) returned lower bioaccessibility values than the static one. The presence of a nutritional matrix returned higher bioaccessibility values, probably because of complexation with soluble organic components in the intestinal solution. In addition to bioaccessibility measurements, we used a bioassay to measure the affinity of 'bioaccessible' PAHs to bind the aryl hydrocarbon receptor (AhR). We found that the percentage of soil-bound PAHs binding the AhR was always lower than the bioaccessibility values obtained from either digestion model. We conclude that the static *in vitro* gut system is more suited for high-throughput screening, whereas the dynamic system represents a more realistic, but more elaborate method to measure bioaccessibility. In addition, the AhR bioassay proves a useful method to estimate whether bioaccessible PAHs can interact with a relevant receptor for oral PAH exposure.

TC6 - Model human digestive system for the determination of bioaccessibility of environmental pollutants.

Collins C[1], Tilston E[1], Tuohy K[2], Gibson G[2]. [1]Dept. Soil Science, University Of Reading, Whiteknights, Reading, RG6 6AW, UK; [2] *Department of Food Biosciences, University of Reading, Whiteknights, Reading, RG6 6AP, UK, c.d.collins@reading.ac.uk*

KEYWORDS: Bioavailability, PAHs, soil, microbially colonized colon

In the UK mathematical models such as the Environment Agency's 'Contaminated land exposure assessment model' are used to assess the risks to human health from soil pollutants. The models assume 100% bioavailability for all the contaminant to which an individual is exposed. This assumption might not be true because many soil contaminants form close chemical and physical associations with the organic matter and mineral phases of soil, potentially reducing their bioavailability to humans. In this research two established gut models: the British Geological Survey's model of the stomach and small intestine and the University of Reading's model of the colon were combined to develop a robust laboratory-based model of the gastrointestinal tract suitable for determining the bioavailability of polycyclic aromatic hydrocarbons (PAHs).

In order to produce a robust analytical system the laboratory model performance was tested under a range of conditions. These included; flow rate of nitrogen to maintain the system anaerobic and inclusion of active microbes in the colon. Nitrogen flow increased the losses of the more volatile PAH e.g. naphthalene, while microbes reduced PAH concentrations in the colon. Within the three components of the gut system the colon and the stomach were seen to have the most pronounced influence, but only the microbially colonized colon impacted PAH concentration in a closed system. Further investigation of the performance in-vitro gut system is required before it can be adopted in a regulatory role.

TC7 - Environmental and military depleted uranium aerosol pollution: health and exposure assessment in light of recent UK and US studies

Parrish R, Dept of Geology University of Leicester and NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham, UK, NG12 5GG

KEYWORDS: Depleted uranium, health, Gulf War Illness, Environmental Pollution, Uranium, urine testing

This talk will review recent research involving both a comprehensive programme of uranium isotope urine testing conducted in the UK on potentially DU-exposed military personnel, and research in the US on an exposed civilian cohort subjected to DU particulate aerosols arising from DU munitions manufacturing. Together the work shows that DU oxides arising from combustion result in very insoluble particulates, that DU from significant inhalation exposure can be found in urine more than 20 years afterwards, and that retrospective studies of the health of such exposed cohorts is possible though lacking. Research of this sort should be done to shed light on the health consequences of long term DU aerosol inhalation, but such robust scientific studies are so far lacking. The author recently testified to the US Congress on these issues, and the outcome of that hearing has resulted in a renewed call by the US Congress to conduct such work and reform the agency tasked with oversight of such issues, the Agency for Toxic Substances and Disease Registry.

TC8 - A geological re-evaluation of the Xuan Wei lung cancer epidemic

Large D[1], Somerfield C[1], Kelly S[2], Spiro B[3], Longyi S[4] and Tian L[5]. [1] Division of Fuel and Power Technologies, Faculty of Engineering, University of Nottingham Nottingham, NG7 2RD, UK; [2] Division of Epidemiology and Public Health, University of Nottingham, Queen's Medical Centre, Nottingham, NG7 2RD, UK; [3] Department of Mineralogy, Natural History Museum, Cromwell Road, London; [4] The State Key Laboratory of Coal Resources and Safe Mining and the Department of Resources and Earth Science, China University of Mining and Technology in Beijing, D11 Xueyuan Road, Beijing 100083, P.R.China; [5] School of Public Health, Chinese University of Hong Kong.

KEYWORDS: China, Xuan Wei, lung cancer, coal, quartz

Chinese health officials report that parts of Xuan Wei County (pop. 1.2 million), Yunnan Province, China have the highest known lung cancer mortality in non-smoking women with peak lung cancer mortality in women in Xuan Wei reaching $400/10^5$ up to 20 times mortality levels in the rest of China. This high mortality displays a clear spatial relationship to the mines producing coal from the uppermost Permian (C1) coal seam and epidemiologists have attributed this to two possible causes; high concentrations of PAH's or exposure to fine grained silica in the coal.

In this presentation we will demonstrate that the single geochemical property that makes this coal unusual is its high concentration of authigenic quartz (13.5 wt%) of which 35-55% occurs as <10μm grains. A person using 8 tonnes of Xuan Wei coal per annum would handle approx 0.5 tonnes of <10μm quartz. Furthermore we will propose a new method for assessing the combined influence of quartz and volatiles and use this as a basis for re-evaluating existing epidemiological data. Finally we will propose a mechanism linking the abundance of fine-grained authigenic silica to events at the Permo-Triassic Boundary, which occurs directly on top of the C1 coal.

TC9 - Human toenails as a biomarker of exposure to elevated environmental arsenic

Button M[1], Jenkin GRT[2], Harrington CF[3] and Watts MJ[1]. [1]British Geological Survey, Keyworth, Nottingham, NG12 5GG; [2]Department of Geology, University of Leicester, Leicester, LE1 7RH, UK; [3]School of Science and Technology, Nottingham Trent University, Nottingham, NG1 4BU, UK.

KEYWORDS: Biomarker, arsenic, speciation, exposure, soil

A pilot study was conducted to determine the applicability of toenails as a biomarker of exposure to elevated environmental arsenic (As) levels. A total of 17 individuals were recruited for the pilot study: 8 residents living near to a former As mine, Devon, UK, forming the exposed group, plus 9 residents from Nottinghamshire, UK, with no anticipated As exposure who were used for comparison as a control group. All toenail samples were thoroughly washed prior to analysis and the wash solutions retained for As determination via ICP-MS to provide an indication of the background environmental As levels for each group. Total As was determined in washed toenail samples via ICP-MS following microwave assisted acid digestion. Concentrations of total As in the toenails of the exposed group were elevated, ranging from 858 to 25981 µg kg-1 (geometric mean = 5406 µg kg-1), compared to the control group whose toenail As concentrations ranged from 73 to 273 µg kg-1 (geometric mean = 122 µg kg-1). Higher levels of exogenous As contamination were present on the toenails of the exposed group (geometric mean = 506 µg kg-1) compared to the control group (geometric mean = 4.0 µg kg-1) providing evidence of higher environmental As levels in the exposed group. Total As concentrations in toenail samples were positively correlated to environmental As levels ($r = 0.60$, $p < 0.001$). HPLC-ICP-MS analysis of aqueous toenail extracts revealed inorganic arsenite (AsIII) to be the dominant species extracted (83%) with lesser amounts of inorganic arsenate (AsV) and organic dimethylarsinate (DMAV) at 13% and 8.5%, respectively. Arsenic speciation in analysed toenail extracts from the two groups was comparable. The only notable difference between groups was the presence of small amounts (<1%) of organic methylarsonate (MAV) in two toenail samples from the exposed group. Toenails are presented as a viable biomarker of exposure at sites with elevated environmental As, such as the former mining sites found throughout Devon and Cornwall, UK.

TC10 - A novel field-based approach to assessing arsenic contamination in environmental and human samples from La Pampa and San Juan, Argentina

O'Reilly J[1], Watts MJ[2] and Ward NI[1]. [1] Chemical Sciences, Faculty of Health and Medical Sciences (FHMS), University of Surrey, Guildford; [2] British Geological Survey, Keyworth, Nottingham, NG12 5GG.

KEYWORDS: Arsenic, contamination, waters, hair, urine, Argentina

In recent years arsenic (As) has become a major concern in terms of its toxicological effects on humans and the environment. Studies are needed to help identify and quantify the levels of As that preside in the environment, particularly the more toxic As^{3+} species. Development of a field-based method utilising disposable Bond Elut SPE cartridges incorporating strong cation exchange (SCX) and strong anion exchange (SAX) phases for the determination of As^{3+}, As^{5+}, DMA and MA has been employed for natural water supplies in Argentina. This methodology enables the separation and preservation of As species in the field with subsequent elution and analysis in the laboratory.

Levels of arsenic reported in waters from two regions in Argentina (La Pampa and San Juan) ranged typically from 102 to 1364 µg/l (WHO drinking water level is 10 µg/l As), with an average of 76 % contributed by As^{3+}. Contaminated well waters provide a possible uptake of As into the local populace, potentially leading to chronic As poisoning. Therefore studies have been carried out on human samples (scalp hair and urine) to establish a link between the natural As levels and the current state of health. Human health, in regions like La Pampa has reported many cases of skin legions, pigmentation changes, hyperkeratosis and various forms of cancer associated with the consumption of this water.

TC11 - Beta-2 microglobulinuria in a Jamaican population exposed to cadmium through diet

Wright PRD, Lalor G, Rattray V, Hanson, R. International Centre for Environmental and Nuclear Sciences, Kingston, Jamaica.

KEYWORDS: Cadmium, renal, β_2-microglobulin, urine, survey, Jamaica

Soil surveys carried out by ICENS have identified elevated concentrations of naturally occurring Cd mainly in the bauxitic soils of Central Jamaica up to 100 to 1000 times higher than typical worldwide levels. Some food crops cultivated on these soils absorb significant amounts of Cd. Autopsy studies of kidney Cd concentrations confirm elevated human exposure and persons, long resident in Central Jamaica exceed the general population average by a factor of two. Diet studies have ascertained that a population in Central Jamaica is at risk of being exposed to Cd levels in excess of the PTWI set by the WHO. Elevated levels of U-Cd and β_2-M concentrations were confirmed with a strong correlation between soil Cd and the U-Cd. Also, higher β_2-M concentrations (>200μg/g creatinine) were found in the population with U-Cd concentrations greater than 2.5μg/L. While this identification is often taken to indicate impairment in the re-absorption capacity of the renal tubules leading to renal disease, there is no evidence in the mortality records of enhanced deaths in Central Jamaica compared with the general population, resulting from renal disease or diabetes related complications. The highest median age of death in the island is found in Manchester, the parish with the highest average Cd concentration. While we have identified a possible Cd linked renal dysfunction, significant indications of morbidity are not present in the general population. These data join others in literature that suggest that in some cases significant exposure to Cd may not lead to detectable morbidity in the population.

FC1- Bioaccessibility in human health risk assessment for regulatory purposes: Implications for the proposed Soil Framework Directive

Nathanail CP. University of Nottingham and Land Quality Management Ltd.

KEYWORDS: Bioaccessibility, risk assessment, soil framework directive, contaminated land, PBET

Bioaccessibility based surrogates of bioavailability have been used to in detailed quantitative risk assessment under both Part IIA of the Environmental Protection Act 1990 and for Planning purposes in the England and other parts of the UK for almost a decade. Other regulatory domains now embrace bioaccessibility testing as one of the lines of evidence to inform risk evaluation and characterisation. Despite understandable reticence from the Environment Agency, many local authorities have embraced the concept in their regulatory function. The draft Soil Framework Directive places the onus of defining unacceptable risk on individual member states. Various drafts of the text refer to [total] concentrations rather than bioavailable concentrations or effective doses. A truly risk based approach to the management of historically contaminated land is an essential prerequisite for sustainable development. Whether it is the PBET or the BARGE Unified Method, bioaccessibility measurements benefit from an understanding of the site-specific geological and industrial processes, geochemical speciation and likely land use patterns to provide robust risk evaluations. The new CIEH guide on regulatory review of risk assessment reports invoking bioavailability recognises this. As always, the "*numbers alone are not enough*".

FC2 - Risk assessment of technological materials: The importance of medical geology in crossing disciplines

Smith B. IntelliScience Ltd.

KEYWORDS: Uranium, tungsten, medical geology, bioavailability

The continuing development of technological materials and their introduction into the natural environment is often viewed purely from an "anthropogenic" viewpoint without much interaction with the natural sciences. This has been particularly evident in the development of concerns in respect of the military use of depleted uranium and in regulations dealing with the introduction of "new" formulations or engineered forms of naturally occurring chemical elements.

During this presentation I will draw from a number of recent developments in military technologies to emphasise the need for (a) the active involvement of the natural sciences in assessing the potential health and broader environmental implications of deploying these new technologies, and (b) the need for closer interaction between geological and medical sciences in conveying the science behind such assessments to politicians, decision makers and the public.

FC3 – Groundwater arsenic attributable health risks in West Bengal – Application of probabilistic risk assessment

Polya DA[1], Giri AK[2], Mondal D[1,2], Kundu M[2,1], Banerjee N[2,1], Banerjee M[2,1], Lawson M[1], Adamsom G[1], Rodriguez-Lado L[3], Hegan A[3,1], Hery M[1], Lloyd JR[1], Ballentine CJ[1], Ganguli B[4], Roy S[4], Chatterjee D[5], Boyce AJ[1], Bradford W[1], Hennerman K[6] and Majumbder S[5]. [1]SEAES, University of Manchester, M13 9PL, UK, david.polya@manchester.ac.uk; [2]Molecular and Human Genetics, IICB, Kolkata-700 032, India; European Commisio, JRC-IES, ISPRA, Italy;

[4]Dept. Statistics, Calcutta University, Kolkata, India; [5]Dept. Chemistry, University of Kalyani, Nadia, 741235, India; [6]SUERC, East Kilbride, G75 0QF, Scotland; [7]SED, University of Manchester, M13 9PL, UK.

KEYWORDS: Groundwater, arsenic, hazard, exposure routes, rice, genetics

We briefly describe the key elements of a probabilistic model being developed by UKIERI-funded PRAMA project to predict health risks attributable to groundwater arsenic, with particular application to West Bengal, India – one of the regions most impacted by the chronic usage of such waters for drinking, irrigation and cooking.

The model systematically considers groundwater arsenic hazard distribution, exposure routes and dose-response relationships for various arsenic-attributable health outcomes in human receptors. Key preliminary findings include: (i) although drinking water is the most important exposure route, rice is also a major exposure route that will not be diminished by mitigation measures, however effective, that are focussed solely on drinking water; (ii) genetic damage, shown elsewhere to be linked to higher cancer risks, are evident in arsenic-exposed populations that do not yet exhibit visible skin lesions; and (iii) certain genetic polymorphisms appear to be somewhat protective.

There exist, however, considerable data uncertainties, particularly in relation to dose-response relationships for drinking water arsenic much below 100 ng/g and how these are impacted by age, gender, genetics, nutrition and other social factors. Key model uncertainties include the possibility of future secular increases in groundwater arsenic and soil arsenic attributable to human activities – better understanding of arsenic biogeochemistry is required to assess these possibilities.

FC4 - An overview of human health risk and exposure assessment training needs across the European Union

Duarte-Davidson R. Chemical Hazards and Poisons Division (CHaPD) of the Health Protection Agency (HPA).

KEYWORDS: Risk assessment, training, quality, environmental pollution

The European Commission has identified as a priority the need to improve the availability of trained risk assessors to conduct consistent high quality assessments of health risks in accordance with EU policies and legislation and to serve on EU risk assessment committees. Current training schemes available across Europe are limited and lack opportunities to gain applicable practical training, which is a fundamental requirement for qualification in risk assessment. To address this gap the EC has funded a project, which aims to promote and facilitate risk-training initiatives and provide a comprehensive Risk Assessment and Management – European Training Programme (Risk ASSETs). This project will give special attention towards addressing the areas of toxicology, exposure assessment to chemicals and environmental pollution. The project will also build upon and take into consideration existing training programmes on risk assessment throughout the EU. This presentation will (i) provide an overview of Risk ASSETs to raise awareness of this initiative; (ii) provide an opportunity to discuss and take forward specific risk training requirements of the medical geology community; and (iii) discuss opportunities for collaboration.

FC5 - Micronutrient deficiency in maternity and child health: Exploring agricultural, medical and social influences on iron and zinc deficiencies.

Dickinson N, Gulliver J, MacPherson G, Atkinson J, Hursthouse A. University of the West of Scotland.

KEYWORDS: Micronutrients, malnutrition, iron, zinc, maternity, interdisciplinary, soil-plant-human transfer, GIS

Global food insecurity is associated with micronutrient deficiencies and it has been suggested that 4.5 billion people worldwide are affected by deficiencies in iron, vitamin A and iodine. Zinc has also been identified to be of increasing concern. The most vulnerable are young children and women of childbearing age. A project, funded through the UK's NERC managed E&HH has attempted to link the geochemical and agricultural basis of micronutrient supply through spatial variability to maternal health and associated cultural and social aspects of nutrition. The aim is to establish the opportunity for concerted action to deliver step change improvements in the nutrition of developing countries. A preliminary spatial evaluation is presented, linking soil quality, food production and the nutritional health, behavioural and cultural attitudes of women and children in two regions of southern Malawi. The particular emphasis of the study is on the multidisciplinary opportunities and the barriers to progress in development support in subsistence communities.

FC6 - Could exposure to silt adversely affect early life respiratory health?

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KEYWORDS: Asthma, soil, lung function, birth cohort

Asthma is a significant UK public health concern, affecting 5.2 million people and costing the economy £2.3 billion annually. It has been hypothesised that the recent increase in asthma is a consequence of improved early life hygiene and declining exposure to soil microbes passively carried into the home. We have investigated this idea by using postcodes to combine the National Soils Database with data from a well-characterised birth cohort (n=2000) recruited from NE Scotland.

Multivariable modelling with adjustment for known and potential confounding factors for asthma was used to relate soil properties in the location of the child's residence at the time of birth to respiratory data collected prospectively up to 5 years of age (n=1253). Soil variables included major exchangeable cations, heavy metals, nutrients, pH and size separates. Increasing silt content was associated with increasing likelihood of wheezing symptoms and doctor confirmed asthma by the age of 5 years. In addition increasing silt was associated with decreased lung function and increased markers of lung inflammation (exhaled nitric oxide) at 5 years.

Different hypotheses to explain the association of silt on early childhood respiratory health include mediation by microbes associated with silt and/or direct reactive effects of silt.

FC7 – Is Environmental arsenic associated with increasing basal cell carcinoma incidence in Britain?

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KEYWORDS: Basal cell carcinoma, skin cancer, arsenic, environmental health

Skin cancer is the most common cancer in humans, and incidence is increasing worldwide. Most skin cancers are non-melanoma skin cancer (NMSC); predominately basal cell carcinoma (BCC) and squamous cell carcinoma. Although UV light exposure is the main cause of skin cancer, animal models have shown that the combination of arsenic and UV produced larger and more numerous tumours than those caused by UV alone. Whilst a relationship between NMSC and arsenic in groundwater has been clearly demonstrated in some countries, this is unlikely to explain the increase in NMSC in Britain since water arsenic levels are monitored to protect public health. However BCCs have been seen in people exposed to chronic, low levels of arsenic from other sources and people living in areas with high soil arsenic have high levels in toenails. We therefore examined whether there was an association between soil arsenic levels and BCC rates in Britain. Using 11 health regions as a crude geospatial indicator, we noticed that BCC rates were greater in areas mapped with greater soil arsenic levels: namely, Wales, the South West and the Midlands. Arsenic is an established human carcinogen and these findings clearly warrant further investigation at a higher spatial resolution.

FC8 - Climate change and its impact on health

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KEYWORDS: Climate change, flooding, dust

Climate Change endangers health in fundamental ways it is not just an environmental issue it has the capacity to impact on the health of every individual on the planet. It will have an unequal impact on the world population and the greatest risks are to the poorest people. It will affect the basic requirements for maintaining health.

The key drivers identified by WHO for climate change effects on health are:

- Agriculture;
- Extreme weather events;
- Waterborne diseases;
- Heatwaves;
- Changing temperatures and rainfall patterns;

The BGS holds data resources and expertise which can be used to understand and predict how CC can affect the UK environment and impact human health. As an example, the mobility of PHEs has been shown, through international research, to be affected by events such as flooding, a phenomenon which may become more common with continuing climate change effects such as extreme flooding events. The land mass 'at risk' from such events is expected to substantially increase in size by 2050, requiring investigations into the managed sustainability of brownfield use, as many locations lie within current floodplains. The consequences of this could be increased mobility of PHEs such as arsenic leading to increased human bioavailability, increased plant uptake, potential ecosystem impacts and groundwater vulnerability.

BGS hold extensive geochemical survey data of UK soil which can be used to identify the locations of the most vulnerable areas, and can help to predict outcome of future flooding through an understanding of past flooding events (e.g in East Anglia and around the Wash).

FC9 – Chemical speciation to assess bioaccessibility of potentially harmful elements in surface soil and house dust, Lavrion urban area, Attiki, Hellas

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KEYWORDS: Chemical speciation, bioaccessibility, soil, house dust, Lavrion, Hellas

In the Lavrion urban area study, Hellas, a five-step sequential extraction method was applied on samples of soil (n=224) and house dust (n=127) in order to study the potential bioaccessibility of elements to plants, animals and humans, i.e.,

- exchangeable phase,
- carbonate phase,
- reducible phase,
- oxidisable phase, and
- residual phase.

On each of the five extractant solutions 22 elements were determined by ICP-AES, i.e., Ag, Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, La, Li, Mn, Mo, Ni, P, Pb, Sr, Ti, V and Zn.

To our knowledge this is the first study to analyse routinely such a large number of soil and house dust samples by a five-step sequential extraction method, and to present the multi-element results geographically. Inter-element relationships in each step were studied by means of boxplots, linear correlation coefficients, R-mode cluster and factor analyses.

The very low pH of gastric fluids (1-3), means that a greater proportion of element contents, present in soil and house dust, can be made available for absorption by the human body, i.e., even oxidisable element contents could be bioaccessible. Consequently, it is not surprising that children, and adults alike, have high blood-Pb concentrations and high urine-As excretions.

FC10 – The environmental fate of depleted uranium particulate after 25 years – implications for bioaccessibility

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KEYWORDS: Depleted uranium, uranium-oxide, mineralogy, particulate

Between 1958 and 1984, depleted uranium metal was processed at a National Lead (NLI) plant in Colonie, NY, USA. Combustion of scrap metal resulted in emissions of uranium particulate into the environment. Contamination is evident in a sediment core collected downstream of NLI. The ATSDR concluded that the inhalation of DU emissions from NLI could have increased the risk of health effects for Colonie residents. [1]

Uranium contamination was from aerial deposition of episodic stack emissions, prior to 1982 and dispersed by prevailing winds. Existing survey data have been interpolated and integrated to estimate 3.4 tonnes of uranium contamination within 1 km^2 of the plant [2]. Uranium isotope ratios from ICP-MS and LA-MC-ICP-MS reveal further details of the contamination footprint surrounding NLI.

Individual spheres of uranium-oxide, with diameters 30 - 60 μm have been isolated from soil and dust samples. These have been imaged and characterised by electron microscopy (SEM-EDX), and by X-ray absorption spectroscopy (μEXAFS). UO_2 particulate contamination survives in the terrestrial environment for more than 25 years. This is one of the least bioaccessible and most environmentally stable phases of uranium mineralogy.

1. ATSDR, *Health Consultation: Colonie Site.* 2004, Agency for Toxic Substances and Disease Registry: Atlanta, USA. p. 144.
2. Parrish, R.R., et al., *Depleted uranium contamination by inhalation exposure and its detection after ~20 years: Implications for human health assessment.* Science of the Total Environment, 2008. **390**(1): p. 58-68.

FC11 - EGG: European Groundwater Geochemistry Part I: Mineral Water

Reimann C[1], Birke M[2] and the EGG working group. [1]Geological Survey of Norway,7491 Trondheim, Norway; [2]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Postfach 510153, 30631 Hannover, Germany.

KEYWORDS: Mineral water, geochemistry, drinking water, action level, health

In Europe 1800 "mineral water" brands are officially registered and bottled drinking water and mineral water is in large parts of the continent rapidly developing into the main drinking water supply for the general population. Due to the wide geographical spread of the producers bottled mineral and drinking water can also be used for getting a first estimate of "groundwater geochemistry" at the European scale. The EGG working group has used its network to buy commercially sold water bottles from shops all over Europe. More than 1500 water samples were finally collected at the laboratory of the Federal Institute of Geosciences and Mineral Resources in Hanover, Germany and analysed for more than 70 parameters. The data set can be used to get a first impression about the natural variation of the determined chemical elements and additional parameters in groundwater at the European scale.

In the European regulations drinking water action levels as defined for water works supplying the general population with drinking water are expressively not valid for mineral water. This is due to the fact that mineral waters were originally marketed for medical purposes and not as "general purpose drinking water" (as they are often used today). If drinking water action levels are applied to mineral waters a substantial number of compliance failures are observed. The health implications of natural element variation in mineral waters replacing drinking water need political attention. Natural variation observed for most elements in the 1500 analysed water samples is large (several orders of magnitude for most elements). To protect the health of the general population variation of natural groundwater quality, including mineral waters, needs to be known and documented at the European scale.

2.2 POSTER PRESENTATION ABSTRACTS

P1 - Volcanic fluoride: bioavailability and risk.

Calkins J and Delmelle P. Environment Department, University of York, York, UK.

KEYWORDS: Volcanic, fluoride, bioavailability, fluorosis

Excessive exposure to natural fluoride (F) in drinking water creates an endemic health problem in many parts of the world. Volcanoes are inarguably a prominent natural producer of fluoride, constituting a steady or intermittent source of F emission and deposition into the environment. Direct links between volcanic fluoride in the environment and health are provided by consumption of water and food, inhalation of gas and particulates, and the incidental ingestion of soil and ash by children. However, the health risk posed by volcanic F is typically evaluated in reference to contaminated drinking water only, with little consideration for other exposure routes. Further, neither the environmental fate of volcanic fluoride nor factors affecting biological absorption are well-constrained.

Currently we are working to establish the parameters controlling bioavailability of volcanogenic fluoride in each exposure pathway. By performing synthesized gastric digestion on ash, soil, and water samples from fluoride-rich volcanoes, we have initial results of F dissolution and bioavailability in the human gut environment. These data permit improved evaluation of the relationship between exposure dose and absorbed dose (the absorption factor) of volcanogenic F, and are interpreted in light of the F geochemistry and mineralogy. This risk assessment method allows for a more precise hazard calculation.

P2 - Bioavailability of arsenic and antimony to earthworms in abandoned mining soils

Gál J, Hursthouse A, Cuthbert S. University of the West of Scotland.

KEYWORDS: Mining wastes, bioaccumulation, arsenic, antimony, earthworms, SW Scotland

The mobility and bioavailability of As and Sb to earthworm species (*O. cyaneum* and *L.terrestris*) was evaluated for soils at a former Sb industrial site (SW Scotland, UK). A comparison of chemical extraction and bioaccumulation factors was undertaken to assess the availability of As and Sb to earthworms. Pseudo-total (aqua-regia) levels of As and Sb in the soils varied between 12-25,300 mg kg^{-1} and 15-64,000 mg kg^{-1}, respectively. Both elements were associated with Fe (or Al) oxides/hydroxides via adsorption around silicate grains and occasionally with sulphide phases and significant portions of both elements are associated with phases which are sensitive to long term environmental change. High values of As and Sb in biota were recorded in the earthworms (960 mg kg^{-1} and 27 mg kg^{-1}, respectively) and SEM-EDX analysis of individuals revealed the presence of As in the crop, gizzard and intestines associated with S and Al. Bio-concentration factor values for both elements were below 1. Total and leached As levels in soils and earthworms were positively and very significantly correlated. Bioavailability of As for earthworms was shown to be limited by soil pH with weaker association for Sb and distinct species differences in accumulation.

P3 - Determining bioaccessibility / bioavailability of metal contaminants in soils

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KEYWORDS: Bioavailability, bioaccessibility, in vivo, in vitro, nickel, lead, copper

The transfer of soil-bound contaminants to mammals has been tested mainly *in vivo*, and the data suggests that bioavailability can be considerably less than indicated by chemical extraction. Relatively inexpensive *in vitro* methods that could predict relative oral bioavailability of matrix-bound metal contaminants could be useful in risk assessment, after validation against *in vivo* data. The objective was to use various *in vitro* and *in vivo* to estimate bioaccessible/bioavailable Cu, Ni and Pb in field-contaminated soils separated into several particle size fractions, and relate those estimates to soil mineralogy. Bioaccessibility of Cu determined by *in vitro* uptake did not vary among soils and among particle sizes, likely because of Cu homeostasis. Bioaccessibility and bioavailability of soil borne Pb and Ni varied among soils and particle sizes within soils. *In vitro* methods return similar estimates of bioaccessible nickel, and identified the same difference in bioaccessibility for Ni among particle sizes. *In vivo* studies of the soils demonstrated that almost 100% of the ingested Ni is excreted within 72 hours. As the oral RfD for Ni is based on $NiSO_4$ that was about 40% bioavailable in our study, there is potential for site-specific downward adjustment of oral exposure to Ni through ingestion of soil.

P4 - Evaluation of the physiologically-based extraction test for the analysis of polycyclic aromatic hydrocarbons in contaminated soils

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KEYWORDS: Physiologically-based extraction test (PBET), polycyclic aromatic hydrocarbons (PAHs), pressurised fluid extraction (PFE), gas chromatography mass spectrometry (GC-MS), contaminated soils

Polycyclic aromatic hydrocarbons (PAHs) are derived from a number of sources including anthropogenic (i.e. industrial processes and combustion of fossil fuels) or natural (i.e. forest fires, volcanic activity and geological sources). The 16 PAH priority pollutants are known for their carcinogenic effect and mutagenic characteristics. The total amount of PAHs on a contaminated land site in N.E. England have been determined using selective pressurised fluid extraction (PFE) with in-situ clean-up of extracts, followed by analysis using gas chromatography – ion trap - mass spectrometry (GC-MS). The environmental risk to humans from the contaminated site has been assessed using the physiologically-based extraction test (PBET). Initial work focused on the evaluation of recovering PAHs from aqueous matrices (water, gastric fluid and intestinal fluid) using a range of options that included liquid-liquid extraction (LLE), solid phase extraction (SPE), solid phase microextraction (SPME), and microextraction by packed sorbent (MEPS). Finally, a PBET approach was applied to the soils collected from a past-industrial site in NE England. The aim of this work is to establish the robustness of the PBET approach for the recovery of PAHs from contaminated soil.

Acknowledgement: Mr. P. Hartley (Newcastle City Council) is acknowledged for providing access to the site and valuable background information.

P5 - The bioaccessibility of metals in soil using a physiologically-based extraction test (PBET) and its role in refining human health risk assessment at a contaminated land site in NE England.

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KEYWORDS: Physiologically-based extraction test (PBET), contaminated soils, metals, microwave dissolution, inductively coupled plasma mass spectrometry (ICP-MS)

A former industrial land site has been evaluated for metal contamination. Selected samples were taken from the site and assessed for their total metal content using inductively coupled plasma - mass spectrometry (ICP-MS). Soil samples were initially prepared using an optimized microwave dissolution procedure. Of the range of metals potentially present at the site as a consequence of former industrial activity (As, Cd, Cr, Cu, Mo, Ni, Pb and Zn), the majority of top soil samples indicated elevated concentrations of one or more of these metals. A key assumption in evaluating human health risk using the UKs non-statutory Contaminated Land Exposure Assessment Model (CLEA) is that the contaminant ingested is taken up by the systemic circulation. Where the contaminant is present in an insoluble form, or strongly sequestered in the soil, then its bioavailability to the human body may be far less that a determination of total concentration suggests. Exposure to soil contaminants can be over- (or indeed under-) estimated if oral bioavailability is not taken into account. This paper reports on our approach to determine bioaccessibility of metals in soil using a physiologically-based extraction test (PBET) and highlights issues around the use of a single approach for assessing the bioaccessibility of a range of metals. Initial work evaluated the recoveries of metals from two certified reference materials; metal recoveries from the gastric, intestinal and residual fractions were compared with total metal values obtained using microwave dissolution and certificate values. The PBET procedure was then applied to soil collected at the site and implications for use in contaminated land risk assessment are considered.

Acknowledgement: Mr. P. Hartley (Newcastle City Council) is acknowledged for providing access to the site and valuable background information.

P6 - The solid phase distribution and bioaccessibility of arsenic, chromium and nickel in natural ironstone soils in the UK

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KEYWORDS: Soil, bioaccessibility, arsenic, chromium, nickel, solid-phase-distribution, ironstone

Jurassic ironstones were heavily exploited in the UK as a raw material for steel making up until the 1970s. The ironstones are sedimentary rocks containing more than 15% iron. The principal ironstones of economic interest in eastern England were the Frodingham Ironstone that outcrops around Scunthorpe and the Northampton Sand Ironstone outcropping further to the south. Sedimentary ironstones can be naturally enriched in arsenic (As) due to the abundance of iron-bearing minerals and especially iron oxyhydroxides that have a high affinity for arsenic. In addition, ironstone derived soils can contain naturally elevated concentrations of chromium (Cr) and nickel (Ni). This study examines the geochemical forms of the As, Cr Ni in selected soil samples in relation to their bioaccessibility to humans through the soil ingestion pathway and the uptake of contaminants through locally grown garden and allotment vegetables.

P7 - Radioactive pollution impacts on human health in Iraq

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KEYWORDS: Radioactive pollution, depleted uranium, human health, cancer

The impacts of the regional radioactive pollution across all of Iraq and the impacts of a domestic site pollution, 30 km West Mosul city at Northern Iraq, were highlighted in this study. The Depleted Uranium-DU weapons used against Iraq since 1991 to date, are the source of the regional radioactive pollution. The pollution rates were estimated using an international computer programme (LUDEP20) designed by FCRP for this purpose. The pollution effects on human health were reported not only in Iraq, but also to the surrounding countries, e.g. Kuwait. The authorized communities announced that thousands of tons of DU missiles were used in Iraq during 1991, and the rate increased several times in 2003. The data shows very high equivalent radioactive dose at the Battle Field which reach 62.7 mSv/y and then decreasing to 28.4 mSv/y at Basrah, 27.7 mSv/y at Zubair and 7.9 mSv/y at Safwan, in comparison with the international accepted level 1.0 mSv/y of ICRP.

While the domestic radioactive pollution was due to an accident case at U-Radioactive Waste Grave. This accident allows the release and distribution of radioactive waste material across an approximate area of 500m x 500m. The two events induce the air, water and soil environmental pollution. A total of 91 blood samples from persons (Male and Female) living near the domestic polluted site were analyzed to determine and calculate the White Blood Corpuscles-WBC, Hemoglobin Blood Concentration-Hb, Packed Cell Volume-PCV, Erythrocyte Sedimentation Rate-ESR and Platelets Count-PC. The results show significant abnormalities in the studied phenomena, which provides preliminary indication of the effect on human health and inducement of different types of cancers for many sensitive organs.

Mosul General Hospital information for the period from 1991 to-date, shows an abnormal increase in the number of cancer cases. The reported data for 45 affected organs show different ratios of response (%) to cancer. The number of organs affected by cancer and percent increasing during the period 1991 till 2008 are as follows: 10 organs 0%, 12 organs 50%, 10 organs 100%, 1 organ 200%, 4 organs 300%, 1 organ 400%, 1 organ 500%, 1 organ, 800% and 1 organ 6400%. The ratio 6400% is related to the skin cancer of the humans living in or around the polluted site. It is a very good indication for the radioactive air pollution in this site and around it especially for radioactive alpha particle emitters within waste DU compounds.

P8 - Multi-media biogeochemical mapping of the Czech Republic – Project CZ0074: creating base data for future geomedical and other research

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KEYWORDS: Czechia, biogeochemistry, mapping, forest, plants

Various geological, geomorphological and climatic conditions, together with the long-term effects of high deposition rates of atmospheric industrial emissions cause anomalies in element distribution in the landscape of the Czech Republic. Geological maps and figures depicting the location of highly industrialised parts of the country (so–called Black Triangles) illustrate these phenomena. Multielement analyses of some natural media (moss, forest floor humus, soil, etc.) carried out in the Czech national and international biomonitoring campaigns revealed previously unknown areas of elevated to very high accumulation of many elements, which are potentially toxic or hazardous, in the analysed samples. Examples are shown of isopleth maps of element concentrations in soil, forest-floor humus and feather moss from selected hot spots (e.g., around a lead smelter, stone-mill grounding stones from a former uranium pit, centre of high deposition of lithogenic elements caused by erosion of arable soil on Carpathian flysch, bioindicated position of hot spots for deposition loads of chosen elements, etc.).

A new biogeochemical project supported by grants from the EEA and Norway has been initiated in the Czech Republic. The project is aimed at a better delineation of zones of deficiency of biologically active elements and of hot spots of hazardous element accumulation, at an evaluation of direct and synergistic impacts in such effected areas and at help in controlling and planning the long-term land use in the Czech Republic. About 36 elements will be determined in soil, humus and plant samples collected in ca. 250–280 forest stands. There is no satisfactory knowledge of the distribution and effects of most of the elements under investigation in the landscape of the Czech Republic. Specific plant indicators of environmental contamination, mobility and accumulation of elements in the landscape will be used. Many new findings concerning the biogeochemical conditions of the Czech territory are expected. It is hoped that the geological, biological, environmental, meteorological and medical communities will make use of the new data of the regional distribution of chemical elements in a variety of different sample materials in their future research.

P9 - A preliminary investigation into possible relationships between environmental geochemical parameters and equine grass sickness in Scotland

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KEYWORDS: Equine grass sickness, trace elements, environmental geochemistry, soil

Equine grass sickness (EGS) is a frequently fatal neurological disease, which affects horses grazing fields in certain geographical locations. The aim of this study was to determine whether the geographical distribution of EGS cases in Scotland was associated with the presence or absence of particular geochemical parameters in the environment. A spatially referenced database of all EGS cases diagnosed at Edinburgh veterinary school since 01/01/1990 and two time-matched controls was produced. Environmental geochemistry data based on stream sediments were obtained from the British Geological Survey (BGS) Geochemical Baseline Survey of the Environment (G-BASE) project. Initial statistical interpretation compared the total geochemical concentrations at each location between the cases and controls. Consideration of the biological and environmental significance of the statistical results in conjunction with subsequent examinations of soil geochemical information (Macaulay Institute) suggested that further detailed, field scale investigation should concentrate on areas with: low cadmium, cobalt, copper, manganese, phosphorus and high selenium. Further investigation was justified for calcium, gallium, nickel, potassium and sodium. This scoping study provided a preliminary interpretation of possible relationships between EGS and geochemical parameters in an attempt to identify factors worthy of further investigation.

P10 - Selenium content of agricultural soils from Scotland

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KEYWORDS: Organic matter, K-feldspar, parent material, selenium deficiency, X-ray diffraction

Selenium is an essential element for human health. A decline in selenium intake by the UK population has occurred recently because of the replacement of American wheat by UK-sourced grain with a lower Se content. Because of this decline, there is interest in gaining more knowledge about the selenium status of Scottish soils. To test the hypothesis that the Se content of Scottish soils is related to the parent rock type, we analysed 47 agricultural soils, which had contrasting parent material. No significant relationship between the *aqua-regia* soluble Se contents of the soils and their mapped parent material was apparent but there was a positive linear correlation with organic matter content. To refine the mineralogical understanding the soils were quantitatively analysed by XRD. Partial least squares analysis of the mineralogical data revealed that the selenium content of the soil was best explained by a three–component model (R^2 = 71%) and was positively related to organic matter (β = 0.68), negatively related to K-feldspar (β = -0.26) with other minerals being less important. The negative link between K-feldspar and selenium in soils may be related to the tendency for K-feldspar to be most abundant in granite and other ‘evolved’ rocks.

P11 - Trace element abundance and human epidemiology in Northern Ireland – the Tellus case study.

Barsby AV[1], Ofterdinger U[2], McKinley JM[1], Young ME[3], Gavin ME[4]. [1]School of Geography, Archaeology and Palaeoecology, Queen's University, Elmwood Avenue, Belfast, BT7 1NN; [2]School of Planning, Architecture and Civil Engineering, Queen's University, David Kier Building, Belfast, BT9 5AG; [3]Geological Survey of Northern Ireland, Colby House, Belfast, BT9 5BF; [4]Northern Ireland Cancer Registry, Queen's University, Mulhouse Building, Belfast, BT12 6BJ.

KEYWORDS: Trace elements, cancer, geostatistics, geographically weighted regression

This project aims to explore the spatial correlation between selected trace element abundances in soil and surface waters as provided by the Tellus Project and spatial disease patterns in Northern Ireland (comprehensive data will be provided by Northern Ireland Cancer Registry). Northern Ireland and Tellus are an important test case, as Northern Ireland's complex geology is a microcosm for that encountered across the UK and Ireland, thus any correlations found may have implications outside of Northern Ireland.

The Tellus Project, managed by the Geological Survey of Northern Ireland is the most concentrated geological mapping project ever undertaken in Northern Ireland. Tellus data provides us with a comprehensive data set of the soil, stream sediment and stream water chemistry across Northern Ireland, sampled on a 2km² grid for more than 50 different parameters.

A literature review has been used to identify geo-chemicals of interest, and their spatial distribution has been explored using GIS and spatial statistics. The potential correlation between the two datasets is being explored using a variety of tools including, Geographically Weighted Regression and the DCluster package in the open source software, R with some preliminary results.

P12 - Soil and Human Health: The National Soils Inventory of Scotland

Hough RL, Shand CA, Avery LM, Campbell CD and Singh B. The Macaulay Institute, Aberdeen, AB15 8QH.

KEYWORDS: Spatial soils data, soil DNA, pathogens, essential nutrients, exposure

During 1978 – 1988, the Soil Survey of Scotland sampled 721 soils on a 10 km grid across Scotland as an inventory of our soil resource. We are re-sampling 25 % of the original locations on a 20 km grid during 2007 – 2009. These data provide vital information on the spatial distribution of chemical attributes, e.g. essential nutrients such as selenium, and other soil properties that may be associated with epidemiologic data (e.g. soil texture class and asthma).

We are also extracting DNA from soils to create a DNA archive. This will enable us to begin to examine the spatial patterns and associations with soil and land use of pathogens (e.g. enteric pathogens capable of surviving in the soil environment). Linking these data with soil characteristics, catchment hydrology and epidemiological data will aid our understanding of how these factors interact in terms of risk to human health.

Overall, the National Soils Inventory of Scotland provides a unique resource for investigating ecological associations between soils and health outcomes. Once hypothesis are formulated, further specific exposure assessments can link hazard to risk. For example, we are developing flow cytometric techniques to determine the effect of exposure to different particles on pathogen viability.

P13 - Field Based Speciation of Arsenic in UK and Argentinian waters

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KEYWORDS: Arsenic speciation, field preservation

The determination of individual inorganic and organic arsenic species is important owing to the variability in their toxicity, mobility and adsorptivity. A field method is reported for the speciation of arsenic in water samples that is simple, rapid and cost effective. The method utilises solid phase extraction cartridges in series for selective retention of arsenic species, followed by elution and measurement by inductively coupled plasma mass spectrometry for total arsenic. The method is suitable for on-site separation and preservation of arsenic species in water. Data is presented to demonstrate the influence of pH and competing anions on the retention of arsenic species. The cartridges were tested at a former mine site in South West England in La Pampa province of Argentina where waters were known to contain elevated levels of arsenic and challenging matrices. The mean recovery of arsenic species in UK mine drainage waters and Argentinian waters was 101 ± 16 % and 99 ± 15 %, respectively. Field speciation was checked using HPLC-ICP-MS, with arsenic species demonstrating good comparison between field and laboratory methods.

P14 - Environmental colloids and pathogens: A novel flow-cytometric approach to understanding their interactions in aquatic systems.

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KEYWORDS: Agriculture, colloids, E.coli, flow cytometry, pathogens, transport

Agricultural run off to surface waters in areas of intensive livestock farming can lead to problems in compliance with EU microbiological standards for bathing water quality. We do not fully understand the processes involved in transport to coastal waters and pathogen transport models often treat pathogens or indicator organisms as free-living cells. However, evidence suggests that enteric bacteria in aquatic systems tend to associate with sediment particles, in particular the colloidal fraction. While attachment to colloids may mediate transportability of pathogens, it is possible that exposure to environmental colloids could also influence metabolic characteristics of pathogens, affecting viability, longevity and infectivity. Thus, understanding the nature of bacteria-colloid interactions could provide significant insights into the pathway term of pathogen transport models and more broadly into the effects of exposure of pathogens to environmental colloids.

We report on a novel approach to characterising pathogen-colloid interactions, applying flow cytometry techniques to model colloid-*E.coli* systems in the laboratory to distinguish between colloid-bound and unattached particles. We demonstrate that changes in electrolyte concentrations can influence binding of *E. coli* to environmental colloids Preliminary data are presented and we discuss the potential human health implications of pathogen interactions with environmental colloids.

P15 - Fluoride concentration in the natural water system of parts of Northern Nigeria, West Africa

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KEYWORDS: Fluorosis, dental caries, alum

Northern Nigeria has a landmass of 692,768 km^2 and is home to more than three quarters of Nigeria's population. Most of this population live in the rural areas where access to potable water is very limited. As such the population relies heavily, for most water uses, on sparse groundwater supplies found in Precambrian Basement rocks and sedimentary formations of Cretaceous age. Dental fluorosis is a common phenomenon in many rural communities in northern Nigeria, and especially in areas underlain by Precambrian Basement rocks. Water samples for this study were obtained from the different sources including, wells, springs, boreholes and streams. Fluoride concentrations range from 0.06 to 7.72 mg/l, which in some cases exceeds the World Health Organization recommended limits for drinking purposes. Inhabitants in areas with fluoride content above the World Health Organization recommended limits show clear evidence of dental fluorosis, with most subjects being in the age group of 7 to 11 years. No cases of dental caries and skeletal fluorosis have been reported in any of these areas. However, with such high levels of fluoride, it is possible that people may be suffering from such diseases. Sources of fluoride released into the natural water system include fluoride-bearing minerals (biotite, hornblende, topaz and fluorite bearing veins which were mined in certain areas of Plateau State). The inhabitants of these areas have no alternative sources of water supply and are unaware of the cause of the coloured teeth. No simple and cost effective technique for removing the fluoride is in use by the inhabitants. The use of alum could greatly help in reducing the levels of fluoride by simple addition to the clay pot used as a storage container.

P16 - Ecosystems health: A case study of dental fluorosis in the Southern part of Zambia

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KEYWORDS: Dental fluorosis, drinking water, fluorides, hot springs, Zambia

A survey involving 128 pupils was conducted at a basic school in Southern Zambia to collect data on pupils backgrounds and their main sources of drinking water between birth and age 7. A dentist examined the pupils teeth and samples of drinking water were collected from locations where the majority of the pupils lived and measured for fluoride. Results of the survey showed a high significant ($p<0.001$) association between pupils sources of drinking water between birth and age 7 and the incidence of discoloured teeth. All pupils who drank water from the hot springs before age of 7 had moderate to severe dental fluorosis, while the majority (96.7%) of pupils who drank water from other sources had no dental fluorosis. Fluoride concentrations ranged from 5.95 to 10.09 mg/l in water from hot springs and 0.003 to 0.06 mg/l in water from other sources. Fluoride levels in water from the hot springs exceeded the 1.5 mg/l WHO guideline values for drinking water, while those from other sources were significantly lower ($p<0.05$). It was therefore concluded that the high prevalence of mottled teeth among residents of the study area is a case of dental fluorosis associated with drinking water from the hot springs containing high concentrations of fluorides.

P17 - Potential groundwater contamination around two industrial estates in South Western Nigeria

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KEYWORDS: Groundwater, contamination, trace elements, industrial estates

The study evaluated potential groundwater contamination with toxic metals in and around two industrial estates, namely Agbara and Ilupeju located in Ogun and Lagos in South Western Nigeria. The water samples were analyzed for pH and Total Dissolved Solids (TDS) whilst trace elements were analyzed by Actlabs of Canada, using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

The pH and Total Dissolved Solids (TDS) were found to be acidic / slightly acidic and freshwater except for one sample from Agbara which was saline. Water samples around Agbara and Ilupeju industrial estates showed a relative abundance of U>Zn>Ba>Sr>Cu>Te>Sb>W>Co and Zn>Mn>Sr>Cu>Pb>Bi>Ni>Sb, respectively for trace elements. Al, Cu, Sr, Sb and Zn were found in water samples around the two sites with ranges of (0.2 - 5.5 mg/l), (10 – 35 mg/l), (30 – 100 mg/l), (0 – 10 mg/l) and (45 – 964 mg/l), respectively. Pb, Bi and Mn were found only in water around Ilupeju Estate with average values of 45.2, 9.3 and 185 mg/l, respectively. Te, U, Ba, Co and W were found only in few water samples that were close to the effluent discharge within Agbara Estate with mean values of 20, 34, 23, 0.5 and 10, respectively. All of the trace elements were above both Nigeria and WHO recommended limits except for Zn and Cu, while Sr, Te, Co and W currently have no recommended limits, but were significant in the water samples measured.

P18 - The Simulation Geological for water shortage from Jifarah Plain Basin Northwest of Libya

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KEYWORDS: Water cycle

Libya is suffering from surface water supply shortage, due to a scarcity of rain and snow in Libya (1.700.000km) in which 95% is arid land. This study focuses mainly on Jifara blain basin with such a complicated geological formation higher to the south and lower to the north with an extreme seaward slope. This area was exposed to cleave movement resulting in two fractures. The first fracture runs north-east toward the Tunisian border as far as Jabal Abu-kirsh, the second fracture runs west and is named the greater Azizia elevate. Such movement led to the formation of three Rock units:

1-Mountain front sequence extending from homes to missiles to the west where it includes gargarish formation constituting sand lime sediments, such sediments formed water reservoirs of great subterranean water reserves.

2-Mountain front sequence extending east and west to Tunisian borders, this line of sequence includes Abu-gailan and Abu-shaiba covered by sand and limestone soil containing underneath lime sediments. It is around 700m above sea level and this formation also contains deep and wide gulfs, including Mjineen and Essirt valleys being the main feeder to most North West area.

3-Hadba surface sequences include the 4th era formations scattered in most edges and centre of the area with rock masses in which much low water exists. It is believed that such rock units moved back to its present place by reason of different erosion factors, the basin is believed to be covered by lime and sand rock that led to the birth of lime water accumulations reaching 2.4 x 1610 km^3. Most parts of this basin have been flooded by sea water during the Miocene and Oligocene resulting in the formation of rock hollows consisting of large quantities of water most of which are accumulated in the sea. It is estimated that there is a large water basin branching from Jifara plain and that the low level in the underground reservoirs is attributed to the low level of the north part of the basin where water flows from the south part towards the lower north part to flow into the sea water forming fresh water reservoirs. The 4^{th} era sediments are considered to have contributed to the basin surface and underground features formation during Holocene containing water carrying sediments such as quaser El-haj formation consisting of lime and grain rocks where reservoirs of Al-Azizia Abushaibs and Abu-Ghailan are located. Through this study we expect to find a trace of water flow from Jifara plain, towards the sea, through a hollow in its north part, this matter resulted in local severe water shortages.

In this study, it is proposed that 3D surveys be carried out in the basin to investigate the geological structure, which led to this natural phenomena resulting in deformation and the study of impact of the installation of water distillation units for the purpose of recharging underground water reservoirs.

P19 - Pollution risk of water quality on human and the aquatic life of Tigris River reach in Mosul City / Northern Iraq

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KEYWORDS: Pollution, human health, water quality, Tigris river, aquatic life, Iraq

A study of the water quality of the Tigris River over a 22 km length in Mosul city, Northern Iraq, was carried out in order to assess the chemical composition and suitability for human use and aquatic life. Laboratory analysis of 15 water samples from 5 sites within the river section , were performed in order to obtain the chemical compostion of Ca, Na, Mg, HCO_3, SO_4, Cl, NO_3, TDS and pH.

The chemical analysis of the water samples was compared with the standard guideline values as recommended by the World Health Organization (WHO) for human and aquatic life. Four samples from the right bank side and one sample of the left bank side (site 3) of the river have poor quality water. While the other samples from the left bank side and the deepest part of the river have high quality water.

The length of river under study is located in a high population density area which creates a large volume of liquid waste discharge into the river. Interpretation of the chemical analysis results in this study take into consideration the most potentially harmful chemical constituents of the water samples and their effect on human and aquatic life such as SO_4, NO_3, and Cl. The pH values were found to be slightly alkaline ranging from 7.5-8.0, with TDS ranging from 410–512 mg l^{-1}. The concentration of most ions increased in the flow of direction of the river, as a result of sewage water discharged into the river. The water in the right bank of the river has Ca-sulphate characteristics. A sulphate spring in this location is the main cause for the presence of high dissolved SO_4 and H_2S. High sulphate concentrations cause a laxative effect on the human system which may results in gastrointestinal irritation.

Sulphate concentration of the right bank (Site 3) exceeds the WHO standard for human and aquatic life of 250 mg l^{-1}. NO_3 concentrations on the left bank at sites (1, 2 & 3) are slightly higher than the permissible level of 40 mg l^{-1}. High concentrations of NO_3 in water samples (>10 mg l^{-1} ,WHO) is toxic and causes Blue Baby disease / Methaemoglobinaemia in children and Gastric Carcinomas.

In the future a complete study should be carried out including analysis of NO_2, Cu, Zn and Al to show the complete quality of the water. Considerable attention should be paid to future recreational uses of rivers and lakes for such purposes as swimming, fishing and for simple esthetical enjoyments. The variation in water quality is due to natural, agricultural, domestic and industrial inputs into the river.

P20 – The Chemistry and Risk Assessment of Mustard Gas Contaminated Soil

The Chemistry and Risk Assessment of Mustard Gas Contaminated Soil

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KEYWORDS:Chemical Weapons, Mustard Gas, Sulphur Mustard, bis(2chloroethyl)sulphide, Human Health, Risk Assessment

Sulphur Mustard, the major constituent of 'Mustard Gas', is a vesicant and genotoxic carcinogen which is simple, relatively volatile and which hydrolyses rapidly in water (t1/2 <10minutes) and yet it is still present in appreciable quantities in soil that has been contaminated for decades. This has in the past been attributed to the formation of 'sulphonium polymers' during incomplete hydrolysis reactions coating and protecting droplets of the agent, though there is little supporting evidence for this assertion and other potential mechanisms are also possible. Clearly, any mechanism of protection for the agent would also modify the exposure assessment at such sites. In the interim, Generic Assessment Criteria for the assessment chronic of risks at sites affected by Sulphur Mustard contamination have been developed using the CLEA v1.04 model released in January 2009 by assuming that the compound is freely available and unreactive in the soil in order to produce conservative assessments. The acceptance criteria indicate that the inhalation of vapour is potentially the most important exposure pathway; this is due in part to the much lower inhalation health criterion value for this pathway. Though vapour exposure has been dismissed in the past due to the assumed rapid hydrolysis in the soil, it would clearly be prudent to investigate the extent to which this assertion is true under field conditions.

3 Meeting Summary

The attendance of the meeting and the breadth the topics covered by the oral and poster presentations shows that there is a lively research community and interest in medical geology. A sign that medical geology, despite its interdisciplinary nature, is now coming of age is the emergence of taught courses and qualifications (TC1 and FC4). There is now a strong emphasis on the development of laboratory and field methods (e.g. TC2, TC3, TC5, TC6, P6, P3, P13) combining the geological/geochemical data with biomonitoring and clinical aspects to help quantify the potential hazard to human and animal health (e.g. TC7, TC9, TC10, TC11, P2, P7, P14, P15, P16, P17, P18). There seems to be a consensus that *in-vitro* tests for the bioaccessibility of inorganic contaminants in soil has reached a stage where the results can be accepted by national regulatory bodies (TC2) and work on organic contaminants is promising but still at an early stage (TC4 ,TC5, P4). There is a growing interest in epidemiological links between the natural environment and disease (FC7, FC8, FC9, P9) and in some instances there are surprising links, such as the silt content of soil and the respiratory health in young children (FC6). Risk assessments are an important tool for human health protection; examples from a variety of applications were presented (FC1, FC2, FC3, P1, P5, P19, P20). These are clearly benefitting from greater collaboration between disciplines and the newly developed tools for monitoring hazards. An interesting finding of many of the human health case studies is the need for a social science input to complement the hard science findings with the social and cultural aspects of the population being studied (FC5). Geochemical mapping continues to be a very important tool for health studies with a number of presentations illustrating hazard maps and spatial links between geochemistry and health (TC3, FC11, P8, P10, P11, P12).