environmental SCIENTIST

May/June 2003

In this issue:

Journal of the Institution of Environmental Sciences

VOL 12 NO 2

EDITOR: Robert Fuller • ASSISTANT EDITOR: Derek Hall • Established 1971 • ISSN: 0966 8411

forthcoming events CONFERENCES

3rd-5th September 2003
RGS-IBG Annual Conference 2003
The RGS-IBG, 1 Kensington Gore, London

For the first time the RGS-IBG international conference will be hosted by the Society in Kensington Gore, London. This location will provide greater opportunity to engage practitioners and policy makers with research agendas. The Society's research groups will continue to provide the intellectual core of the conference.

Theme: *Geography, serving society and the environment*

Plenaries:

- Globalisation
- Deprivation and Health
- Global London
- Geography and the Humanities
- Representation of the City and Creativity
- Global Change
- Geography and the Future of Education
- Environmental Governance
- EU Water Framework Directive
- Voices from Europe
- New Europe and New Geography

Further information: www.rgs.org/ACLondon2003 or email rhed@rgs.org

16th September 2003
The MRC Institute for the Environment and Health
10th Anniversary Open Seminar
Climate change in the UK: impact on environment and health
University of Leicester

£30 registration fee includes refreshments and lunch.

The IEH open meeting, supported by the Department of Health and the Department for Environment, Food and Rural Affairs, will address important questions about the environmental and health impacts of climate change in the UK. Following the launch in 2002 of the new 'Climate Change Scenarios for the UK' and publication of the 'Health effects of climate change in the UK' report, the seminar is very timely for the development of government policies.

The aim of the seminar is to explore the possible impacts of climate change and how these will affect the well-being and quality of life of the UK public. Recognising the interface between environment and health, an important aspect of the seminar will be to encourage discussion and debate between policy makers, researchers, the general public and other stakeholders on interactions between health and the environment in relation to direct and indirect effects of climate change.

Themes to be addressed:

- Historical perspective of climate change and future predictions
- UK ecology – phenology and biodiversity
- UK agricultural impacts – changing landscapes and practices
- Climate change and human health
- Stakeholder perception and communication
- Adaptation strategies
- Poster Session: participants are invited to submit titles for the poster session.

The closing date for registration is 15th August 2003. For further information contact: Seminar Administrator, MRC Institute for Environment and Health, University of Leicester, 94 Regent Road, Leicester LE1 7DD; Tel: 0116 223 1614 Fax: 0116 223 1601; Email: ieh@le.ac.uk; Website: www.le.ac.uk/ieh/

New IES address from 1st July:

The Secretariat, IES,
Suite 1, 38 Ebury Street,
London SW1W 0LU

Tel: 020 7730 5516
Fax: 020 7730 5519
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Contributions

The Environmental Scientist aims to provide a forum for members' contributions, views, interests, activities and news, as well as topical feature articles. Articles of up to 3,000 words should be submitted to the Editor, Environmental Scientist, PO Box 16, Bourne, PE10 9FB, three weeks prior to publication in the last week of January, March, May, July, September and November. Views expressed in the journal are those of the authors and do not necessarily reflect IES views or policy.

Advertising

Advertisements should be submitted to reach the Institution by the 7th of the month of publication. Rates: £50 (half page); £25 (quarter page); £12.50 (eighth page). Full page adverts at £100 can only be accepted under special circumstances, subject to space being available.

Published by The Institution of Environmental Sciences, Suite 1, 38 Ebury Street, London SW1W 0LU.
Tel: 020 7730 5516. **Fax:** 020 7730 5519.
Web Site: http://www.ies-uk.org.uk
Email: ies-uk@breathemail.net
Design and origination by Davies Communications, 020 7482 8844.
Printed on recycled paper by Uniprint Ltd, 36 Jaggard Way, Wandsworth Common, London SW12 8SG.

editorial FAREWELL AND GOOD READING

Having resigned as Hon. Secretary at the end of April (after nine years in post) and also as Membership Secretary from the end of June (after seventeen years in post), this will be my last Journal issue as editor. I will therefore take the opportunity to express my thanks to all those whose support and encouragement have made my work worthwhile.

To my colleagues on the editorial side and to Peter Singer, responsible for compositing and production since 1991, goes a big thank you. To the many committee and Council members over the years go my thanks for their co-operation and assistance. To all the members may I say how much I have enjoyed your interest and the opportunity to help you wherever possible. I shall be continuing as a member of Council and will be pleased, as ever, to continue to represent your interests at their debates. It would seem a pity to break a record of 100% attendance at Council meetings since February 1981! I shall also be continuing my work with the Society for the Environment through which the Institution hopes to obtain the right to award chartered status to qualified members.

Another voice that you will be missing is that of my wife Lynette. Since I took over as Hon. Secretary in May 1994 she has been responsible for the administration work of the Secretariat of the Institution. It is thanks to her industry and efficiency that our affairs have run so smoothly for so long and I am sure that there are many of you who have benefited from her friendly and helpful assistance. It is probable that the business of the Institution will be conducted in the future through our new office in Victoria.

On a slightly different note, apologies are due for the absence of a Journal issue at the end of April. This was mainly due to a re-organisation of the finances and forward spending commitments. Due also to a review of policy regarding publication, this is probably the last Journal issue in this format. Various alternatives are under consideration for the autumn. I am therefore including in this edition all the material currently in hand for publication. This includes, in the Education section, the two remaining papers by our prizewinners of 2002 of the John Connell Memorial Award.

I wish you happy reading!

ROBERT FULLER

feature ASPECTS OF CLIMATE CHANGE

M.R. PHILLIPS MIEnvSc looks at the consequences of climate change and management in the coastal zone

A major current environmental debate concerns climate change together with predictions of causes and effects (*Environmental Scientist*, 1999; Christy, 2001; Croner, 2001; *Nature*, 2002; Matthews, 2003). Some of these predictions, especially with respect to sea level rise, could have significant consequences for the future management of the coastal zone (Granja and Carvalho, 2000; Vilibic *et al*, 2000; Jensen *et al*, 2001; Rivis *et al*, 2002). Erosion poses a threat to all stakeholders and this will be further complicated by concerns over hard engineering sea defences (Basco, 1999; Wiegel, 2002). This could be worsened by sea level rise and the reduction of sediment supply associated with global warming and anthropogenic modification of rivers and coastlines (van der Weide *et al*, 2001). Policy and implementation are driven by socio-economic considerations but human activities are often in conflict with one another as well as with the long-term natural processes. Policies will therefore be suggested for the strategic management of the coastal zone from an overview of the climate change debate, predictions of sea level rise, technical responses and socio-economic considerations.

The climate change debate: an overview

It is generally accepted that on the longest timescale of Earth's geological history, trends in solar output have played a major role in shaping the climate (Kelly, 2000; Croner, 2001). Lassen and Christensen (1995) reported that they had examined all climate changes in the last five hundred years and found that they coincided precisely with changes in solar activity. Climate fluctuations are normal and have often been dramatic, switching between temperate eras and ice ages lasting thousands of years. Against this background of natural variation, the current

debates on global warming centre on predicted changes and human contribution to the process. The 1995 publication of the second climate assessment by the Intergovernmental Panel on Climate Change (IPCC), was the first IPCC publication to state unequivocally that human activities are having a discernable impact on the Earth's climate (*Nature*, 2002). However, there are complaints that uncertainties in the science had been played down and that there is a common reluctance to use probabilities in climate change research. According to Pearce (2000), the natural greenhouse gases in the atmosphere are being boosted by human activities whereas Christy (2001) argues that even with all our cars, factories and cities, human impact on the weather is too small to measure.

There is no easy way of predicting what future carbon dioxide levels will do to the atmosphere but nonetheless, the speed at which the carbon dioxide concentration is changing appears to be unparalleled in human history (Croner, 2001). However, low levels of carbon dioxide are associated with cold periods. When the ocean is cold, it can absorb more of the gas and conversely, during warmer periods, carbon dioxide is released and the atmospheric concentration rises. This has led to the argument that the warmer temperatures are the cause of the higher carbon dioxide levels rather than vice versa (Croner, 2001). There are considerable uncertainties surrounding the possible scale, timing and extent of climate change (Gurney, 1999), but there is mounting evidence that the climate is already changing (*Environmental Scientist*, 1999). Records show that 1997 was the third warmest year on record in the UK (1.1° C above the average between 1961 and 1990). Such a year would be expected once every 17 years but according to the UK Climate Impacts Programme scenarios, by the 2080s such years would occur with increasing frequency. Under a low scenario they would occur every two years and for the other scenarios nearly every year. Thus exceptional conditions are likely to become normal; a prediction possibly supported by the reporting of Matthews (2003) that, on a global scale, 2002 was the second-hottest year ever recorded.

Conversely, according to Matthews (2000) climate change was unsubstantiated and there was evidence contradicting the supposed link between global warming and the floods in the UK during the autumn of that year. He further argued that Britain's weather is naturally capable of much greater extremes than previously thought. This agrees with Christy (2001) who stated that evidence shows a climate of natural variability and that these variations have always occurred, even when humans could not have had any impact. He further argued that hurricanes and tornadoes are not increasing and that storms and droughts do not show any pattern of increasing or decreasing. It should be remembered that following general global cooling between 1940 and 1975, there were grim prophecies of a return of the glaciers (Berry, 1996) and many journals at that time contained articles predicting a new ice age. It seems that within a generation, environmentalists and climatologists have turned their attention from global cooling to global warming.

Currently the prediction of events involves the use of computer models, which simulate natural processes. Christy (2001) commented that he views computer models with a degree of awe and sense of humour and argues that as no computer model accurately portrays our current weather then how can they be trusted with the future? Matthews (2003) clearly shows the uncertainty in generating credible model-based projections of climate change whilst *Nature* (2002) highlighted that models simulating long-term climate changes have no comparable reality check. Berry (1996) viewed studies by computer models as often oversimplified and further argued that, as it is much easier to run a computer model than use studies involving rigorous observations of the real world, there is a great danger of bias in methods of study.

Sea level rise

Despite uncertainties in the climate change debate, there appears to be an international consensus amongst coastal scientists regarding the predicted increase of storm activity and sea level rise. Jensen *et al* (2001) reported that since about 1960, there had been an increase in frequency and duration of storm floods along the German North Sea coastline; Rivis *et al* (2002) stated that between 1948 and 1998 there had been a significant increase in storminess along the coast of Estonia whilst, Vilibic *et al* (2000), predicted that over the next century there would be an increase in storm surges in the Adriatic. Storm surges contribute significantly to beach erosion, leading to considerable damage of coastal infrastructure and such events will be exacerbated with current predictions of sea level rise. Crawford and Thomson (1999) reported estimates of sea level rise of between 3 to 9 mm/year for the next 80 years; Vilibic *et al* (2000) stated that there had been a mean rise of 180mm over the last century and that it was expected to be about 500mm in the next century; whilst Weihaupt and Stuart (2000) logically argued from implications of ancient maps that the mass reduction of the ancient Antarctic ice sheet could lead to the equivalent of a 4m rise in sea level. Although the time-scale for this change is not given, it would have severe implications for the low-lying coastal environments of the world and existing developments, constructed at or near sea level, will be at significant risk. Therefore, activities under threat will include conservation, industry, real estate and the economy.

Schroeder (2000) argued that although storms play a major role in shaping coastal environments, erosion does not generally result in detrimental impacts to unmodified areas and can often provide a net benefit. However, erosion and loss of the existing coastline due to climate change, could have major economic consequences. This is further complicated by coastal land having artificially inflated values from an anthropogenic perspective (Phillips, 2000). The *Environmental Scientist* (2000) reported that strengthening coastal and river flood defences could cost £1.2 billion over the next half century in England and Wales, with buildings and infrastructure identified as areas most likely to be affected. Granja and Carvalho (2000), highlighted problems of erosion on the northwest coast of Portugal; Gillie (1999) illustrated the consequences of erosion on the Victoria waterfront, British Columbia and SES (1997) identified erosion as a major issue for the sustainable management of the Severn Estuary. It will have a significant impact on tourism, which according to the World Tourism Organisation (2001) is the world's largest growth industry. Houston (2002) reported that travel and tourism is the United States' largest industry, employer, and earner of foreign exchange and that beaches were the major factor in tourism. He further identified beach erosion as the number one concern of Americans who visit beaches. With 33,000km of eroding shoreline and 4,300km of critically eroding shoreline, the US Army Corps of Engineers (1994) considered it a serious threat to tourism and therefore a major threat to the national economy. Consequently, sea level rise coupled with storm surges and high tides will pose severe problems for beach managers and coastal engineers.

Management of the coastal zone

The coastal zone has dynamically evolved from many natural and anthropocentric factors and processes. Developments such as ports have demonstrated the tension between cultural and physical environments (Cipriani *et al* 1999). According to Sauer (1963), integration of these factors is essential for effective management whilst Granja (2001) argued that it is important to understand not only present day factors and processes, but also those that have been active in the recent geological past. Integrated Coastal Zone Management (ICZM) is a cyclic process of problem recognition, planning, implementation and monitoring. The approach advocated by van der Meulen *et al* (2001), includes recognition of the country's institutional setting in terms of stakeholders and the respective mandate, capacity, commitment and financial potential. It is important to accept the differences amongst all stakeholders and understand potential conflict when deciding who has most rights. Policy and implementation will be influenced by strategic and socio-economic potential in conjunction with available techniques for defending the coastline. The cost and sustainability of technological solutions will be a critical factor as the use of seawalls to protect the coastline is now being questioned on the basis of cost and effectiveness (Bullen, 1993; Cipriani *et al*, 1999; van der Weide *et al*, 2001; Wiegel, 2002). Although Basco (1999) believes there are many misconceptions behind the perception that seawalls increase erosion and destroy the beach, alternative soft engineering techniques are now increasingly used in coastal management. Examples include groyne field techniques (Kunz, 1999) and beach nourishment (Cipriani *et al*, 1999; Benassai *et al*, 2001; Lupino and Riccardi, 2001; Micallef *et al*, 2001) which work in conjunction with natural coastal processes.

Granja and Carvalho (2000) highlight an objection to fundamental conservation and imply that it is unrealistic to believe that all coastlines can be conserved from impending sea level rise and subsequent coastal erosion. They suggest managed retreat and selective conservation of parts of the coast that are important to society and to use technological developments, where possible, to halt inland beach migration. Measures should be taken to attenuate or reduce the effects of erosion but where irreversible loss is evident, society must be persuaded to undertake a gradual and planned retreat from the waterfront. Beach management and sea defences can be justified on socio-economic grounds for a particular region and community, which depend on the beach, even though these may cause the acceleration of coastal erosion further along the coastline. Computer models such as Environmental Risk Assessment (ERA) (ABP, 1997) based on estimated probability values, can be used as management decision-making tools to evaluate appropriate mitigating measures and responses. These strategies for the management of the coastal zone agree with those generally suggested for coping with the negative effects of climate change. According to the *Environmental Scientist* (1999), they include prevention of loss, tolerance of loss and changing activities and location whilst the mechanisms to achieve these strategies include institutional, legal, financial and technological aspects.

Conclusions

The first section of this article noted that there is much uncertainty as to the causes, extent and consequences of global warming. A true consensus therefore, is still a long way off and as stated by Croner (2001), it is difficult to formulate precise policies to meet the consequences of climate change. With increasing computer processing power and more sophisticated modelling techniques, care must be taken to ensure that computed projections are

p22

feature THE M6 TOLL ROAD

TOM LAWSON outlines the environmental and ecological achievements of the new toll road

Construction of the new and controversial M6 Toll road (formerly known as the Birmingham Northern Relief Road or BNRR), the first toll road to be built in the UK, commenced during September 2000. This was six years after a prolonged public inquiry and two years after considerable protestor action along the route of the new road. The construction of the new toll road is the largest single construction project in the UK and consequently the potential exists for significant environmental benefits to be realised during the construction process.

The Design and Build contract was let to the CAMBBA Construction Group, the joint venture comprising four leading civil engineering companies, Carillion, Alfred McAlpine, Balfour Beatty and AMEC. The tender for the contract, let by Midland Expressway Ltd and valued at £485.5 million, was based on the outline design agreed following completion of the public inquiry in 1995. Midland Expressway Ltd has a 53-year concession agreement for the construction and operation of the new, privately financed toll road.

The construction of the M6 Toll includes 40 km of dual three-lane carriageway, widening of over 6 km of the existing M42 motorway, seven new junctions, more than 50 bridges, seven tolling stations, 60 gantries, over 150 km of drainage and over 80 km of cabling. The earthworks alone involves some nine million cubic metres of excavation and seven million cubic metres of fill, the balance of material being site-processed to produce over three million tonnes of aggregate for drainage stone and concrete production. Construction commenced in earnest after Easter 2001 and, after some 30 months' work (out of a 40-month construction phase) on site, the project is on target to meet the demanding programme.

There have been many published definitions of sustainability. In a major construction project such as the M6 Toll it may be defined as a process (or processes):

- to minimise the use of the earth's natural resources;
- to protect and enhance the local environment;
- to allow people to realise their potential and to learn from their experiences; and
- to minimise the impact of construction on the local environment.

The following provides an outline description of the environmental management during construction and describes the environmental benefits and achievements recorded by the CAMBBA joint venture to date, through the design and construction phases.

Environmental management

Environmental management on the M6 Toll is comprehensive. The joint venture has developed and operates an Integrated Management System combining Health and Safety, Quality and Environmental controls. The IMS is designed to meet the requirements of BS EN ISO 14001 and 18001 for environmental and health and safety management. It also includes a Quality Management System for the design management and construction of the M6 Toll, which has been assessed and registered by the British Standards Institute to BS EN ISO 9001:2000 standard. The effectiveness of the management system has contributed to the overall environmental successes of the project, particularly in minimising the impacts of construction of the local environment.

Early on and prior to construction commencing, a team of up to 60 archaeologists worked through all manner of weather conditions during winter 2000-01 to 'sterilise' the site of all archaeological remains. This phase of the works represented a significant risk to progress but with the adoption of a certification system and regular progress meetings between the construction teams and the archaeologists, construction works progressed virtually unhindered by the 40 archaeological investigations along the route. The extent of the archaeological finds surprised even the County Archaeological Curators. The results of the investigations were presented to the Institution of Field Archaeologists during 2002. Archaeological finds will eventually be returned to local museums for display. The way in which the archaeology was managed on the M6 Toll was a true success and it is anticipated that similar practices will be implemented on future major construction projects.

A similar certification system was used for the many ecological resources identified along the route of the new tolled motorway. Early translocations of ancient hedgerows and wet acid heathland have proven extremely successful. Some 3 km of ancient hedgerow were saved and over one hectare of wet acid heathland has been relocated to a safe area, away from grazing animals and on the boundary of an existing SSSI. The heathland is already showing signs of occupation by a variety of species of amphibians and invertebrates, only one year after its translocation.

So effective was the ecological certification procedure that CAMBBA can demonstrate that no harm has come to protected species or their habitats during construction works. On a 47 km long construction site, this alone is a considerable achievement.

Environmental improvement

Ecological improvement successes include the diversion of some 6 km of watercourses. The design for the watercourses was such that the use of structures was avoided and the extent of new habitats, particularly for water voles and white-clawed crayfish (both protected species) was increased. Many replacement ecological ponds have been built and the success of the vegetation translocation in these ponds is evident, with mature vegetation providing habitat for nesting birds less than one year after excavation of the new pond. Over 35 new ponds will be created as part of the scheme.

During the construction works, continuous monitoring and checking of sensitive areas prior to construction enabled a wide variety of animals and their habitats to be safely collected and relocated away from construction activities. A summary is presented in the table below.

In addition to the ecological works on site, CAMBBA, in consultation with English Nature and Sandwell Metropolitan Borough Council, 'donated' around 100 white-clawed crayfish to Ice House Pool, a pond located within a country park in the Sandwell Borough. Earthworks material has also been provided to assist Dudley Metropolitan Borough Council in the construction of a new badger sett complex in the Wren's Nest National Nature Reserve. These 'additional' habitats would not have been possible without the M6 Toll project or the assistance of the CAMBBA team.

All of the species relocation works were agreed with English Nature and the Environment Agency. CAMBBA obtained licences, where appropriate, for the relocation of protected species to safe habitats away from the construction works.

This planting season (October 2002 to March 2003) landscape planting commenced on the route of the M6 Toll. Almost one million new trees will be planted, plus around 80 km of new 'off-site' hedgerow. CAMBBA placed orders with nurseries during 2000 and the young trees are now being brought into the site and planted out on site as landscaping plots are completed and handed over to the landscape subcontractors.

CAMBBA entered into a further consultation process earlier on during the project and, with the agreement of the County Ecologists, English Nature, the Wildlife Trusts and the Environment Agency, made minor amendments to the planting specification to better reflect current practices on new mass planting. As part of this process, around ten new areas of wild flower planting were introduced into the M6 Toll landscaping. These will be sculpted and seeded during 2003. Species-rich grassland will also be introduced in some locations.

Animal(s)	Numbers Translocated	Notes
White-clawed crayfish	2,000	Many off site to Ice House Pool in Sandwell Metropolitan Borough
Swan Mussels	5,000	All during watercourse diversions
Bullheads (EC designated)	10,000	
Loach (EC designated)	300	
Other fish including stickleback, pike, roach, perch, tench, gudgeon and eel	1,600	
Water voles	7	Removed from burrows during watercourse diversions
Great crested newts	550	From Hanson's Quarry and Chasewater SSSI
Amphibians (non-protected, including smooth newts, frogs and toads)	over 4,000	From ponds and wetland lost to construction
Reptiles	150	From artificial habitats (piles of rubbish) around Chasewater SSSI
Birds (whitethroats, kingfisher, yellow hammers, chaffinches, pied wagtails, robin, great tits and pigeons)	100	Nest sites found during construction that were then protected during construction works.

External liaison

CAMBBA has continued to hold regular liaison meetings with the Environment Agency and also English Nature. These meetings have minimised the Agency's resources and focused mainly on design issues. Areas covered include consents under the Land Drainage Act (over 200 to date), groundwater protection, re-use of potentially contaminated land, waste management and ecological mitigation. CAMBBA has obtained a number of exemptions to the Waste Management Licensing Regulations (1994) for re-use of suitable materials. This has been used to great effect and even materials from a former unlicensed landfill site have been demonstrated to be suitable for construction use by utilising a 'source-pathway-target' type risk assessment.

Regular liaison also takes place with the six Environmental Health Officers whose districts or boroughs the new road passes through. CAMBBA's construction works are subject to Prior Consent issued under Section 61 of the Control of Pollution Act (1974). The requirements of these consents are communicated to the workforce via the Environmental Management System. CAMBBA employs a Community Relations Team, which proactively advises local residents of the construction programme. This is achieved by several means, including a 24-hour help-line, local leaflet drops, an excellent website, the issue of some 15,000 newsletters on a six monthly basis, by giving presentations and updates to parish councils, schools and local interest groups and even by personal contact with neighbours and nearby residents. The exceptionally low number of nuisance complaints to the Environmental Health Officers is testament to the effectiveness of these proactive measures.

Sustainable construction

At the onset of construction, CAMBBA's material engineers recognised the financial and programming benefits that could be realised by the reuse of recycled materials. Prior to construction, a series of exemptions were registered with the Environment Agency to allow the reuse of certain 'waste' materials. A summary of the materials re-used during construction appears below:

Around one million tonnes of imported materials (planings, recycled materials including crushed concrete and hardcore, inert excavated materials, mainly clays and silty sands, from construction sites). All imported material is subject to chemical testing to ensure suitability for use, the Environment Agency being notified of all imports of material to site.

Approximately 1.5 million tonnes of site-won aggregates have been processed in temporary washing and batching plants to provide materials for construction, including drainage stone, concrete aggregates and fine sand. A further 500,000 tonnes of material has been processed to form a cement bound material for use in road pavement construction.

Some 22,000 tonnes of pulverised fuel ash (PFA) has been used in concrete mixes. There are also quality benefits from using this 'waste' material, including less shrinkage cracking in concrete and an improved durability of the finished concrete product.

Some 5,000 cubic metres of vegetation have been mulched and mixed with topsoil. This has proven particularly beneficial to landscape planting as many of the soils along the route of the M6 Toll are sandy, relatively acidic and deficient of organic material.

Some 250,000 tonnes of U1/U2 material (i.e. material that is not suitable for construction under the Specification for Highway Works) has been segregated on site for reuse in permanent works. This was subject to a complex source-pathway-receptor analysis that took several months, but which ultimately saved approximately £750,000 in waste disposal costs.

The total impact on the cost savings has not been calculated as construction is still underway. Initial estimates suggest that the saving as opposed to using naturally arising materials could be in excess of £15 million.

The significant environmental benefit of this is that the site-based operations avoided the need to import over two million tonnes of raw materials to the construction site. The reduction in the impact on the already-congested local road network is considerable.

Sustainable drainage systems have been designed for the new M6 Toll motorway. These include sealed drainage systems though sensitive areas, above ground pollution interceptor devices, wetland treatment areas and discharge via 'soft' outfalls to watercourses. Emergency pollution control devices have been incorporated into the entire motorway drainage system. At junctions with existing side roads, drainage systems have been replaced and upgraded to improve the quality of runoff leaving the side roads.

By continued consultation with the Environment Agency and English Nature, new and replacement watercourses have been created that do include habitat creation (water vole, white-clawed crayfish), do meander and change in bed level, do not incorporate 'structures' and do not contain concrete lined sections, thereby allowing these new watercourses to regenerate naturally, with the best possible start after their construction.

An environmental success?

In terms of ecological benefits, the following may be said.

The ecological certification procedure has proven extremely effective and no harm has come to animals or protected habitats during construction.

There is a significant increase in woodland areas,

p26

EMISSION-FREE HYDROGEN PRODUCTION

PROFESSOR RICHARD CLEGG
of BNFL looks forward to the possibilities offered by a hydrogen-based economy

Approximately 70% of our planet's surface is covered by water. It is one of the most abundant compounds found on this planet. Civilisation and indeed our very own existence is linked inseparably with the need for water. In whatever form – be it drinking water, rain water, sea water or river water – it is essential to our survival. The impact that water has on this planet must also be factored into the current debate on climate change. CO_2 emissions from our burning fossil fuels such as coal, gas and oil are causing irreversible damage to our planet and this is affecting our dependence on water in many ways. Causes for concern are that climate change is speculated to lead to increased sea-levels, greater rainfall is some areas and a lack of rainfall in others; there are unlikely to be any benefits. Almost all environmental groups and NGOs recognise climate change as our most important and pressing environmental challenge. In other ways water potentially offers solutions to climate change through its utilisation as a renewable energy source in the form of wave power, hydro-thermal, hydro-electric and barrages.

Water, which almost everyone knows is made up of hydrogen and oxygen, is also at the heart of another solution to the issue of climate change that is referred to as the hydrogen economy. Hydrogen can be burned to produce power with only water as a by-product with no damaging CO_2. It can also be used to produce both heat and electricity and it can deliver more energy per unit mass than fossil fuels.

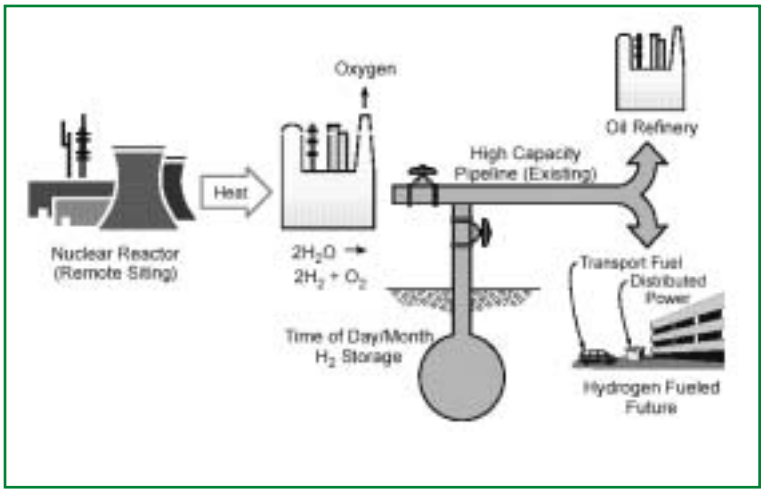
It is possible to utilise hydrogen in this manner through the fuel cell technology that was originally developed as part of the space programme. A fuel cell is an electrolytic cell that allows hydrogen and oxygen to be reacted together to produce electricity. This technology is already proven and 'fuel cell batteries' are available. Indeed motor manufacturers are already developing hydrogen powered cars, and mass production seems possible within the next decade. Compared to conventional batteries, fuel cells have the potential to be lighter, more compact, more efficient and generate greater quantities of electricity for longer.

Hydrogen fuel cells are therefore a potential new means to power transportation. The UK's annual energy consumption for all transportation is equivalent to 55 million tonnes of oil. This makes up about 35% of the total energy demand for the UK. Given that roughly 98% of fuel used to power transportation at the moment is fossil fuel based, this has an enormous impact on CO_2 emissions. Whilst the mechanisms to reduce CO_2 emissions and our dependence on fossil fuels focus on the electricity generating industry, it is important that we do not lose sight of the importance of addressing the significant impact the transportation sector has on CO_2 emissions.

Given that hydrogen can also be readily transported through pipelines as well as stored in batteries, the potential for hydrogen to power domestic and industrial energy needs is enormous.

Unlike fossil fuels, molecular hydrogen (H_2) that is needed for fuel does not exist in nature, it needs to be manufactured. Fortunately all that is needed is water (H_2O) and a power source to convert it to hydrogen (H_2) and oxygen (O_2). Without any intermediate stages, the conversion process would involve significant heating of water to 2500°C such that it breaks down into H_2 and O_2. This is too high a temperature on which to base an industrial process, and so the search is on for other routes that are more viable.

Currently, virtually all hydrogen (97%) is generated through steam reformation of natural gas. The heat to drive the reaction (typically 900°C) is produced by burning part of the natural gas feedstock that yields H_2 and CO_2 as products. There is of course additional CO_2 generated from burning the natural gas. Thus, from a greenhouse gas perspective, there is not much to be gained from the hydrogen economy via this route given the by-product is CO_2 and the resource utilised is natural gas. Any CO_2 emissions saved in the swings of hydrogen use are lost in the roundabouts of the CO_2 emissions generated during its production in this way. The alternative is to use a heat mechanism that does not



generate CO_2 emissions. Unfortunately renewable energy sources such as wind, wave and solar don't generate high temperature heat as part of their generation process.

A study from the US gave the feeling for the scale of things involved. In 1997 the number of miles covered by vehicles totalled 2600 billion miles. Assuming that 0.013kg of hydrogen is required for every mile driven, then 240 Gigawatts of new electrical capacity would be required to generate the hydrogen needed to power this transport. That capacity is almost four times the generating capacity of the UK. Assuming that wind-power is used to generate this electricity and that a typical windmill has an electrical capacity of 0.0015 Gigawatts with a footprint of 70 acres, to generate 240 Gigawatts of electricity would require 640,000 windmills with an area occupying 71,000 square miles, a significant fraction of the total land area of England. For biomass, the US farming output would have to be increased by a factor of four and solar would require 3000 square miles of photo-voltaic panels. By comparison, therefore, perhaps the best means for generating hydrogen without contributing to CO_2 emissions is nuclear power where each unit typically generates 1 Gigawatt.

Nuclear reactor systems all provide virtually carbon free energy which could be used to generate hydrogen. However, High Temperature Gas Cooled reactors (HTR) are particularly suited to the hydrogen economy, because these produce heat at around the desired 800 to 900°C. Whilst these were developed almost 50 years ago in the UK, USA and Germany, the Light Water Reactor design based on Westinghouse and General Electric technology took precedence. Recently there has been renewed interest in HTR technology in Japan, South Africa, US, France and China. This interest is mainly due to the improved safety, operational, environmental and economical benefits these designs can bring. Indeed South Africa is currently developing the Pebble Bed Modular Reactor (PBMR), which is based on a modular design and is therefore also suitable for delivering power to locations that do not have a well developed electricity distribution infrastructure. Whilst new developments in HTR technology are at the demonstration stages Japan have already built a working HTR system that they plan to link to a steam reforming process for hydrogen production in 2008.

The high temperatures available from HTRs are particularly well suited to the Iodine-Sulphur (I-S) thermo-chemical process for generating hydrogen. The whole process consumes only water and high temperature heat (roughly 800°C) and releases only hydrogen, oxygen and low temperature heat. Research on this process is being carried out in Germany, Japan and the US. The most advanced application of the process is at Japan Atomic Energy Research Institute where a pilot-scale facility is to be linked to their HTR to demonstrate the process is under construction.

At present there are a number of international developments in the design of new reactor systems for use with the hydrogen economy that meet the ever tightening constraints of safety, economic, security, and environmental impact. The US is leading the Generation IV initiative which involves a number of the committed nuclear countries such as Japan and France who are demonstrating foresight over the importance that nuclear will play in the 21st century. The Generation IV initiative aims to develop through international collaboration nuclear reactor systems that will meet sustainable development targets.

However, the UK is not as committed as many other countries to future nuclear technology and only operates at the periphery of this research. Whilst other nations are taking the hydrogen economy and benefits of nuclear power seriously, the UK lacks a joined up approach and relies on a downsized nuclear industry to supply both the resource and the people. This is unfortunate given the lead the UK once had in such technology. Unless the UK is involved in current international efforts it will be excluded from benefiting from the developments. This means that at the very least, in ten years time we may have to import the technology, at the worst we would no longer be a world leader in international policy. The UK has already has a close association with water being an island nation; we now have the opportunity to lead the world in the utilisation of water through the development and deployment of the hydrogen economy.

◆ This is the text of a presentation made to the House of Commons Parliamentary and Scientific Committee on 9th December 2002. Reprinted from *Science in Parliament* Vol. 60 No.1 Spring 2003 by kind permission of the publishers.

NITROGEN DIOXIDE INSIDE A MATERNITY UNIT

DAVID HOLMES MIEnvSc compares

Nitrogen Dioxide concentrations inside and outside a maternity unit

Introduction

In November 2001 a rural district council published its Third Stage Air Quality Review and Assessment Report – Consultation Draft. This report marked the final stage of a series of reviews and assessments of air quality under a process known as Local Air Quality Management. The Local Air Quality Management process involved examining seven air pollutants against objectives or targets set in the Air Quality Regulations 2000 and the National Air Quality Strategy.

The Reviews and Assessments identified that for the vast majority of the district the objectives would not be exceeded for these air pollutants. In the main town, however, a limited number of areas have been identified as being at risk of exceeding the annual mean objective for nitrogen dioxide. These areas include the main A-road network passing close to a District Hospital.

Concerns were expressed that there appeared to be exceedences at the Maternity Unit, a location that might be considered particularly sensitive in view of the presence of very small and premature babies. These concerns were increased when information provided by the District Hospital indicated that there was a Special Care Baby Unit on site. This unit cares for very sick and premature babies, and unlike the normal maternity wards where the stay is for only a couple of days, babies could be in the Special Care Baby Unit for a number of weeks, increasing their exposure to air pollution at a vulnerable time.

The health impacts of nitrogen dioxide

Nitrogen dioxide is an air pollutant which is associated with effects on health, especially at very high concentrations. At lower concentrations it has been suggested that the gas may have both acute, short-term and chronic longer-term effects on health (EPAQS). The mechanism by which it causes damage is likely to be related to its properties as an oxidising agent that can damage cell membranes and proteins (EPAQS).

Asthmatics are more sensitive to nitrogen dioxide than non-asthmatics (WHO) and children living in homes with gas cookers have been shown to have increased risk of respiratory infections compared to those with electric cookers (WHO), gas cookers being a significant source of indoor nitrogen dioxide.

Despite contacting the local health authority, Department of Health and the Building Research Establishment, we have not been made aware of any studies specifically on the effects of nitrogen dioxide on very young children and babies. It may be the case, however, that very young and premature baby could be especially susceptible to nitrogen dioxide due to very immature and developing respiratory and immune systems. The International Programme on Chemical Safety (World Health Organisation United Nations Environment Programme and International Labour Organisation) has published a comprehensive report into nitrogen oxides. This observes that there is little research into the effects of nitrogen dioxide on very young children and babies. Studies on children have tended to be on older age groups, i.e. older than five years. The report identifies that some studies have shown that small increases in respiratory diseases have been observed in children whose bedrooms have tended to have higher nitrogen dioxide concentrations. The report also identifies some evidence that early respiratory illness, which may be associated with nitrogen dioxide exposure, may be a risk factor in later lung damage

The sources of nitrogen dioxide and the current air quality objectives and standards

In high temperature combustion nitric oxide gas is produced by the reaction of nitrogen and oxygen. Nitric oxide is converted to nitrogen dioxide in the atmosphere by combining with ozone. The sources of nitrogen dioxide include road vehicles and industry. In many urban areas, most nitrogen dioxide in areas close to roads is the result of road vehicle emissions.

The Air Quality Regulations 2000 set outdoor air quality standards for nitrogen dioxide, for areas where people may reasonably be expected to be exposed. These are a one-hour mean of 105-ppb (200 µg/m^3) not to be exceeded more than 18 times per year, and an annual mean of 21 ppb (40 µg/m^3). Except where close to a few industrial sources or extremely busy roads, monitoring has shown that it is most unlikely that the one-hour mean objective would be exceeded. However, many local authorities have identified that exceedences of the annual mean are likely in proximity to busy roads.

There are very few standards or objectives for indoor air quality, especially in relation to non-occupational exposure such as for young children. The Health and Safety Executive publishes occupational exposure standards which are mandatory in workplaces (HSE). These are a long-term exposure limit (8 hour time weighted average) of 3 ppm, (5700 µg/m^3) and a short-term exposure limit (15 minute) of 5 ppm, (9600 µg/m^3). These standards do not relate to longer-term periods such as over a period of weeks and assume exposure by a

healthy adult rather than a group who could be especially susceptible.

The hospital site

The District Hospital is situated close to a junction of two busy A-class dual carriageway roads. At this junction the roads meet on an inner ring road at a roundabout known as Hospital Roundabout. Traffic flows in 1997 were 35,000 and 23,610 vehicles per day on the roads respectively. There is additional local traffic using the access road to the hospital, the hospital car park and from vehicles in nearby residential streets.

The hospital site also includes a large boiler plant used for heating, hot water and steam generation, as well as emergency back-up generators. The boiler plant is gas-fired and may contribute to local nitrogen dioxide concentrations. Emissions from the plant are via a nearby chimney which is approximately 32 metres high, some 20 metres higher than the top of the nearby maternity unit.

The maternity unit is to the south east of the main hospital site in a building shared with the women's hospital. On the ground floor are the reception area and consultation rooms; the top floor houses the delivery suites. The Special Care Baby Unit is situated on the second floor of the four-storey building at the western end of the building (i.e. the end furthest from the nearby road). The building is situated on a lower area of ground than the boiler house.

The Special Care Baby Unit is ventilated mechanically and has no opening windows. The intakes are situated on the rooftop.

Monitoring methodology and locations

Methodology

The survey was carried out using diffusion tubes. These tubes are a relatively simple and inexpensive method of monitoring gaseous pollutants. The nitrogen dioxide tubes are plastic tubes approximately five centimetres long which contain a material which specifically absorbs the gas under investigation. The tubes are placed at suitable locations for a known period. Once removed from site they are analysed by a laboratory, with the amount of pollutant absorbed compared against the exposure period of the tube to give a mean for the period.

The tubes are normally positioned as close to adult head height as possible but in out-of-the way locations so as to avoid disturbance. Sources of possible interference such as ventilation or central heating boiler plant outlets are assessed when the monitoring sites are selected.

Locations

Four diffusion tubes were located outside the maternity unit to provide indications outside the unit. All the sites were at ground floor level. Inside the unit one diffusion tube was located at the reception area on the ground floor, while two tubes were located at the nurses' station in the centre of the Special Care Baby Unit on the second floor.

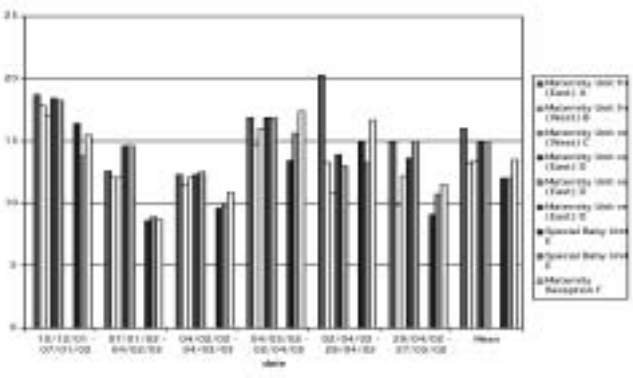
At one outdoor location and in the Special Baby Care Unit duplicate tubes were used to provide an indication of reliability. A blank control tube (i.e. unexposed) was used to check for any contamination of the tubes.

To assess the accuracy of the diffusion tubes, three tubes were co-located with the real-time oxides of nitrogen analyser situated elsewhere on the hospital site. This enabled any significant under- or over-read (bias) by the tubes to be calculated and corrected.

Results

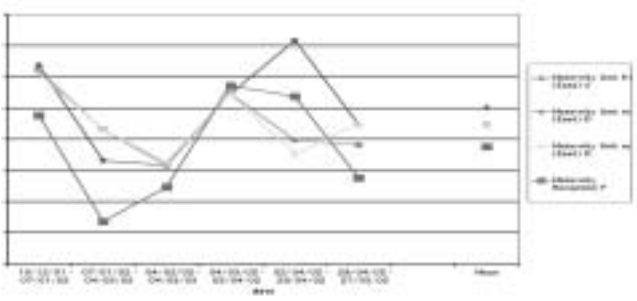
Table 1 (opposite) shows the results, corrected for bias using the tubes co-located with the real-time analyser.

Graph 1: Corrected results for each month



The results show that outdoor concentrations are higher than indoor concentrations, with concentrations being greater at those locations closest to the nearest A road.

Graph 2: Maternity reception compared with outdoor concentrations

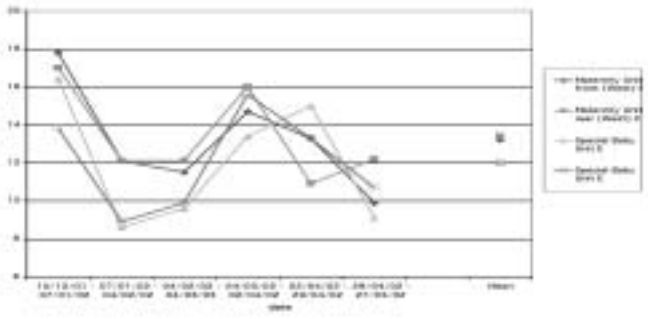


The results at the maternity reception and the closest monitoring points have shown that indoor concentrations are 1.5-2.5 ppb lower than the outdoor concentrations, at ground level.

Table 1: Diffusion tube concentrations in parts per billion

Site	10/12/01 - 07/01/02	07/01/02 - 04/02/02	04/02/02 - 04/03/03	04/03/02 - 02/04/02	02/04/02 - 29/04/02	29/04/02 - 27/05/02	Mean
Outdoor sites							
Maternity Unit front (East) A	18.7	12.6	12.3	16.9	20.3	14.9	16.0
Maternity Unit front (West) B	17.8	12.1	11.5	14.7	13.3	9.9	13.2
Maternity Unit rear (West) C	17.0	12.1	12.1	16.0	10.9	12.2	13.4
Maternity Unit rear (East) D	18.4	14.6	12.3	16.9	13.9	13.6	14.9
Maternity Unit rear (East) D	18.2	14.6	12.5	16.9	13.0	15	15.0
Indoor sites							
Special Care Baby Unit E	16.4	8.6	9.6	13.4	15.0	9.1	12.0
Special Care Baby Unit E	13.8	8.9	9.9	15.6	13.3	10.7	12.0
Maternity Reception F	15.5	8.7	10.9	17.4	16.7	11.5	13.5
Blank	0.0	missing	0.0	0.0	0.0	0	0.0

Graph 3: Special Care Baby Unit compared with outdoor concentrations



In the Special Care Baby Unit concentrations were lower than at the maternity reception; this may reflect that this unit is situated at the end away from the nearest main road. The results were 1.2-1.4 ppb lower than the closest ground level external monitoring locations. The lower results in the Special Care Baby Unit may also be the result of the air handling plant which draws air from the roof above, the greater intake height allowing for greater dispersion of pollutants from the nearby roads.

The overall lower indoor concentrations compared with outdoor ones could be a function of nitrogen dioxide decay. This is where reaction with indoor furnishing and surfaces, especially porous surfaces such as wallboard, brick and blockwork reduces indoor concentrations compared to outdoor ones. Decay such as this could provide some degree of protection against high outside concentrations – if there are no combustion sources in the building. Where decay is important, it is reported that higher indoor concentrations occur in the summer than in the winter, as there tends to be more infiltration and ventilation in warm summer periods. Due to the relatively short monitoring period it is not possible to see if nitrogen dioxide decay is a significant factor in indoor concentrations in this case.

No background site monitoring was carried out during this study. However, a study completed as part of the Third Stage Review and Assessment Report recorded concentrations in urban background locations not far from this location of between 5.1 and 7.6 ppb. Rural background concentrations in the area have been measured at 6 ppb.

Comparison with air quality standards and objectives

No air quality standard or objective, either outdoor or indoor occupational, was exceeded during this study. However, without information on particular thresholds for young children and babies, no comment can be made on the acceptability or any effects of the concentrations

p24

education JOHN CONNELL MEMORIAL AWARD: I

Below we publish the papers by the 2002 prizewinners
Andrew Frost (1st prize) and Alana Cunningham (3rd prize)

An evaluation of the use of Radon (^{222}Rn) in assessing groundwater and surface-water interaction.

By ANDREW FROST

Dedication

I would never have started this degree without the understanding, support and love of my wife Andrea, who lost her brave fight against cancer on 23rd December 2002. This is dedicated to her: my thanks to her for everything, especially for always being there.

Abstract

The management of river catchments to prevent flood, maintain a safe supply and protect against pollution is of increasing importance as more demand is placed on this resource. The hydrologist's main problems are closing the water budget and obtaining reliable boundary information for catchment modelling. There are major problems with these when one of the main assumptions of catchments, water-tightness, is found not to be the case, due to faulting and fracturing of the underlying geology. These features have been found to act as preferential flow paths for groundwater, both into and away from the catchment. The use of radon-222 (^{222}Rn), a soluble radioactive noble gas, as a natural environmental tracer has been investigated, to evaluate its suitability for investigating groundwater/surface-water interactions, at Greenholes Beck catchment, Caton Moor, Lancashire and for identifying spoil leachate at Greenside Mine, Glenridding Beck catchment, Cumbria. This involved the development of an extraction method using toluene, which was found to have an extraction efficiency of 35%±3%. The samples were then counted using liquid scintillation spectrometry. At each sample point a 500ml water sample was collected and conductivity, temperature and pH were recorded. The second area studied at Caton Moor identified an area of fault water seepage that showed an activity of 397.77mBql^{-1}, compared to an upstream activity of 37.14mBql^{-1}. This 'pulse' of activity decreased by 78% over 25m downstream from the input and indicates that ^{222}Rn is suitable as an environmental tracer, being more sensitive than conductivity. The investigation at Greenside Mine showed that ^{222}Rn activity increases as water interacts with spoil and showed 'pulses' of activity at 236.17mBql^{-1} and 298.22mBql^{-1}. These 'pulses' were not identified by conductivity and again suggest that ^{222}Rn has potential as an environmental tracer, not only for groundwater but also spoil leachate.

Introduction

Catchments are defined by the surface topography with the assumption that the groundwater divide is the same as the surface divide and that it is watertight. Investigations at Slapton in Devon, show that fractures in the solid geology act as preferential flow paths for ground water and influence the movement of nitrate through the hydrological system (personal communication, Chappell, 2000). This highlights the importance of identifying and quantifying groundwater/surface-water interactions to enable us to better close the water-budget, obtain accurate boundary conditions for catchment modelling and understand how pollutants may migrate through a catchment, and from one catchment to another.

^{222}Rn is a naturally occurring soluble radioactive noble gas with a half-life ($t_{1/2}$) of 3.825 days (Ball, T.K, *et al*, 1991). It is the product of the decay chain of uranium-238 (^{238}U), its parent being ^{226}Ra, $t_{1/2}$ of about 1600 years, the concentrations of which in any source material has a direct bearing on ^{222}Rn concentrations. ^{238}U is not homogeneously distributed throughout the environment as it is readily oxidised and is soluble in this state. It can therefore be leached from rocks and soils, transported in solution until reducing conditions are encountered, resulting in the precipitation of ^{238}U (Ball T.K *et al*, 1991).

The properties of the mineral have an important bearing on the production of ^{222}Rn. The fact that ^{238}U and ^{226}Ra are present in rock is not sufficient to cause high ^{222}Rn gas concentrations. ^{222}Rn is transferred from the solid by two mechanisms: diffusion and alpha recoil, typical recoil range is 20-70nm (Michel, 1987). These processes allow ^{222}Rn to be released from the solid, allowing it to migrate through the soil or bedrock. The gas diffusion mechanism of ^{222}Rn depends on the nature and structure of the rock and can be enhanced by the presence of fractures and faults in the rock (Wilson *et al*, 1991).

^{222}Rn is soluble at low temperatures, about 0.5gl^{-1} (Ivanovich and Harmon, 1992), can easily be dissolved in groundwater and is often found in concentrations far in excess of its parent ^{226}Ra (Andrews & Wood, 1972). When transported by ground water its limiting factor is usually its half-life. The ^{222}Rn in river water is supplied both by groundwater seepage and directly from the sediments of the riverbed. Since the latter is negligible, groundwater seepage can be treated as the only source of ^{222}Rn in river

water (Ivanovich and Harmon, 1992). It is should be possible then to determine where groundwater seeps into a river, based on the distribution of ^{222}Rn in the river water.

Historically ^{222}Rn has been used in areas such as uranium and gold prospecting (Ivanovich and Harmon, 1992) and in the prediction of seismic and volcanic events (Cothern, 1987). The use of ^{222}Rn as an environmental tracer in groundwater/surface water interactions depends on its occurrence and concentration in groundwater and surface water, its inert nature and its loss due to aeration of the surface water. Investigations by Heath (1991), Seidel *et al* (1993), Ellins *et al* (1990) and others has demonstrated that these features make ^{222}Rn a potential tracer for surface/groundwater interactions.

The aim of the dissertation was to explore the potential use of ^{222}Rn as a natural hydrological tracer for groundwater/surface-water interactions compared to the other important hydrological parameters; temperature, pH and conductivity.

Method development

Toluene was used to extract the ^{222}Rn from the water sample as ^{222}Rn is much more soluble in toluene than in water (Bem *et al* 1994), is readily removed from water by agitation and aeration (Heath, 1991), only ^{222}Rn is extracted, any ^{226}Ra is left in the sample (Belloni *et al*, 1995) and extraction efficiency of 40% has been reported (Hamada, 1998).

The extraction of ^{222}Rn followed the following steps:

1. Sample removed from cold store and placed in fume cupboard.
2. 20ml aliquot of water removed.
3. Sample weighed.
4. 20ml aliquot of toluene added.
5. Sample agitated on end over end shaker for 10 minutes to disperse the toluene throughout the sample (Freyer *et al*, 1997).
6. Sample returned to fume cupboard for 1 hour to allow the clean separation of the two phases (Hoehn & Gunten, 1989).
7. 10ml aliquot of toluene removed and placed in glass counting vial with 10ml of the liquid scintillation cocktail Ultima Gold™ LLT.
8. Blank prepared, consisting of a 10ml aliquot of toluene and a 10ml aliquot of Ultima Gold™ LLT.
9. Vials sealed and shaken to reach a stable distribution of ^{222}Rn between the Ultima Gold™ LLT and the toluene.
10. Vials wiped down, placed in counting rack and checked for contamination.
11. Vials were then placed in the LSS counter and left for 4 hours to allow equilibrium to be reached between ^{222}Rn and its α-emitting daughters; ^{214}Po and ^{218}Po.

To ensure that only ^{222}Rn was extracted, the samples were counted repeatedly and a second extraction was carried out on certain samples. These confirmed that no ^{226}Ra was extracted as the ^{222}Rn was unsupported and decayed until no measurable activity was present in the recounts and the second extractions.

To evaluate the technique and to calibrate the results, spiked samples were prepared as follows:

1. Sample bottles weighed and a spike of known mass of ^{226}Ra was added.
2. 550ml of Milli-Ro deionised water added.
3. 20ml of toluene added.

The samples were left for 30 days to allow ^{222}Rn to grow into secular equilibrium with its parent ^{226}Ra (Blackburn & Al-Masri, 1993). The counting gave an average extraction efficiency of 34.5±3%. LSS counting was carried out using a Packard TRI-CARB 3170TR/SL Liquid Scintillation Analyser, which utilises QuatraSmart™ and Spectra Works™ software. To calculate counting efficiency and extraction efficiencies of the LSS, gamma spectrometry was also used.

Pulse Decay Discrimination (PDD) Optimisation

The ^{222}Rn decay chain involves 3 α-emissions and 2 β-emissions:

^{222}Rn α —> ^{218}Po α —> ^{214}Pb β —> ^{214}Bi β —> ^{214}Po α —>

The ability to discriminate between α- and β- particles lies in the small difference in pulse shapes, the detection and classification of which can be optimised and in this investigation the method outlined by Spaulding and Noakes (1993) for ^{222}Rn, which is in equilibrium with its two α-emitting daughters, ^{218}Po and ^{214}Po, and its two β-emitting daughters, ^{214}Pb and ^{214}Bi was used.

1. Two counting vial weighed and spike of known mass and activity of ^{226}Ra added.
2. 10ml aliquot of toluene added this vial and a second vial, which was to be used as the background.
3. 10ml aliquot of Ultima Gold™ LLT added to both vials.
4. Vials sealed, shaken for 5 minutes, wiped down and placed in a counting rack in the LSC to equilibrate for 4 hours.
5. The two vials were then counted by LSS for 40 minutes with the PDD set at 50, 90, 100, 110, 120, 130, 140 and 160, with a wide-open counting window.
6. The α-MCA count rate is then plotted against the PDD settings.

In this investigation a PDD setting of 110 was chosen.

LSS sample counting

After the background and sample vials have equilibrated they are counted by LSS for 60 minutes, giving the alpha and beta gross count rate in counts per minute (cpm), and

tSIE (quenching). This data then has to be calibrated, normalised and decay corrected to the time of extraction, and then time of sampling. The calibration process involved the use of gamma spectroscopy using the daughter nuclides, ^{214}Pb (294.97keV), ^{214}Pb (351.54) and ^{214}Bi, of ^{222}Rn.

Calibration

The following steps were followed to calibrate the results of the LSC:

1. The spiked sample and background prepared for the PDD investigation were allowed to equilibrate for 30 days to allow secular equilibrium to be reached
2. Counted by gamma spectroscopy and the efficiency calculated (efficiency = counts per second/Activity (Bq)) $2.37 \times 10^{-2} \pm 4.54 \times 10^{-4}$ Bqcps^{-1}
3. The spiked counting samples were then counted by LSS giving an efficiency of 4.90 ± 0.4Bqcpm^{-1}.
4. This figure was then used to calibrate the field investigation count and extraction efficiency result.

Lowest Limit of Detection (LLD) for LSS

This is given by (Curry, 1968):

$$LLD\ (cpm) = (2.71 + 4.65 * \sqrt{\mu})/t$$

where t = count time and m = average background in counts.

In this investigation the LLD (cpm) was found to be 1.03cpm.

Decay correction

It has been assumed that the ^{222}Rn is unsupported and that radioactive decay follows first order kinetics (Pates, 2001), given by $A_o = A_t e^{\lambda t}$, where A_o = initial activity, A_t = final activity, λ = decay constant (3.825 days) and t = elapsed time. For decay correction the data from each count is weighted according to the data's uncertainties, (personal communication, Pates, 2001)

$$A_o = \text{sum A/sum B } \{\text{error} = \sqrt{[1/\text{sum B}]}\}$$

$$\text{where sum A} = [\text{net cpm} * e^{-\lambda t}] * [1/\text{net cpm error}^2]$$

$$\text{and sum B} = [e^{-2\lambda t}] * [1/\text{net cpm error}^2]$$

Sample collection

Due to the volatility of ^{222}Rn (Heath, 1991), the sample must be disturbed as little as possible to avoid aeration and ^{222}Rn loss. 500ml glass sample bottles with o-ring seals, plastic screw caps and a slightly narrow neck were chosen. Prior to the fieldwork, each bottle was weighed and marked. At the sample sites a bottle was fully immersed to half stream depth, to minimise sediment disturbance and prevent ^{226}Ra entering from the streambed. The bottle was filled to overflow for two minutes and then sealed while immersed, to minimise loss of ^{222}Rn. Temperature and conductivity were recorded in triplicate with a WPA CMD 200 electrical conductivity meter (resolution ± 0.1ms/cm) and the pH was obtained using a Radiometer PHM 201 pH meter. The samples were stored inverted to minimise the risk of loss of ^{222}Rn from the screw cap storage.

APPLICATION TESTING

Fieldwork was carried out at two locations: the catchment of Greenholes Beck, Caton Moor, Lancashire, to assess its suitability as a groundwater tracer and Greenside Mine, Cumbria, to ascertain its suitability as a tracer for spoil-heap seepage.

Greenholes Beck, Caton Moor

Greenholes Beck catchment covers an area of 1km^2 and is located in the Forest of Bowland, draining the southwestern flank of Caton Moor, Lancashire, which is an upland area of moorland dissected by deep channels. The area is located on a basement of sedimentary rocks, all carboniferous in age, belonging to the Millstone Grit group (Brandon, 1992). During the Pleistocene period the area was glaciated which has led to the deposition of glacial till, on average 1 to 4 metres thick, with some deposits reaching up to 12 metres (Brandon, 1992).

Results

The results obtained for sample area two, Greenholes Beck, Caton Moor show that:

- The area identified via an electroconductivity survey has identified sample site four as the area investigated by Strachan (1997) at NGR 5710 6335.
- There is an increase in the observed activity in the samples collected at sample site three (312.5mBql^{-1}) and sample site four (397.77mBql^{-1}) compared to upstream, 37.14mBql^{-1}.
- At sample site four the highest conductivity (667.0µs), lowest temperature (11°C) and highest pH (6.5) readings for the entire profile are obtained.
- This confirms that groundwater is flowing into the stream in this vicinity.
- The profile suggests that this is not occurring as a point source but is more diffuse e.g. in a fault zone.
- The increased ^{222}Rn activity suggests that the groundwater is flowing along a fault, which is acting as a preferential flow path for groundwater.
- The activity decreases by 78%, from 397.77mBql^{-1} to 92.32mBql^{-1} over 25m, whereas the electroconductivity decreases by 40% from 667.0µs to 397.0µs.
- This suggests that any further inputs of groundwater downstream would be easily distinguished by using ^{222}Rn rather than electroconductivity.
- ^{222}Rn appears to be more sensitive than electroconductivity and is therefore suitable for use as a groundwater tracer.
- Repeat counts indicate that the ^{222}Rn was unsupported, as by 13/08/00 the count indicated that the activity in all sample vials was below the LLD.

Greenside Mine

Greenside Mine (NGR NY 364 174) is located in the Glenridding Beck Catchment, west of Glenridding village at the southern end of Ullswater, Cumbria. The area is believed to have been worked since 1690 for lead and silver which occurred in several veins, until 1962 when the site was abandoned (Tyler, 1998).

The solid geology consists entirely of the Birker Fell formation, which is part of the Borrowdale volcanic group. These are fine-grained igneous rocks, Ordovician in age (460-450MaBP), consisting of basalt, basaltic andesite, normal andesite, rhyolite and dacite, deposited by lava-flows, pyroclastic-flows, ash-falls and volcaniclastic sediments. These are underlain by metasediments, the Skiddaw Slates, consisting of mudstones, siltstones, and subsidiary greywacke sandstone. These have undergone contact metamorphism as a result of the emplacement of a large granite intrusion approximately 390MaBp. The drift geology of the area is dominated by glacial, fluvioglacial and fluvial deposits, screes and spoil from the centuries of mining operations (Mosley, 1990).

Sampling was carried out at two locations, Glenridding Beck and Swart Beck.

Results

The results obtained for Glenridding Beck show that:

- ^{222}Rn activity increases in water as it flows through spoil.
- ^{222}Rn is suitable as a tracer for spoil leachate.
- ^{222}Rn is more suitable for identifying spoil leachate than conductivity, temperature and pH.
- Even in areas where sampling can be far from ideal due to low-flow conditions, a 'pulse' of ^{222}Rn activity can still be observed in the sample.
- Although the hydrology of the area has been disturbed and extensive mining activity has occurred ^{222}Rn activity can still be used as a tracer for spoil leachate.

The results obtained from sample area two show that:

- ^{222}Rn activity in water increases as it flows through spoil.
- ^{222}Rn activity also increases in mine drainage water.
- The increase in ^{222}Rn activity is not always reflected by an increase in conductivity, as shown at Top Dam.
- This suggests that ^{222}Rn is more suitable as a tracer for spoil leachate than conductivity.
- Activity has been shown to decrease in the downstream profile, again indicating that it is suitable as a spoil leachate and mine drainage water tracer.

CONCLUSION

The method development has shown that:

- The use of toluene, the agitation time of 10 minutes on an end-over-end shaker and the standing time of 1hr for clean separation, has achieved an extraction efficiency of 34.5±3%.
- The extractions were clean, with no ^{22}Ra being extracted and the ^{222}Rn being unsupported.
- The PDD setting of 110 was not correct as beta particles were being misclassified as alpha particles.
- The selected counting window of 100-810keV may not have been the most appropriate due to the inexperience of the operator.
- The LSS counting efficiency was calculated to be 4.9 ± 0.4Bqcpm, which was incorrect due to the misclassification of beta events as alpha events.
- The method developed for sample collection and counting via LSS has however proven to be successful in both the method development stage and the application testing.

The application testing to assess the use of ^{222}Rn as a groundwater tracer at Greenholes Beck catchment, Caton Moor, Lancashire has shown that:

- The sample collection, extraction and detection techniques have been successful.
- ^{222}Rn activity increases in groundwater in faults and has been used to successfully identify an area of groundwater input into the surface-water.
- The observed decrease in ^{222}Rn activity in the downstream profile of sample area two indicates that ^{222}Rn is lost by turbulent aeration, as the stream flows through riffles, over steps and through pools.
- The above point indicates that further inputs of groundwater in the downstream profile could be identified, by using ^{222}Rn as a natural tracer.
- The observed activity of ^{222}Rn decreases more rapidly than the conductivity and suggests that although conductivity may be used successfully to identify the initial input, as in this case, it is not as sensitive as ^{222}Rn.
- The observed change in conductivity, temperature and pH has confirmed that the observed 'pulse' in ^{222}Rn activity is due to an input of groundwater into the surface-water, at sample site two.
- The above points indicate that ^{222}Rn could be successfully used as a natural tracer for groundwater and surface water interactions.

The application testing to assess the use of ^{222}Rn as a spoil leachate tracer at Greenside Mine has shown that:

- The sample collection, extraction and detection techniques have been successful.
- ^{222}Rn activity in water increases as it flows through mine-spoil.
- The observed ^{222}Rn activity in the surface water decreases in the downstream profile, after an input from spoil leachate.
- ^{222}Rn activity indicated sources of spoil leachate that was not indicated in the electroconductivity sampling.
- It was also found that ^{222}Rn activity also increased in mine drainage-water and showed a 'pulse' of activity even

p26

education JOHN CONNELL MEMORIAL AWARD: II

Detection and sensitivity analysis of *Cryptosporidium parvum* oocysts in the shellfish *Mytilus Edulis* by nested PCR of the 18S rRNA gene.

By ALANA CUNNINGHAM[1], M.B. FINN[1], C.J. LOWERY[1,2,3], J.S.G. DOOLEY[1], AND J.E. MOORE[2]

Abstract

We report the suitability of a previously designed 18S rRNA nested PCR assay for detecting the protozoan parasite *Cryptosporidium parvum* in mussel tissue. A sensitivity analysis of spiked mussel tissue samples was investigated using the 18S rRNA nested PCR assay which was shown to able to routinely detect as few as 1 x 106 oocysts per ml of homogenised mussel tissue. This study highlights the potential for shellfish such as *Mytilus Edulis* to be used as biological indicators for this parasite, and further describes the application of molecular techniques to environmental monitoring.

Introduction

Cryptosporidium parvum, a spore forming apicomplexan protozoan, is an obligate intracellular parasite that infects the microvillus border of the epithelium cells especially those along the gastrointestinal tract (Argenzio *et al*, 1994 and Tzipori *et al*, 1983). In 1907 Ernest Tyzzer identified and named *Cryptosporidium muris*, a protozoan parasite which he frequently found in the gastric glands of laboratory mice (Tyzzer, 1910). He was able to recognise stages of asexual and sexual reproduction and oocysts, which he detected in the faeces, measuring 7x5µm. During Tyzzer's investigations, he discovered and explained descriptions of a single generation of schizogony, micro- and macrogametogony, fertilisation, oocyst wall formation, sporogony, excystation and experimental transmission of oocysts. He recognised that the parasite was capable of undergoing complete development within the gland and able to autoinfect (Fayer, 1997). In 1912, Tyzzer discovered *Cryptosporidium parvum*, in the mouse, with oocysts measuring 3-4.5µm. The endogenous stages of this species were distributed over the entire surface of the intestinal villi and not in the glands as with *C. muris* (Fayer, 1997). Then again in 1925, Tyzzer discovered cryptosporidia in the caecum epithelium of chickens and rabbits, which were indistinguishable from *C. parvum* (Tyzzer, 1929).

To date twelve recognised species have been identified. Infection was reported to be asymptomatic and *Cryptosporidium*, which was then thought to be non-pathogenic, received little attention. It was Slavin (1955) who established the link between morbidity and mortality, with *Cryptosporidium meleagridis* being identified as the aetiological agent.

Cryptosporidial infection results from oral ingestion of oocysts from contaminated food or water, through direct contact with infected animals or humans, or on contaminated surfaces. Due to the rapidity of *Cryptosporidium's* life-cycle, plus the autoinfective cycles, huge numbers of organisms can colonize the intestinal tract in several days. The ileum soon becomes crowded and secondary sites are often infected, such as the duodenum and large intestine. In immunosuppressed individuals e.g. cancer and transplant patients, parasites can sometimes be found in the stomach, biliary and pancreatic ducts, and respiratory tract. Symptoms generally begin 2-10 days after being infected. They include: diarrhoea, loose or watery stool, abdominal pain, upset stomach, a slight fever and weight loss. However, some people are asymptomatic, making diagnosis more difficult.

Symptoms usually last about two weeks, with the patient seeming to get better and then worse. Once the patient does feel better, they continue to pass *Cryptosporidium* in their stool for up to two months. During this two month period the oocysts are still infective. Those who have a severely weakened immune system e.g. HIV/AIDS patients, are at risk of more serious disease symptoms, that can be life threatening.

The life-cycle of *C. parvum* (Fig.1) begins with ingestion of the sporulated oocysts, the resistant stage found in the environment. Excystation (a) occurs and sporulated oocysts, containing four sporozoites, exit from a suture located along one side of the oocyst, and parasitize epithelial cells (b, c) of the gastrointestinal tract (or other tissue such as the respiratory tract). These parasites are intracellular, enclosed by a thin layer of host cell cytoplasm. A unique, desmosome-like attachment organelle, plus accessory foldings of the parasite membranes, develop at the interface between the parasite proper and the host cell cytoplasm. This attachment organelle is sometimes referred to as the feeder organelle.

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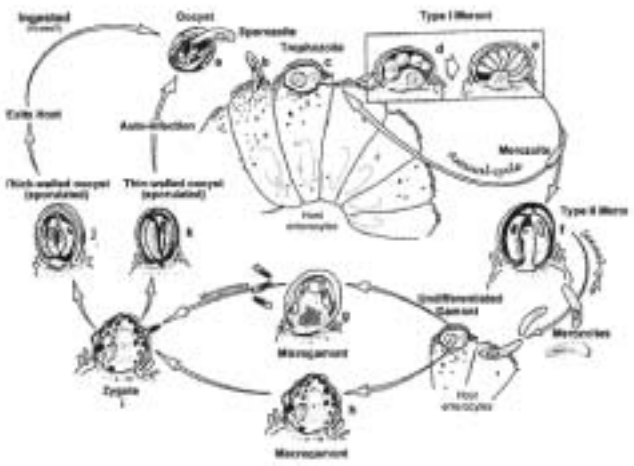
In these cells, the parasites undergo asexual multiplication (schizogony or merogony) (d, e) and then sexual multiplication (f). Microgametes (male) (g) fertilise the macrogamonts (female) (h) and a zygote (i) is formed and oocysts (j, k) develop that sporulate in the infected host.

Approximately 20% of the oocysts produced are devoid of a wall, and only a series of membranes surround the developing sporozoites. They are sometimes termed as 'thin-walled oocysts' and can excyst while still within the host, to infect new cells (autoinfection). Alternatively, thick-walled oocysts may be formed which are excreted via the faeces into the environment.

Figure 1. Cryptosporidium Life Cycle (from: Juranek DD. Cryptosporidiosis. In: Hunter's Tropical Medicine, 8th edition. Strickland GT, Editor.)



Transmission

Farm and companion animals are potentially important sources of zoonotic infections. There are numerous reports of human infection resulting from exposure to infected calves and lambs (Fayer and Ungar, 1986; Crawford and Vermund, 1988; Ungar, 1990; O'Donaghue, 1995), and among veterinary students, exposed to infected animals (Current, 1986; Casemore, 1990; Current, 1994). Further reports of transmission include household contacts of calf and sheep handlers and daycare and school contacts resulting from educational and recreational farm visits (Casemore, 1990; Nouri and Toroghi, 1991; Nouri and Karami, 1991; Dawson *et al*, 1995; Nimri and Batchoun, 1994; Miron *et al*, 1991). Refuse and promiscuous-landing filth flies, such as house flies (*Musca domestica*), are recognised as transport hosts for a variety of parasites (Public Health Laboratory Service Study Group, 1990).

Waterborne transmission

Water has been recognised as an important vehicle for the transmission of *Cryptosporidium* (Baer and Wright, 1990; Smith and Rose, 1990; Smith, 1992). In fact, water is considered to be the 'primary' mode of transmission for the parasite. The disposal of both animal and human excreta to land, by slurry spreading on pasture, may lead to the spread of protozoan parasites. In England and Wales up to a quarter of the cases of cryptosporidial infection are followed by cases of gastroenteritis among other members of the household to infection directly by aerosol spread or indirectly by contamination of water courses and reservoir feeder streams (Casemore *et al*, 1997).

Information derived from investigation of waterborne outbreaks is limited and difficult to interpret because of the time lag between the contamination event, the onset of symptoms in the exposed population and subsequent investigation to identify the source. Waterborne outbreaks however, are rare, and are believed to result from short term 'spikes' of contamination from increases in protozoa numbers in the source water, or failure in normal water treatment processes, or a combination of both factors.

Foodborne transmission

The consumption of raw foods is a risk factor for infection from *Cryptosporidium* (Casemore, 1990). The first foodborne outbreaks were linked with travellers returning from Mexico, the United Kingdom and Australia, the suspect foods being salad, raw milk, sausage and tripe. Since then there have been five other outbreaks in the US linked. Each case can be linked to a possible entry point for cryptosporidia oocysts. Confirmation of Cryptosporidia initially was limited to microscopic examination of intestinal biopsies, which limited the number of positive identifications. Food product safety is a primary concern of the food industry. Renewed interest in food safety has led to discovery or rediscovery of pathogenic organisms. The Public Health problems associated with molluscan shellfish and sewage pollution were recognised in the early part of this century. This led to implementation of the Public Health (Shellfish) Regulation, 1934 and 1948, which forged the long-established collaboration between the shellfish industry and environmental and public health authorities, to safeguard the consumer (West *et al*, 1985).

Molluscs

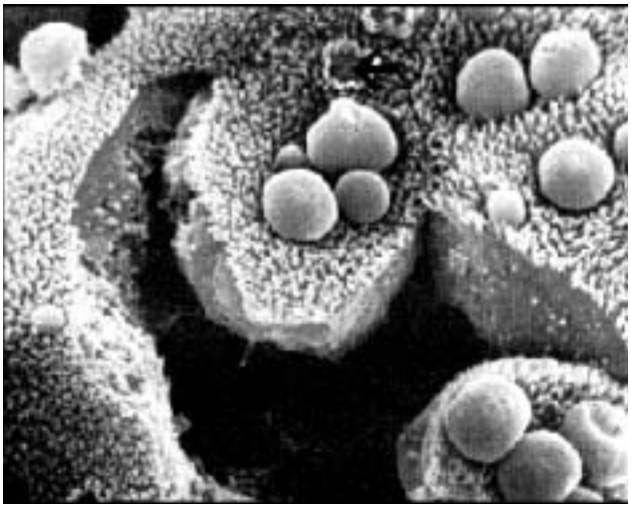
All bivalve molluscs feed and respire by passing water between the two shells and over the gill surfaces where particulate matter is strained off for ingestion. During this process, bivalve molluscs may ingest faecal bacteria and viruses present in the water and it is this potential for accumulation and concentration of enteric pathogens during natural physiological activity, which establishes bivalve molluscs as a route for transmission of enteric

waterborne disease. The gills and outside surfaces of crustaceans and molluscan, can become contaminated if exposed to faecally contaminated waters.

For molluscs that are consumed raw (Freire-Santos, 2000), it is necessary to identify factors important for sanitary control and treatment, and to establish high levels of standard for water quality, especially since oysters can remove *Cryptosporidium* oocysts from artificially contaminated water and retain them in hemocytes, on gills, and within the body for at least one month (Fayer *et al*, 1997; Graczyk *et al*, 1997).

Despite improvements in the amount of sewage treated, large numbers of micro-organisms, which cause a variety of gastroenteritis and diarrhoeal disease syndromes, continue to be discharged into the aquatic environment. Sewage treatment is primarily designed to reduce organic and particulate matter and not to remove micro-organisms, so that effluents even from sewage given secondary treatment contain high numbers of faecal organisms. This has unfortunate consequences for shellfish growing in waters receiving discharges of sewage.

Figure 2. Electron micrograph of *C.parvum*-infected mouse villous tissue, showing the spherical *C. parvum* oocysts attached to the gastric epithelium (Fayer, 1997).



Materials and methods

Sample selection

Samples were collected from marine sites around Northern Ireland. DNA extraction was carried out as described and one set of samples picked on a negative nested PCR basis. Nine 1ml aliquots from a marine site, prior to phenol chloroform and Quiagen DNA extraction, were spiked with a known concentration of oocysts.

Haemocytometer counting

An initial count of *Cryptosporidium* oocysts (Moredun, Paisley, Scotland) was made using a Neubauer Haemocytometer, 1/400mm_, depth 0.1mm (Weber, England). The concentration of oocysts/ml was calculated. From this the working dilutions of $1 \times 10^8 - 1 \times 10^0$ oocysts/ml were produced and spiked into DNA extractions *Cryptosporidium* gill tissue extract which had previously tested negative for *Cryptosporidium* using the nested PCR assay.

Viability count

The fluorogenic vital dye inclusion/exclusion assay using [4, 6-diamidino-2-phenylindole (DAPI) and propidium iodine (PI)], and as previously described by Campbell *et al* (1992), was used to determine the percentage of viable *Cryptosporidium* oocysts present in the initial stock solution.

Mussel tissue preparation

Gill filaments were dissected from the internal tissue of *Mytilus Edulis* mussel samples and stored in Potassium Dichromate ($K_2Cr_2O_7$) at 4°C. Gill tissue extract was processed by maceration and the final combined weight of homogenised tissue in 25ml of $K_2Cr_2O_7$ was recorded. The samples were washed for four times and the pellet resuspended in 1ml of sterile millipore water (11,500g for 10min). DNA isolated from each sample using Phenol Chloroform extraction and Qiagen QIAamp DNA Stool Mini Kit (Qiagen UK Ltd., Crawley, West Sussex).

Nested PCR

All primary amplification reactions were performed twice in 100ml of reaction volume containing 76ml of 6.0mM magnesium chloride master mix, 2µl UltraPure 50mg/ml BSA, 10µl each of F1 and R1 primers, 1µl (5U) of Taq polymerase and 1µl of *C. parvum* nucleic acid extract to produce a 1318 bp product. The secondary amplification mixture contained 76µl of 3.0mM magnesium chloride master mix, 2µl UltraPure 50mg/ml BSA, 10µl each of F2 and R2 primers, 1µl (5U) of Taq polymerase and 1µl of the amplified primary product. The secondary product was a 833 bp PCR amplicon. PCR conditions for both steps were identical: 94°C for 2 min 30s: [94°C for 30s: 60°C for 45s: 72°C for 30s] for 35 cycles: 72°C for 10 min: 4°C pause. All amplification reactions were carried out on a Biometra TRIO Thermoblock (Gottingen, Germany). Results for 10µl of secondary PCR were visualised on 1.5% agarose/10X TBE gels by ethidium bromide staining. Electrophoresis gels were run at 100V for one hour, using a Life Technologies™ (Invitrogen) Horizon® 11.14 electrophoresis tank and a Bio-Rad™ (Hercules,CA, USA) 200/2.1 power pack.

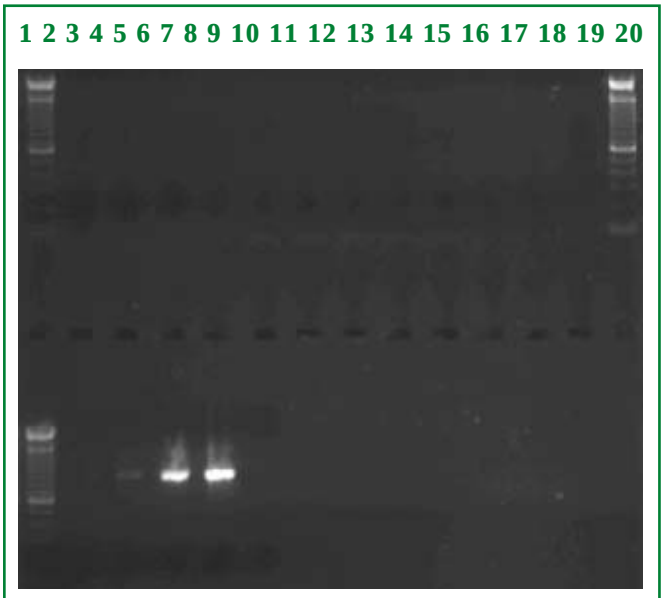


Fig. 3. Results of nested PCR using second set of spiked samples

Lane 1, 14, and 15:	100bp ladder
Lane 2-7:	**shellfish DNA extracts**
Lane 8-13:	1 x 10^0 – 1 x 10^5 oocysts/ml
Lane 16:	1 x 10^6 oocysts/ml
Lane 17:	1 x 10^7 oocysts/ml
Lane 18:	1 x 10^8 oocysts/ml
Lane 19:	positive control
Lane 20:	negative control

Results and discussion

This is the first report of a sensitivity study being carried out using nested PCR analysis of the 18S rRNA gene of the protozoan parasite *Cryptosporidium parvum* in shellfish tissue.

Initially, DNA extraction was carried out on samples from marine sites, followed by nested PCR. Mussel samples from one chosen marine site were spiked with 9 known concentrations of oocysts. The results of the sensitivity analysis of *Cryptosporidium* oocysts in mussel tissue samples using Nested PCR detection of the 18S rRNA gene can be clearly seen in Fig. 3. From electrophoresis gel image in Fig. 3 we can see that negative results were obtained for oocyst counts ranging from 1 x 10^0 to 1 x 10^6 oocysts/ml (lanes 8-13 and lane 16). Spiked samples of 1 x 10^7 and 1 x 10^8 oocysts/ml (lane 17 and 18) produced a positive PCR product. Use of the inclusion/exclusion of fluorogenic vital dye technique, however, revealed that only 10% of the original stock solution of oocysts were viable, the remaining 90% being dead oocysts which contained no internal DNA structure. Taking this into account, the nested PCR assay was shown to routinely detect as few as 1 x 10^6 oocysts/ml of *C. parvum* oocysts.

In Fig. 3 it can be noted that the Ethidium Bromide – DNA complex viewed under the UV light differs for the two positive samples observed on the same gel. This is due to a difference in the concentration of oocysts present in the two samples. Lane 17 has a concentration of 1 x 10^6 viable oocysts/ml and has therefore got a lower band intensity than the PCR product observed for 1 x 10^7 viable oocysts/ml in Lane 18. All experiments conducted within this study were carried out in duplicate to confirm the accuracy of the results.

This research represents a preliminary study of the potential use of nested PCR to investigate the epidemiology of *Cryptosporidium* oocysts isolated from mussel tissue in Northern Ireland. Research into *Cryptosporidium* species in N. Ireland is limited to three main surveys, one of which found *Cryptosporidium parvum* in mussels collected from Belfast Lough (Lowery *et al*, 2000). This research work follows on from this limited survey.

Previous studies within Ireland have shown *Cryptosporidium parvum* to be present in *Mytilius edulis* tissue, although no concentration levels have been reported (Lowery, *et al*, 2001; Chalmers, *et al*, 1997). This is the first study to report detection sensitivities of *Cryptosporidium* in shell fish tisssue using nested PCR. This study highlights the potential use of molecular-based processes for rapidly screening pathogens in raw food and shows the ability of such techniques to generate crucial epidemiological data for use in studying the transmission of diseases throughout the environment. Furthermore this study informs us of the potential use of molecular biology techniques to address other important environmental issues such as waste management and microbial diversity.

Acknowledgments

MBF is supported by a Department of Agriculture and Rural Development (Northern Ireland) Postgraduate Studentship. CJL and JSGD are supported by an EU Fifth Framework Project Grant [PLK1-CT-1999-00775].

education LTSN-GEES UPDATE

Learning & Teaching Support Network Subject Centre for Geography, Earth & Environmental Sciences (LTSN-GEES)

The LTSN-GEES Resource Database

The LTSN-GEES Resource Database is a web-based database that holds information about learning, teaching and assessment resources for the higher education geography, earth and environmental sciences community. The database provides easy access to resources through a single area on the LTSN-GEES website at http://www.gees.ac.uk

The database holds carefully selected records covering many types of resource. Below are a few examples of how the database could help support your learning and teaching activities:

You may wish to try something new in your teaching and would like to see what other colleagues have done in that area. The database can identify numerous good practice abstracts that can inform your practice.

If you are looking for specific course components to use in your learning and teaching, or ideas upon which to base your own materials, the database can identify information provided by both learning and teaching projects and individual academics.

It may be that you are interested in pedagogic research within the GEES subjects. The database carries information on current and former learning and teaching projects allowing access to existing research.

What goes into the LTSN-GEES Resource Database?

Every resource that is catalogued in the database is first examined for quality and relevance. In this way we hope that the records you find when searching the database will be highly relevant to learning, teaching and assessment in the higher education GEES disciplines. It should be noted that while the database includes materials such as tutorials, case studies and pedagogic research it tends not to hold general subject-based content. For example, the LTSN-GEES resource database would hold a record describing how a GEES academic used the NASA website in their teaching but not necessarily store a record describing the NASA website itself.

How can I contribute to the growth of the LTSN-GEES Resource Database?

We would like to know about any learning and teaching initiatives or resources you have used, are using or are currently developing, which you feel may be of interest to fellow practitioners. Our focus for inclusion is on the learning and teaching value and context of each resource rather than acting simply as a knowledge content database. For example, rather than providing a textbook title and description, a record will, ideally, also include reviews by members of the GEES community, including descriptions of usage. If we could get one resource from each of our potential GEES colleagues we would be well on the way to offering an extensive yet focused resource for the whole GEES HE community.

For more information see the Resource Database itself or contact LTSN-GEES at the address below.

Finally, please feel free to send us your feedback. We value your comments and constructive criticism on the use of the database. Please email the database administrator, Dr Yolande Knight, at yolande.knight@plymouth.ac.uk.

◆ LTSN-GEES, Room 509, The Money Centre, University of Plymouth, Plymouth PL4 8AA; Tel: 01752 233 530; Fax: 01752 233 534; Email: info@gees.ac.uk

◆ Environmental Science-specific activities: For further details of the services offered by our Senior Advisor for Environmental Science, contact Mrs Jennifer Blumhof, University of Hertfordshire; Email: j.r.blumhof@herts.ac.uk; Tel: 01707 284 595; http://www.herts.ac.uk/natsci/Env/ches/newches/home.htm

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p5

verified by the collection of physical data. This is not only for calibration purposes but subsequently to improve model accuracy.

Sea level rise is expected to increase erosion and have a detrimental effect on coastal infrastructure. Protecting the coastline could become an economic burden and with the progress being made in sustainable management practices, there will be more soft engineering solutions working alongside natural coastal processes. This does not mean that hard engineering solutions will not be used where necessary. However, as advocated by van der Weide *et al* (2001), to design appropriate mitigating measures, causes should be properly analysed and the technical and economic feasibility of such mitigating measures should be evaluated.

Difficult decisions will need to be taken irrespective of stakeholder interests and there will be economic consequences. Policies will therefore need to reflect the complex inter-relationships of all activities. The use of risk assessments in conjunction with benefit-cost analyses must justify policies of managed retreat where irreversible loss is evident.

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information PP4SD AND BARCLAYS

Barclays business leadership programme

Ask bank managers about climate change and the chances are they'll be at a bit of a loss. But not for much longer – at least if it's a Barclays manager you're talking to.

Over 100 graduate trainees at Barclays have recently broken new ground with special training in sustainable development. The aim was not just to tell them about climate change and other important environmental or social issues, but to help them see how their everyday decisions might have wider impacts which they ought to think about.

Take the example of building on flood plains. In the past, lenders will have considered a loan application on much the same grounds as any other loan. Look at the security and the financing of the project. Assess the financial risks. If it looks OK, fix an appropriate interest rate and off go the property developers.

The recent graduates were encouraged to think about what happens next. Jimmy Brannigan, National Learning Manager at the Environment Agency, who led the project, explained: 'If there is building on a flood plain, they'll need flood defences, which may have to be paid for by the local authority. Then there's the insurance angle – it's hard to get insurance cover. And at some point people will get flooded, so we wanted them to think about the impact of that. These things all flow from a decision to lend the money in the first place. It's important to consider the impacts and where the responsibilities lie.'

Of course it's not just bankers who need to think harder about sustainable development. Managers and professionals in all organisations do. This workshop stems from a project known as Professional Practice for Sustainable Development (PP4SD). It is a collaboration set up in 1999 between the Environment Agency, the Institution of Environmental Sciences, The Natural Step, WWF-UK and several other organisations, aimed at helping professionals in all walks of life to meet the challenge of sustainable development in their everyday work.

It is based on the notion that if organisations and their development are to be more sustainable, professionals must be able to connect the global issues to their everyday decisions.

The project has developed training materials in co-operation with 14 institutions ranging from purchasing professionals to architects. The wide range of professional bodies means that a broad approach was taken, so that the material is relevant to any profession. Pilot programmes were carried out with accountants and town planners, for example, as well as cross-professional groups.

The highly interactive course aims to challenge and stimulate participants to assess their own knowledge, skills and experiences in the context of sustainable development, helping them to understand the principles of social and environmental as well as economic sustainability. It includes business case studies which illustrate how the principles are being applied.

Components cover aspects such as ethical and social responsibility, managing risks, social reporting and stakeholder engagement and value creation – all part and parcel of sustainable development.

The materials are intended to be used by professional bodies in courses for their members, but the project has received government backing to expand specifically in the financial sector and Barclays jumped at the chance to adapt the material for its graduates.

This is the first time that sustainable development issues have been introduced in the initial training for the bank's graduates, although it is included in other areas of management development. It will now be an annual fixture.

Phil Case, Barclays' environment director, explained: 'Addressing sustainable development is part of being a good corporate citizen, which Barclays believes is intrinsic to our future. Obviously, graduates are also intrinsic to our future direction, so this is something it's important they understand.'

As in any business, the thrust of most initial training is about the business, how it works and what are the business drivers. But if businesses are to address sustainable development the managers of tomorrow need to understand the social and environmental implications of what they are doing in their jobs. For many professionals, it is easy to understand the need to reduce carbon dioxide emissions, but not at all clear how they contribute to the problem or what they can do to help resolve it as part of their everyday work or life.

'We need to get across the idea of sustainability and what we need to do – for example, decoupling economic growth from resource use. But then we need to explain what it means in practice. Integration is the key – this is not a side-of-the-desk thing,' Mr Case said.

Mr Brannigan agrees that making the connections is critical. He says the aim of the course is to get people to think about the wider impacts of their actions, and stresses that it was important to adapt the generic material to make the sessions relevant to the bank.

The result was a workshop which gave the graduates an insight into how sustainable development is already being integrated into decisions elsewhere in the financial sector, as well as providing a grounding in the concepts of social and environmental sustainability. Case studies were used to demonstrate how businesses are benefiting from adopting a sustainable approach.

'It's always an issue when you're talking about sustainability or corporate social responsibility (CSR) to make sure you make it relevant to the current situation. So we raised issues that we think the sector needs to be thinking about,' Brannigan says.

Financing flood plain development was one. Closing rural branches was another. The graduates role-played an annual meeting where some of them acted as directors, defending the bank's action, while others played shareholders and campaigners.

For Mark Bolton-Maggs, one of the trainees, it is the spaceship exercise which has stuck in his mind after a spell back at work in Barclaycard. The exercise begins with the trainees drawing up a packing list for a weekend trip to the moon. Typically they want to take the usual holiday paraphernalia – camera, music, books, perhaps the odd bottle of champagne.

Then disaster strikes and they are unable to return to Earth for ten years. If they had known that in advance, what would they have wanted to take? Now thoughts turn to survival – means of producing water and food, and possibly creating an 'ark' which could eventually regenerate Earth.

The graduates are then asked if they think such a spaceship exists, prompting thoughts about emergency modules for the US president waiting in a bunker at Cape Canaveral. The answer is that such a spaceship does exist – it's called Earth.

It sounds a bit trite in black and white on the page, but in the classroom it is a vivid means of bringing home to people the difference between a transient, throwaway approach and sustainable living – between short and long-term thinking.

'When it's put in that context you realise we all have to make sure we can survive,' says Bolton-Maggs.

The whole day left a big impression on him, although he admits to some scepticism initially. 'When I saw sustainable development on the training schedule I was interested but a bit unsure how relevant it was. I'm in the Finance stream, and you expect training to be about taking decisions based on financial issues.'

Post-training assessments show that most of the graduates were similarly impressed. Around 90% said they now have a better understanding, not just of sustainability issues, but also of how this affects Barclays and how their decision-making can take account of sustainability. The overall average score for the workshop was an impressive 8 out of 10. Among other reactions, several trainees registered a determination that Barclays should become a leader in sustainable development in the financial sector.

Back at Barclaycard, it is not so easy to see what should be done differently, although Bolton-Maggs says the workshop reinforced the need for responsibility in lending.

But these future managers know that sustainable development is not going to go away. For one thing, they receive a direct reminder three months after completing the course. The final exercise was to write down three things which they could do to advance sustainable development in Barclays. Those commitments were written on postcards and are mailed back to them.

Most of the action points were in the environmental management field, such as saving energy and reducing waste. Community affairs issues, such as volunteering, were the next most common area, but there were also commitments on equality/diversity and financial inclusion. But the common theme was that corporate responsibility translates into managers' personal responsibility, summed up in comments such as: 'We need to make a difference today,' 'Every individual has responsibility,' and 'The implications of doing nothing are huge.'

Those are the messages which PP4SD was set up to bring home to professionals everywhere.

Roger Cowie

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p13

measured in the Special Care Baby Unit.

Comparison with other studies

Indoor concentrations in domestic houses with gas cookers may be higher than those measured here. The Expert Panel on Air Quality Standards (EPAQS) suggests a figure of 15 ppb on average. Where gas cooking is not present concentrations may be lower. Average indoor concentrations in domestic bedrooms in urban areas are suggested by the Building Research Establishment as being in the order of 7-8 ppb, higher when the method of cooking is gas (personal communication).

While indoor air quality is not included in the current air quality management regime, studies are being undertaken in a number of guises elsewhere and the number of such studies is likely to increase, as the importance of indoor air becomes more apparent

Conclusions

1. There is no evidence of exceedence of any of the current Air Quality Standards or Objectives.
2. Concentrations within the Maternity Unit were lower by a margin of 1 to 2.5 ppb than outdoor concentrations.
3. Concentrations outside and inside the units were higher than typical urban background concentrations for the town.
4. The concentrations measured inside the Special Care Baby Unit and at the reception area appear higher than domestic bedrooms in urban areas, where gas is not used for cooking, but lower than concentrations found in houses where gas cooking is carried out.

◆ *The views in this article are personal and do not necessarily reflect those of my employer.*

ies NEW MEMBERS

The Institution is pleased to welcome the following new members:

Mr S.R. Ballantine	Environmental Consultant BMT Cordah Ltd
Mr T.L. Boyle	Assistant Environment Protection Officer, SEPA
Ms S.J. Bullows	Recent Graduate, Manchester Metropolitan University
Mr L.J. Champion	Recent Graduate Plymouth University
Mr C.K. Chong	Health Inspector of Food and Environmental Hygiene Dept. Government of Hong Kong
Miss M.F.A. Chowdhury	Organic Analyst Harwell Scientifics
Mr P.J. Clapham	Education & Training Manager CIWM
Mr C.R. Davies	Environment: Projects Engineer, AES, Medway Power Station
Mr J. Devlin	Field Officer, SEPA
Miss G.L. Dowling	Environment Protection Officer, SEPA
Dr G.P. Middleton	Environment Manager Orange PLC, Bristol
Mr G.E. Evans	UK Atomic Energy Authority Electrical Engineer
Miss Farnsworth	Postgraduate Student University of Gloucestershire
Mr C.T. Farrell	Environmental Engineer Foster Wheeler Energy Ltd
Dr D.R. Franklin	Principal Lecturer University of Portsmouth
Mr A.B. Frost	Recent Graduate, Lancaster University
Miss V.H. Ife	Environmental Scientist Glebe Mines Limited
Miss L.D. Inch	Assistant Engineer H2Ok Consultants
Ms J.R. Jarvis	Environment Protection Officer SEPA
Mr N.D. Johnston	Environment Protection Officer SEPA
Mr S. Johnstone	Field Officer – Chemistry Department, SEPA
Mr E. Jow	Hydrologist, SEPA
Mr D.J. Lewis	Recent Graduate University of Plymouth
Dr C. Linstead	Researcher Forum for the Future
Ms K.I. MacCalman	Environment Protection Officer (Graduate Trainee), SEPA
Miss C. Macintosh	Assistant to Director of Operations SEPA
Mr G.D. McGregor	Environmental Engineer Johnson, Poole & Bloomer
Miss S. McLaughlin	Environmental Scientist Johnson, Poole & Bloomer
Miss H.V. Mitchem	Water Watch Project Manager Mersey Basin Campaign
Mr T. Mehmood	Safety, Health and Environmental Manager, Hazlewood Sandwiches
Dr J.R. Merefield	Advance Environmental Wolfson Laboratories; Senior Consultant & Lecturer at University of Exeter
Dr J.W. Muir	Senior Environmental Chemist Johnson, Poole and Bloomer
Mr D.P. Muldoon	Environmental Advisor BAE Systems
Mr E.U. Nicol	Agricultural Development Officer, Shetland Islands Council
North Somerset Council	Associate Member
Ms M.A. O'Connell	Operations Manager Egeneration web site Kent County Council
Mr J.P. Olosundé	Environmental Consultant
Mrs S.A. Pickford	Contaminated Land Specialist SEPA
Dr S.K. Pitcher	Recent Postgraduate
Mrs O. A. Potapova-Crighton	Modeller/Oceanographer SEPA
Miss L.M. Pritchard	Environmental Consultant Entec UK Ltd
Mr J. Rook	Assistant Site Manager English Nature
Miss E. Simpson	Hydrogeological Support Officer, SEPA
Miss G.E. Smith	Assistant Chemist, SEPA
Mr G.S Smith	Environment Protection Officer SEPA
Mr C.S. Taylor	Principal Environment/ Head of Residential Services Groundsure Limited
Mr W. Tippett	Director of Development Milliken Carpet
Miss S.D. Tough	Environment Protection Officer SEPA

p8

hedgerows, watercourses and ponds as a result of the construction of the M6 Toll motorway.

There is a resulting increase in ecological habitat, also as a result of the construction of the M6 Toll motorway.

'Safe' habitats will be provided for a large variety of animal and plant species. Almost all of the new habitats created will be inside the motorway boundary and therefore safe from harm from the public.

Safe passage will be provided for animals moving across the new M6 Toll motorway. Provision of a variety of types of animal fencing along the site boundary, tied in to mammal passes throughout the length of the M6 Toll, will ensure that animal mortality from road kill is avoided.

The works undertaken on the M6 Toll have demonstrated that significant ecological habitats can be retained and protected as part of the construction of a new road network. It could therefore be concluded that major road schemes of this type can provide a significant and positive benefit to the surrounding environment, particularly in terms of habitat retention and creation.

Regarding the principles of sustainable construction: using 'recycled' and site-won materials for construction has diminished the need to use resources of raw materials.

There has been minimal impact on the local environment during construction.

There is a net increase in ecological habitat and 'safe' habitats will be provided for a large variety of animal and plant species.

An additional benefit exists in that staff and operatives involved with the M6 Toll are more aware of the environment and the consequences of their work. This is in part attributable to the adoption of the comprehensive Environmental Management System, an environmental site induction and assessment of environmental risks throughout the construction phase.

Long term ecological monitoring, continuing for some 15 years after the opening of the M6 Toll road, will provide invaluable information concerning the effects of the construction of the controversial new motorway. Early indications are that the project, at least in terms of ecological improvement, will be a success, this following on from the successful implementation of the principles of sustainable construction.

Referring back to the principles of sustainability, there is no straightforward means of actually measuring any overall success. The considerable successes achieved during construction of the M6 Toll include many instances of environmental improvement. These, combined with CAMBBA's adoption of the principles of sustainable construction, go some way to showing that these principles have been met as part of the M6 toll construction. The project is well on course to demonstrate that major construction works can have an overall positive benefit on the ecological environment and at the same time, can still provide positive returns to shareholders.

◆ More information about the Environmental Issues on the M6 Toll project can be found at *www.m6toll.co.uk*

p17

after turbulence in the surface-water, both in the drain-pipe, the falling of the water to the stream bank and transport in 5m of the stream channel.

◆ These above points indicate that ^{222}Rn could potentially be used as a natural tracer for spoil leachate and also mine drainage water.

This investigation has found that ^{222}Rn levels are elevated in groundwater, spoil leachate and mine-drainage water. The method that has been developed for sampling, extraction and counting have been successful and there is the potential for ^{222}Rn to be used as a natural tracer for these sources and their interaction with surface-water, and developed as a tool to assist in the management of catchments. Before consideration can be given to using ^{222}Rn as a tracer and developing a mass balance expression the following work is required:

◆ To improve the efficiency of this method further work on sample collection, extraction, counting and calibration is needed.
◆ Repeat samples need to be collected from the locations identified to assess the accuracy of the results obtained.
◆ The sample data needs to be considered alongside other hydrological data, such as precipitation and discharge.
◆ A full literature review is required of tested mass balance expressions, such as those developed by Lee and Holliday (1993), and Ellins *et al* (1990, prior to any development.

Hopefully, this work will be of some relevance to future investigations into the use of ^{222}Rn as a natural tracer in hydrology. This investigation has shown that its use has benefits over electroconductivity, temperature and pH.

Acknowledgments

I would like to thank Dr Jackie Pates, Adam Stackhouse and Pat Last of the Environmental Radioactivity Research Group; and Iris Dootson and Anne Wilkinson for their help in putting together the equipment that I needed.

bibilography VOLUME 11/2002

Article	Author	Issue	Section
A Vision for Sustainable Agriculure	Policy Commission on the Future of Farming and Food	1	FE
The Future of Fisheries	Barrie Deas	1	FE
Environmental Scientist Bibliography Vol. 10		2	GEN
Editorial Comment	Dr R. A. Fuller FIEnvSc	1	ENC
Boost for LPG as 1000th Gas Station opens		1	NEW
Government Seeks Views on Priorities for Environment Agency		1	NEW
Consultation on Flood Defence Funding Arrangements		1	NEW
The Professionals' Dilemma?	Stephen & Maureen Martin	5	FE
Consultation on the Research Assessment Exercise	Professor James Longhurst	1	ED
Science, the Environment and Government	Professor David King FRS	5	FE
Survey Reveals Improvement in Environmental Career Prospects	Dr R. A. Fuller/ENDS Directory	2	FE
Conviviality, wealthism and Bjorn Lomborg	Professor Michael Bassey AcSS	2	FE
Sinking and Suing		2	ENC
Kyoto to be Ratified by EU		2	ENC
Rendezvous at Nightfall: The Voyages of Robot Ocean Explorers	Professor Gwyn Griffiths	5	FE
Green Chemistry	Professor James Clark	5	FE
Framesworks for an Integrated Global Climate Management Strategy	Dr Mike Hulme	5	FE
New Era for Wind Off the Norfolk Coast		2	ENC
Drilling Into Alaska		2	ENC
Rubbish or Resource?	Professor Lynne E. Frostick	3	FE
Brown Goes Cool On Green Issues		2	ENC
The Ice Field Cometh		2	ENC
Dredging the Channel		2	ENC
Sustainable Energy: The PIU Energy Review		2	ENC
£58.6m Green-Up Fund Should Mean Cleaner Quarries and Fewer Lorries		2	ENC
UK Condemns Japanese Move to Increase Whaling		2	ENC
Welcome and Vision Statement	Professor Jim Longhurst	2	
Disabled Divers to Take Part in Marine Conservation	Caroline Walsh AMIEnvSc	2	RP
Waste Management - Devlivering Change Through Regulation	Dr Cathy O'Brien	3	FE
Professionals and Sustainability	Professor Stephen Martin FIEnvSc	3	FE
World Summit on Sustainable Development: The Turning Point for a Better World		3	ENC
Buying Time For Forests		3	ENC
Shape Up For Sustainability: The Professional Approach	Mr John Baines MIEnvSc	4	FE
Dump Less Rubbish, Beckett Tells Councils		3	ENC
Kyoto Protocol Ratified - And Rejected		3	ENC
Pollution Hits The Poor		3	ENC
UK Business and Biodiversity: Progress and Obstacles		3	ENC
Minister's Early Warning On Climate Change		3	ENC

Article	Author	Issue	Section
Launch of the Science Council		3	INF
EIA Practitioners Register Launched		3	INF
London To Ban Polluting Motor Vehicles		5	ENC
Route Map For Business Sustainability		3	INF
The UK Science & Engineering Research Base: Issues & Policy		3	ED
Non-Food Crops: The Initiative of Goverment & Industry	Mr Rob. Margetts CBE	4	FE
The Role of Renewable Raw Materials in the European Climate Change Programme	Dr Joachim Ehrenberg	4	FE
High Floods Insurance At Risk		5	ENC
The Urban Exposure Project	Guy Coulson AMIEnvSc	4	FE
Britain in Bloom: Saviour or Disaster for the Environment?		5	ENC
Project Carrot: An Exercise in Sustainable Farming	A Concept	4	FE
Salary Survey 2002 by Environment Business	Dr R. A. Fuller FIEnvSc	4	ENC
Environmental Education for Sustainable Development	Russian-British Conference	4	ED
National Parks 'At the Heart of Sustainable Development'		5	ENC
Sewage Sludge Regulations to be Improved		5	ENC
Uncertain Future for UK Coal		5	ENC
Scottish Timber Switching From Road To Sea		5	ENC
UK Global Diversity Programme		5	ENC
Ammonia Booklet Aims to Spread the Word on Pollution		5	ENC
New Atlas of British and Irish Flora		5	ENC
Sustainable Development in Europe's Protected Landscapes	Adrian Phillips	6	FE
Consultation Process to Improve Public Rights to Comment on GM Crop Releases		5	ENC
Working with the Grain of Nature: A Biodiversity Strategy for England		5	ENC
Learning and Teaching Support Network		5	ED
Book Notice	Rolf Jucker	5	GEN
Justice and Science for Sustainable Development	Nick Brooks and Neil Adger	6	FE
John Connell Memorial Award		6	GEN
Ocean Cruising: A rapidly Growing Global Phenomenon	Professor Derek Hall MIEnvSc	6	FE
Scotland's Second Class Beaches		6	ENC
Can the Professions Survive?		6	ENC
Career Profile: Dr Suzanne Jordan MIEnvSc		6	GEN
Education Events in Johannesburgh		6	ED
Should the Higher Education Sector embrace Sustainability?	Stephen Martin FIEnvSc & Rolf Jucker	6	ED
The Crowded Greenhouse: Population Growth, Climate Change & Creating a Sustainable World	Dr R. A. Fuller FIEnvSc	6	BR
Course: Teaching & Learning for a Sustainable Future		6	GEN

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BR = Book Review **ED = Environmental Education** **ENC = Environmental News and Comment**
FE = Feature Article **GEN = General** **NEW = Environmental News** **RP = Research Project**