JEHR

Chartered Institute of Environmental Health

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Editorial - Julie Barratt

What is research for? That may seem like a strange question for the Associate Editor of a research journal to be asking, but it is a question that does merit some consideration. Marston Bates suggested that research is the process of going up alleys to see if they are blind, and certainly there are some pieces of research that can be filed in the 'so what' category and some that establish as fact what most people regard as staringly obvious, but there is no denying that research has advanced human civilisation to the point at which we find ourselves today. Research takes many forms, from the deeply theoretical to the quick and dirty pragmatic, but it is the application, not the research, that is ultimately valuable.

Research is important for what it tells us we can do; what it may not tell us is whether or not we should do it. This is graphically demonstrated by government's recent volte face regarding the growing of crops for the generation of biofuels. Ruth Kelly has acknowledged that while biofuels have the potential to cut carbon emissions and combat climate change there are "increasing questions" about them. A panel of government experts, chaired by Professor Ed Gallagher, head of the Renewable Fuels Agency, has looked at the impact of energy policy on land use, and has concluded that biofuels should be introduced more slowly than planned until controls are in place that will prevent higher food prices and land being switched from forests or agriculture. His review predicts that current policy could see grain prices in the EU rise by 15%, sugar by 7% and oil seed by 50%, and that an extra 10.7 million people in India could find themselves in poverty, with countries such as Kenya, Malawi and Bangladesh seeing hundreds of thousands of their populations affected. There is acknowledgement that the rush to grow palm oil in Malaysia has caused the loss of ancient rain forest and habitat for the endangered orang-utan. Hilary Benn, Environment Secretary, said: "To tackle climate change we will need to develop newer, cleaner fuels – but that does not mean pushing forward indiscriminately on biofuels that do more harm than good."

All of which takes me back to my point: research has shown that we can derive energy from some types of biofuels, but that of itself is not enough. The bigger question is should we, or will we be doing more harm that good? We need to consider fully the impact of what we do before we do it, rather than be taught by hindsight that something possible was not actually something desirable. Integrated Impact Assessment tools, such as that used by the Welsh Assembly Government to test all policies it advances for consultation, should be the norm. To attempt to identify all of the potential consequences of actions or the lack of them before they manifest themselves is preferable to stopping mid programme or having to hastily instigate a remediation programme. Luc Montagnier, himself a scientist, noted: "Top class research is good. Knowing what to do with the results is better." Research tells us what we can do; impact assessment tells us what will happen if we do. One should not be advanced without the other.

Guest Editorial - Mark Elliott: Chair, CIEH Council

I am very pleased to have been invited to make a contribution to JEHR in my year as Chair of CIEH Council. I must confess immediately that my knowledge of JEHR up to now has been limited.

This has been my loss. I knew it existed and had seen summary publications. However, a review of the JEHR website showed me the breath and depth of research articles available. From "Performance assessment in local authority food safety services" to "A Practical Evaluation of Objective Noise Criteria used for the Assessment of Disturbance due to Entertainment Music", a wealth of knowledge is available. Environmental health practitioners are dealing with difficult environmental and public heath problems and issues on a daily basis and these problems and issues no doubt will recur in different locations across the country, if not the world.

Capturing the solutions to these problems and information collection by environmental health practitioners through properly applied research techniques would grow the knowledge and research base for all. Along with the certainties of death and taxes, you can be sure someone somewhere has previously dealt with the same or very similar problem that faces you today. We now live in a world of 'connectivity' through devices ranging from mobile phones, personal digital assistants and laptops, with accessible knowledge a few keystrokes away. But connectivity is a two-way process, just as knowledge transfer is.

We need to make this knowledge available to all, whether tackling environmental or public health issues in Pembrokeshire or Peru. Connectivity has meant the death of distance. What better time to consider how to encourage colleagues to undertake and submit research and knowledge using the 'new online tools' sprouting in abundance on what is referred to as web 2.0. What are these tools?

There is not the space to go into detail but two examples are Wiki technology, allowing many to work on and contribute to a paper (Wiki technology is famous for its use in the online collaborative encyclopedia Wikipedia). Another example is using virtual worlds such as Second Life to help test a hypothesis. This is already happening. Networks, connectivity and the new collaborative technologies on the web now allow group effort and cooperation. Colleagues can work collaboratively on research easily.

There is no need for an individual to discover a eureka moment alone, when you can discover it together. The work of James Michael Surowiecki in The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations explains about the aggregation of knowledge and information in groups, which results in decisions that, he argues, are often better than could have been made by any single member of the group. Much more of the collective group wisdom of environmental health practitioners needs to be gathered and collected through research practices so that we all can benefit. I would respectfully urge all colleagues to use this resource and most importantly provide research contributions.

Brownfield sites, Land Remediation, Reclamation and Regeneration: Novel Technology as a Public Health Protection Measure - Jeffrey L Russell1 MSc BSc (Hons), Peter G Davies1 MSc (Dist) FCIEH, Dr David Russell1 BSc MBBCh MSc Dip Med Tox FRCPath, Dr Christopher D Johnson1 PhD BSc (Hons) MRSC and Alan Brown2

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Abstract

The UK has an industrial heritage of contaminated land. There are known to be large numbers of brownfield sites, many of which are contaminated. Current government policy encourages redevelopment of such sites with a view to conserving greenfield sites. This paper describes the remediation of a former landfill site in Caerphilly, South Wales that has been remediated by means of conditions attached to the planning consent and subsequently utilised for housing. Historical records indicated that the site had previously been used as a waste tip for organic contaminants, pulverised fuel ash, drummed chemical industrial and other solid wastes. The location of the drummed waste was identified by geophysical investigation, which subsequently led to the removal of 100,000 tonnes of waste material. Concerns over the limitations of such investigation necessitated the additional measures of the placement of a capillary break layer and gas protection measures in housing. The paper describes the role of public health professionals from the Local Health Board, the National Public Health Service for Wales and Health Protection Agency in the risk assessment and risk communication process as part of a multi-disciplinary agency.

Key words: Contaminated land; capillary break layer; contaminants of concern; environmental health; public health; remediation

Introduction

Contaminated land is typically the unwanted legacy of past industrial and waste disposal activity. With the contraction of heavy industry, many industrial sites have fallen into a state of disuse and thus have become available for redevelopment. Currently planning policy recognises and encourages such re-utilisation for the purposes of housing, recreation and other social and community facilities. Accordingly, the Public Service Agreement Target 6 (Planning) produced by the Department of Communities and Local Government (CLG, 2004), states that at least 60% of new build homes in England should be built on previously developed land (brownfield sites). Many of these sites are classified as derelict i.e. “land so damaged by industrial or other development that it is incapable of beneficial use without treatment” (DoE, 1991). Additionally, many of these sites are contaminated and will contain significant levels of residual chemical contamination.

It is recognised that there are many brownfield sites in the UK, with the Environment Agency estimating that that there may be up to 33,500 contaminated sites in England and Wales alone (Environment Agency, 2005). Similarly, a report by Communities and Local Government

outlining, results from the National Land Use Database, estimated that in 2006 there were 62,700Ha of land suitable for redevelopment of which, 34,900Ha were vacant or derelict (CLG, 2007).

The large number of sites, together with the inherent toxicity of many of the contaminants and the policy requirement to reutilise brownfield sites, raises concerns regarding the potential public health implications of exposure to the contaminants contained on such sites and methodologies for mitigating health risks. Indeed, it is estimated that between 5-20% of sites in England and Wales may require action to ensure that unacceptable risks to human health and the environment are mitigated (Environment Agency, 2005). Risks to human health from exposure to contaminated land to date have been tackled almost exclusively in the context of planning legislation as is the case here and/or through voluntary remediation by the appropriate person or persons, rather than through the contaminated land regime i.e. Part IIa of the Environmental Protection Act (1990).

This paper discusses how a grossly contaminated waste tip site in South Wales has been remediated through the planning process and subsequently reutilised for housing development and public open space. The paper describes the contaminants involved, the novel strategy employed for mitigating the risk and the subsequent communication to the public.

The site

The Castlegate Development, located in Caerphilly, South Wales, is the site of the former Penrhos landfill, operated as a non-regulated waste tip between 1948 and 1968. Although a complete inventory is not available, historical records suggest that the site received a wide variety of industrial waste products, including solid wastes (rubber, glass, quarried shale waste), large quantities of Pulverised Fuel Ash (PFA), a range of organic compounds and drummed chemical and industrial waste principally from industrial sources. The drummed chemical waste was deposited into two excavations in the south central area of the site and it is reported that the drums were buried at depths of 3-6m with a covering of 2-3m of clay. After 1968, the site was only used for the landfilling of inert materials such as PFA, colliery spoil and sub-soils.

During the 1970s, a number of developments occurred bordering the site including the Glenfields housing estate to the east and the northern Caerphilly by-pass to the west. Planning permission was granted in September 2004 for the Castlegate development, an area of approximately 26 hectares for the building of approximately 500 houses and areas of open land for amenity purposes.

Site investigation

The site investigation consisted of a desktop study of all available information and site reconnaissance using nonintrusive and intrusive techniques. The desktop study served to collate information pertaining to a number of intrusive investigations conducted since 1972, which examined the nature, distribution and extent of contamination present. A subsequent geo-physical survey using magnetic gradiometry identified the presence of buried metallic drummed waste in areas of made ground at depths deeper than the initially proposed remediation works. Subsequent excavation pits identified in excess of 100,000 tonnes of drummed waste and contaminated material.

Further intrusive site characterisation involved the digging of machine excavated trial pits, 17 rotary boreholes and 25 shell and auger boreholes to investigate further the depth and extent of chemical drums and the hydrology and chemical characteristics of the area. Excavations were evaluated through a combination of visual assessment, on-site monitoring of volatile organic compounds (VOCs) emanating from the waste, solid sampling of the excavated materials and laboratory analysis of a suite of organic and inorganic contaminants.

Risk assessment

The conceptual model identified several potentially significant pollutant linkages. Analysis of soil samples taken from trial pits and boreholes identified a number of potential Contaminants of Concern (COC), the presence and distribution of which varied across the site. The analysis identified the principal soil contaminants as a suite of volatile and semi-volatile organic compounds and heavy metals, which are shown in Table 1.0.

Arsenic	Copper	Nickel	Zinc	1,2-Dichloroethane
Trichloroethene	Vinyl Chloride	1,3-dichloropropane	n-propylbenzene	1,3,5-trimethylbenzene
1,2,4-trimethylbenzene	Sec-butylbenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	Naphthalene
Isophorone	Acenaphthylene	Acenaphthene	Fluorine	Pentachlorophenol
Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo-a-anthracene
Chrysene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene	Benzo(g,h,i)perlene	Aniline	Benzoic acid	

The developer undertook a detailed quantitative risk assessment (DQRA) and developed a conceptual model for the site considering two principal scenarios of exposure to contaminated soil or groundwater. The first alludes to exposure during site excavation, preparation and construction (risks to construction workers and other site visitors) while the second scenario examined postdevelopment risks to occupiers and maintenance workers. The conceptual model identified six potential completed pollutant linkages using these two scenarios, including direct exposure to soil and ingestion, inhalation of contaminated dust (indoors and outdoors) and VOCs.

Utilising the Risk Based Corrective Action (RBCA) risk modelling tool amended to take account of UK guidance and statistical analysis, the developer calculated Site Specific Target Levels (SSTLs) for the COCs. The model identified that arsenic, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, vinyl chloride, 1,2-dichloroethane, 1,2,4- trimethylbenzene, aniline and acetophenone over various parts of the site required remedial action as they were present in concentrations that exceeded the SSTLs and therefore posed an unacceptable risk to human health. With regards to the risk posed by volatilisation of contaminants from groundwater to outdoor or indoor air, elevated levels of benzene were identified as an unacceptable risk on a small area of the site, as the monitoring indicated that the levels exceeded the SSTLs.

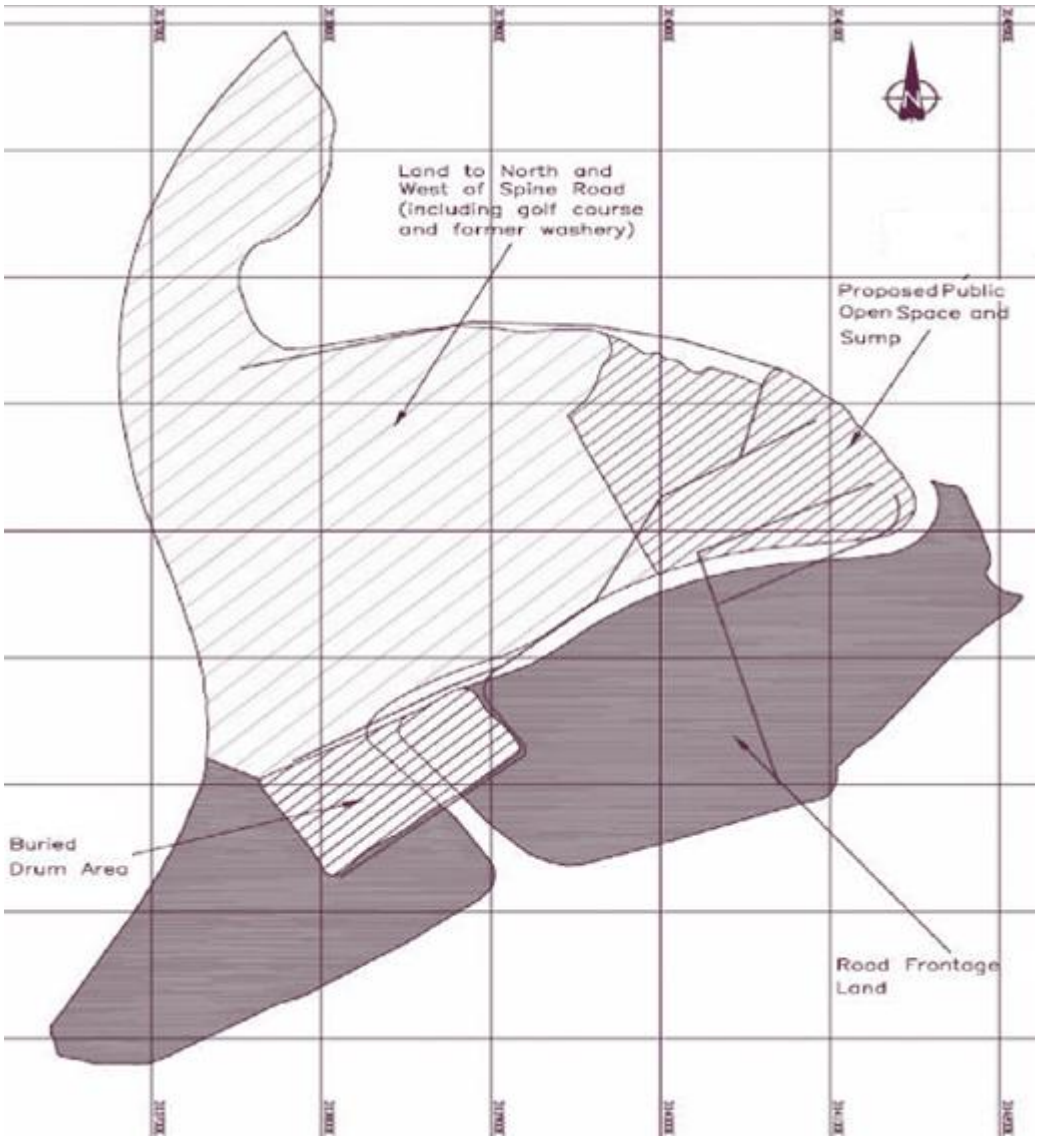
The risk assessment and conceptual model identifying the COCs and the potential pollutant linkages formed the basis of the remediation strategy.

Remediation strategy

A remediation strategy at a cost of £15 million was produced which involved excavating 140,000 tonnes of contaminated solid waste and 6 million litres of contaminated water and liquid waste. In addition, as a further safeguard, the remediation strategy identified the need for the insertion of a horizontal capillary vapour barrier break layer across the site, together with gas protection measures in all of the houses on the development. It is believed that this was the first time that

such a capillary break layer had been used in the UK as a public health protection measure for remediation of contaminated land. Once the barrier was installed, the whole site would be covered with clean imported material.

The objective of the remedial works was to remove contamination presenting a potential risk to human health and the environment. To achieve this, all contaminated solid and liquid waste was to be removed from the two principal waste cells identified in the southern part of the site and any other materials deemed as 'contaminated' based upon the SSTLs for the identified COCs. The site investigation, together with the risk assessment, identified the four main areas of the site which required detailed remedial work as being: i) the buried drum area; ii) land to the north and west of spine road; iii) road frontage land and; iv) the 'sump' and public open spaces (see figure 1).



Remediation of the buried drum area was required to prevent leakage of any chemicals that they may contain. In addition to drummed waste, the area contained gross organic liquid and solid contamination confined to two cells formed in low permeability material. The remedial works for this area required the excavation and disposal off-site of all the contaminated waste material within the two cells. On completion of the excavation, the resulting void was backfilled to 500mm below proposed finished ground level with clean imported fill material. To facilitate

excavation, this area was de-watered with the collected waste water passing through a treatment system before being discharged under consent. This was implemented prior to and during the excavation works, as necessitated, by ground conditions and the volumes of perched water encountered.

The land to the north and west of Spine Road (figure 1) comprised localised areas of shallow contamination. The remedial works for this area included excavation of all significant contamination associated with drummed waste by the geophysical survey and excavation and removal of contaminated material from the top 2m of made ground. In the road frontage land area (figure 1), the primary remedial works concerned improving the geotechnical properties by excavation, overturning and compaction. The works required for the 'sump' and public open space areas involved the excavation and removal of the top 1m of contaminated materials and backfilling with clean imported material to final-finish level. The remainder of the site was excavated and contaminated materials removed, with the land being backfilled and compacted. Although the developer undertook thorough site investigation works and subsequent excavation of the site, concerns regarding the limitations of the geophysical survey remained. As the physical limitations could mean that additional drums at depth remained undetected and any residual drums were likely to contain hazardous chemicals, it was apparent that there was a potential risk to public health. Accordingly, in order for the developer to satisfy the planning conditions, it was necessary to include further measures to protect the health of future site occupiers from exposure to any volatile organic vapours that could potentially leak from the undetected buried drums. The developer therefore decided on two further remedial actions, namely to utilise novel technology establishing the installation of a horizontal vapour barrier across most of the site as an additional protection measure and to install gas protection measures in all houses. This technology, as far as we are aware, has not previously been used as a protection measure on a remediated site to be used for a residential development.

Horizontal vapour barrier

A horizontal vapour barrier was designed by Sladen Associates (2004) and proposed for areas of land to the north and west of the site with identified contamination and deep made ground, together with all of the proposed public open space (figure 1). The purpose of the barrier is to remove the pathway for volatile organic compound (VOC) vapours that may be present at depth migrating to the surface and to prevent vertical migration of contaminants dissolved in groundwater into overlying soils. The consultants considered a number of options in the design stage but the primary design requirements were agreed as robustness, longevity, ease of installation and ease of restoration following any disturbance.

On undertaking feasibility modelling studies into the different types of barrier designs available, it was concluded that only an engineered soil barrier met the basic requirements of the selection criteria. Based on the conceptual model laboratory tests were carried out on potential materials for use in the barrier, testing for grain size, mineralogy and suction characteristics. Accordingly, a pulverised fuel ash (PFA) sourced from a local power station was selected.

The vapour barrier consisted of four layers of material in sequence. The base layer was comprised of a 150mm layer of 6mm stone acting as a capillary break by ensuring a low negative water pressure. Above this was laid a 100mm quarry dust layer, which will reduce the risk of contamination to the vapour barrier layer; next, a 200mm PFA layer which acts a barrier to vapour migration and remains close to saturation during periods of little or no rainfall. Finally, a top layer of a 100mm quarry dust was laid, designed to reduce the disturbance to the PFA

layer and enabling a wide range of backfill materials to be used without impacting on the performance of the vapour barrier.

All areas for construction of the vapour barrier were dynamically compacted and the ground was graded and rolled in preparation for application of the barrier. Materials for each layer were tipped across the site and spread and compacted to the specification thickness. In areas of proposed housing, the depth of the upper surface of the vapour barrier was set at a minimum of 2m below the proposed development level in order to avoid drainage and service corridors for the development. Once the vapour barrier was completed, the whole site was backfilled to restoration level with excavated material from the site and completed with 500mm of clean imported material.

The vapour barrier was designed to establish a zone of water saturation above the level of the natural water table through the use of an engineered permeability contrast in soil layers. This serves to reduce the potential for migration of volatiles by the presence of a permanently saturated layer. This technique is based on the principle that gas moves through the soil by the processes of advection and diffusion. The rate of advection through the soil is controlled by the gas permeability of the soil and requires a positive pressure difference. The gas permeability of soil reduces rapidly with the degree of saturation and when saturation exceeds 85% most soils are effectively impermeable to gas.

Environmental monitoring

During the works, environmental monitoring was undertaken by the consultants for dust, vapours and health monitoring of workers. Additionally surface and ground water was monitored. This was carried out in accordance with the Sampling and Monitoring Method Statement adopted by the consultants in collaboration with the local authority. Dust and vapour monitoring was undertaken as part of the strategy to protect the workers on site and the wider public health of the nearby receptors during excavation of the site. This involved the use of personal monitors for staff on site and a rigorous monitoring regime using fixed monitors at the site boundary and portable monitors around the site work areas. The results from this monitoring indicated that there were a few occasions when the concentrations of volatile organic compounds in the ambient air exceeded the tentative trigger levels, which were based on Workplace Exposure Limits as set out in EH40 (HSE, 2005), especially during excavation of the buried drum waste area. The tentative trigger levels were set for VOC vapours and were used simply as a guide by the contractor during excavation of hotspots. If the levels were breached, work would cease until the levels returned to below the trigger values. Dust monitoring results indicated that the occupational exposure limits (OELs) were never exceeded on site and the average dust levels were between one and two orders of magnitude below the OEL. The results therefore indicated that it was unlikely that the vapour and dust emissions emitted during excavation of the site would impact adversely on public health.

Prior to and during the remediation works, the quality of surface and groundwater at and immediately adjacent to the site was monitored. The objective of this monitoring was to assess and minimise any potential impact on local water resources. The results of the water quality monitoring indicated that there were no significant changes in water quality at any of the local water resources during or immediately after site remediation works. However, longterm impacts upon water quality can only be determined by ongoing monitoring; hence development of the post works strategy.

The consultant in conjunction with the regulators developed a post-works monitoring strategy to help corroborate that site conditions at key receptor locations were consistent with expectations. The strategy briefly comprises quarterly monitoring of surface and groundwaters, drainage waters, ground gas and vapour barrier moisture content. The site contains 27 ground vapour monitoring wells, 10 groundwater monitoring wells and 16 vapour barrier layer moisture content monitoring locations. There were also three designated surface water monitoring points and two drainage monitoring points.

Discussion

It is believed that this was the first time that a horizontal capillary break layer as a vapour barrier had been used in the UK as a public health protection measure in terms of remediation of contaminated land for housing development. The use of this technology as part of the remediation process was very much a 'belt and braces' approach because even though most, if not all, of the drummed waste had been removed it could not be categorically guaranteed that there were no undetected drums still buried on site. This therefore raised a number of issues from the public health team with regards to the robustness of this technique, including the limitations of using such a novel technique and the models used for validating the design of the adopted engineering solution. This involved a number of questions being submitted to the developer in order to satisfy the public health teams concerns.

As it is essential that the vapour barrier remains saturated in order for it to perform its role preventing the migration of vapours upwards through the soil, concerns were raised with regards to the validation of the model used for residential development. The model was validated by assessing the performance of the barrier under worst case scenario conditions where a theoretical source of VOCs occurred underneath a house. The model results indicated that even under extreme climatic conditions such as periods of low or high rainfall, the barrier remained saturated and VOCs could not penetrate through to the surface. The validation of the model therefore provided the evidence that theoretically the barrier should work.

There was some concern about the safety factors built into the model in relation to changes in meteorological and hydrological conditions and the likely effect on the performance of the vapour barrier should saturation fall below 100%. The developer, however, proved that the vapour barrier did not fall below 100% effectiveness during any of the simulated model runs. The model utilised 20 year rainfall and potential evaporation data for the site and four-year simulations were run under a number of scenarios including an 'extreme drying case for 2-3 years'. The resulting model runs showed that the vapour barrier performance remained the same as the normal year model runs when comparing these extreme worst cases scenarios. Therefore, it is unlikely that any extreme climatic conditions will cause the failure of the vapour barrier and allow any vapour migration to the surface.

The issue of appropriateness of this technology and its previous uses in other residential developments was also raised. The developer addressed this issue by providing four examples where the use of vapour barriers has been successfully used as a remedial technology in housing developments. It was, however, acknowledged that this was the first time that a vapour barrier had been used in the UK.

Monitoring of the barrier was proposed as part of the post work strategy, although there was no indication of the time period that the monitoring would cover and it was suggested by the public health team that monitoring should be carried out for a minimum of a 10- year period post

remediation. This time period was chosen as this would allow many of the climatic conditions that were used in the model to be realised and in turn allow the validation of the model results and provide reassurance to the site occupiers that the vapour barrier is working effectively.

It was proposed by the developer to extend the vapour barrier to 10m beyond the areas where there was a possibility that residually contaminated ground might remain. This raised the concern related to the placement of the vapour barrier and how the 10m extension had been calculated and whether this would provide adequate protection to those areas where the vapour barrier was not present. The public health team were not convinced that the 10m overlap of the barrier had been scientifically justified. However, following discussions with the developer's consultants, it was eventually agreed to extend the barrier to the whole of the area where residual ground contamination could remain.

Detailed discussions also took place with regards to the depth of the barrier which took into account tree root penetration and any possible digging and excavation in gardens by home owners and through excavation of utility services on the development. As the barrier was to be two metres below the final restoration height, it was considered to be well below the depth for garden use or the digging for the laying of any foundations. In addition to this and as a further precaution, the planning consent removes any permitted development rights. The construction of extensions, etc. will therefore require planning permission. Also, when land registry searches are undertaken on these properties, the searches will identify the presence of the vapour barrier. Finally, it was recommended by the public health team that in addition to the added protection that the vapour barrier provides, all residential housing built on the site should have approved gas protection measures complete with passive gas venting.

Risk communication

Residents of housing adjacent to the development were concerned about the effect the remediation works would have on their health and therefore they formed an action group. The group took their concerns about exposure to odours and dust to the Local Health Board. The group requested that the Local Health Board set up a health register similar to the format of the cancer registry. In consultation with the Health Protection Agency and the National Public Health Service for Wales, it was agreed that it was not appropriate to set up a health register as the monitoring results from the site indicated that there were no exceedances of any assessment levels for any prolonged periods of time. The exceedances refer to a short-term acute period and the medical advice was that that there would be no long term sequela from such an exposure.

As is the case with many scenarios involving remediation of contaminated land sites, the risk communication strategy for nearby residents is often difficult and needs to be seen as open and transparent in its approach. The public health team in collaboration with the local authority were in this case involved in communicating the risks that the excavation works at the site would have on the health of the nearby population. This was done via a series of letters, meetings and drop-in centres, the purpose of which were to keep the residents informed and allow them to voice their concerns and ask questions of the relevant professionals.

One issue that became apparent to the public health team was the lack of trust between the community and the local authority, so it was important that the involvement of the public health specialists was seen as independent and impartial, in order to gain the trust of the community in any advice that was given. The public health team devised and implemented a risk

communication strategy that kept the local community informed and updated with regards to the site remediation. The developer held liaison meetings with local residents covering all aspects of the proposals with regards to development of the site, covering a range of health concerns. The concerns from the residents specifically raised regarded the health effects from odours that migrated off-site during the site excavation and remediation. The planning permission granted required the developer to address any odours that would arise from the development of the site. The developer therefore implemented an environmental monitoring programme as required by planning conditions in conjunction with an occupational monitoring programme of on-site staff. Site works were also scheduled to ensure particularly odorous excavation areas were not excavated during days when the prevailing winds were in the direction of the nearby residential estate. Deodorising sprays were also used as an additional measure of protection on the site during the excavation works.

Conclusions

Given the pressure to re-develop brownfield sites, all forms of remediation options must be considered. During periods of rapid increase in land values such as those experienced in recent years, even grossly contaminated sites costing many millions of pounds to remediate can be seen to be economically viable to redevelop. Local authorities have responsibilities to ensure that the remediated land does not present a risk to existing or future residential or commercial occupiers. It is essential that public health professionals are consulted in contaminated land development schemes, particularly when untested novel technology is employed, in order that the risk to future users can in the long term be considered in the public health context. In the case of the Castlegate development, there were many uncertainties relating to the site where tipping of waste occurred before legislative controls were in place and therefore no full records of contaminants that were tipped there or at what depths were available. This in turn led to issues of uncertainty with regards to public health protective measures and additional measures were installed as a safeguard to public health over the lifetime of the development. For other similarly contaminated sites, there may be comparable issues around accuracy of records of chemical contaminants and knowledge of migration of pollutants over time. Where it is not possible to determine the level of contamination of a site because of the limit of detection of non-intrusive investigations, the additional protection measure of including an effective vapour barrier system should be considered. If such barriers are considered, site specific assessments need to be undertaken, which should include geology, hydrogeology and local availability of possible materials for use in the vapour barrier. This is essential when there is a risk of migration of vapours from soil to atmosphere in order to ensure the protection of the health of future users of the site. Although the remediation and risk communication strategy was a success in this case, the outcomes could have been improved if the public health team was engaged at an earlier stage of the process in order to have a greater input into the site risk assessment and remediation strategies.

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Abstract

The Tate Modern Art Gallery (London) hosted the Shibboleth installation between October 2007 and April 2008. Doris Salcedo, the artist, created a crack in the floor of the Turbine Hall some 167 metres in length, up to 100mm wide and over 300mm deep in places. During the exhibition a number of visitors were injured falling over the crack.

There are legal standards for the safety of floors in the Workplace (Health Safety and Welfare) Regulations 1992 and general duties of care in the Health and Safety at Work Act 1974. These are designed to prevent people being exposed to hazards and being injured. In the context of the arts how do duty holders and environmental health practitioners (EHPs) balance practical and sensible risk management against the legal requirements without reinforcing perceptions that heath and safety is unnecessarily bureaucratic?

At Shibboleth, would legal intervention by EHPs have resulted in further negative publicity or could it have been used positively as an example of good health and safety management?

The problem of striking the correct balance between health and safety and art is not unique to the Shibboleth at the Tate Modern; the Diana Memorial Fountain in London was associated with a number of injuries in 2004 and was temporarily closed for remedial works. The author concludes that the Shibboleth installation breached statutory requirements and the Duty Holder should have implemented further measures to prevent people being exposed to the hazard. EHPs should have been prepared to take appropriate enforcement action.

In this paper the relevant law is systematically reviewed and the options open to duty holders and EHPs who face making similar judgements in the future is discussed.

Key words: Environmental health; floors; health and safety enforcement; legal requirements; Shibboleth; slips and trips; sensible risk management.

Introduction

“I am surprised that health and safety haven’t closed it”

While visiting the Tate Modern in November 2007 to view Shibboleth, the author overheard two visitors discussing the installation. One said: “I am surprised that health and safety haven’t closed it”. When the author introduced himself as a ‘safety officer’ the other visitor responded “But it’s art!”. The response implied that art is sacrosanct and cannot be corrupted with such mundane considerations as health and safety.

However health and safety was important. The Times newspaper reported on 26 November 2007 that 15 visitors to the installation had been injured in the first month of its opening (Times, 2007). This was not the first work of art to cause safety concerns. The Diana Memorial Fountain in Hyde Park was closed for remedial works within a few days of opening in July 2004 after a number of people slipped and were injured (Times, 2004).

The warning 'Danger of Falling' was displayed at the entrance to the Shibboleth installation. The warning was necessary because Doris Salcedo, who created Shibboleth had "opened up a long, snaking crack across the vast length of the Turbine Hall, fracturing the concrete floor, her work strikes at the very foundations of the museum....Gouging open the very ground that we walk on" (Tate Modern, 2007). Members of the public and gallery staff were able to walk on the floor of the Turbine Hall and freely interact with the installation.

Health and safety is presented by elements of the media as being over prescriptive and protective towards minimal risks. For example The Times reported on 5 February 2008 of a pancake race being tossed aside after 600 years by health and safety rules (Times, 2008). In some cases, such as the Shibboleth, it is difficult for duty holders and EHPs to achieve a sensible balance between the expression of the arts and the protection of people from risk. Whatever Shibboleth represented artistically, it was, in reality, a huge crack in the floor.

The Health and Safety Executive (HSE) launched Sensible Risk Management in 2005 with a view to understanding the issues that appeared to be behind the proliferation of popular stories that were focusing too much attention upon trivial risks and unnecessary bureaucracy and distracted attention from the risks that cause real harm and suffering (HSE, 2005).

This paper considers aspects of flooring safety arising out of the Shibboleth installation and explores whether the arts are exempt from health and safety regulation, and if not, what provision may apply. This is followed by a review of relevant case law and how it might apply to the Shibboleth.

Are the arts exempt from health and safety regulation?

The arts cover a wide range of different forms of expression presented in an equally wide range of ways and places, so there is no simple answer. The question needs to be considered on a case by case basis.

The 'practice or presentation of the arts' are allocated to local authorities for enforcement under Schedule 1 of The Health and Safety (Enforcing Authority) Regulations 1998 (UK Government, 1998) but it does not follow that all art is subject to health and safety regulation.

What is art?

It is not possible to give a succinct definition of art and many eminent philosophers have written extensively on the subject. Leo Tolstoy (Tolstoy, 1896) wrote a book called What is Art? in which he developed a series of definitions including:

'The activity of art is based on the fact that a man, receiving through his sense of hearing or sight another man's expression of feeling, is capable of experiencing the emotion which moved the man who expressed it'

and

'It is upon this capacity of man to receive another man's expression of feeling and experience those feelings himself, that the activity of art is based'.

The key to determining whether any particular artistic endeavour is subject to health and safety regulation is to establish if a 'work activity' is involved. If there is, then the Health and Safety at Work etc Act 1974 will apply (UK Government, 1974). For there to be a work activity someone has to be employed or be acting in a self employed capacity.

In establishing whether there is a work activity, it is necessary to consider this in its widest sense. Many places, such as at the Tate Modern, are obviously a workplace as people are employed. For example, stewards in the Turbine Hall assisted visitors and oversaw their interaction with the exhibit. The Turbine Hall with the Shibboleth crack in the floor is their 'workplace'. Although it is the crack (Shibboleth) that is being exhibited, the room itself should not be treated any differently to a more traditional art gallery. Such galleries would fall within the definition of a 'workplace' and the Turbine Hall is no different.

In other instances there may be a mixture of work and non-work activity involved in an artistic endeavour, for example, an amateur dramatic society performing in a local commercial theatre. As people are employed to work at the theatre, the amateur production would be subject to health and safety regulation. The theatre is a workplace and booking the amateur group to perform is included in the broad remit of the theatre's undertaking, bringing with it the general duty of care to non-employees under Section 3 of the Act (UK Government, 1974).

However, the same amateur dramatic society performing the same piece in a local resident's garden would not be subject to regulation. Residential dwellings are not workplaces – Regulation 2 Workplace (Health Safety and Welfare) Regulations 1992) – and there is no work activity being undertaken as no one is employed.

Having established that there was a work activity being carried on at the Tate Modern and that the Turbine Hall was a workplace, further consideration can be given to the specific legal requirements.

What legal provisions apply to the safety of floors?

Legal responsibilities arise out of civil and criminal law and there are differences between their functions.

In the health and safety field, criminal law establishes obligations on duty holders to prevent exposure to injury. The law is enforced by statutory bodies such as the HSE and local authorities. Breaches of the law are prosecuted in the criminal courts and punishment levied against the duty holder. Victims of slip or trip accidents do not receive compensation for their injuries or financial losses under criminal law although these can be sought through a civil claim.

Criminal law

The main criminal provisions relating to floors are found in:

Health and Safety at Work etc Act 1974

Employers have a general duty to ensure, so far as is reasonably practicable, the health, safety and welfare of their employees (Section 2) and people who are not employees but who may be affected by their undertaking (Section 3) or use premises made available to them for work purposes eg. visiting workers and contractors (section 4). In an 'arts' context these duties may be considered as protecting gallery staff (section 2), the public (section 3) and visiting artists (section 4).

Workplace (Health, Safety & Welfare) Regulations 1992 (UK Government, 1992)

Specific requirements for floors are laid down in Regulation 12. Floors must be of suitable construction, be free from holes or slopes and not be uneven or slippery so as to be a risk to

health or safety [Regulations 12 (1) & (2)]. Floors should, so far as is reasonably practicable, be kept free from obstructions articles or substances which may cause a person to fall [Regulation 12(3)]. Regulation 5 requires the workplace, including floors, and equipment to be maintained. These regulations only apply to "workplaces", which means "….any premises or part of premises which are not domestic premises and are made available to any person as a place of work" [Regulation 2(1)]. Some workplace floors are exempt e.g. floors that are in aircraft, locomotive or rolling stock [see Regulation 3(3)].

Management of Health and Safety at Work Regulations 1999 (UK Government, 1999)

Risk assessments required by Regulation 3 would include flooring safety.

Civil law

Civil law provides for the compensation of injuries or loss incurred by a plaintiff. There are three common grounds for claims relating to slips and trips:

- Common law duty of care (negligence);
- Breach of the Occupiers Liability Acts – Occupiers Liability Act 1957/1984 and 1960 (Scotland) (UK Government 1957, 1960 and 1984);
- and Breach of statutory duty e.g. regulation 12 Workplace (Health Safety & Welfare) Regulations 1992 (UK Government, 1992)

Review of case law relevant to floors

All the case law reviewed arose from civil claims following slipping or tripping accidents. To date there have been no significant decisions in the higher courts following criminal proceedings.

What is a floor?

Not all surfaces that pedestrians walk on are covered by the Workplace (Health Safety & Welfare) Regulations 1992.

Regulation 12 applies to floors and traffic routes in workplaces. Traffic routes are defined in regulation 2(1) but floors are not. The definition of a floor was considered in the cases of Sullivan (1964) and Campbell (2004). The normal and ordinary meaning of a floor is the lower surface of an enclosed space such as a room but could be applied to surfaces on which people walk or stand. Therefore a floor can exist outside an enclosed space but it would have to be constructed or adapted for people to walk or stand on.

Does Regulation 12 of the Workplace (Health Safety & Welfare)

Regulations protect visitors to the Shibboleth? Regulation 12 applies to those who were employed at the time of their exposure to the risk but does it also apply to visitors? Visitors to the Shibboleth were either members of the public or were there in some capacity connected to their employment, e.g. teachers supervising a school trip.

- Members of the public. Initially a wide interpretation of the word ' person' in regulation 12 saw a number of successful claims by members of the public including Banna (1999) and O'Brien (1999), but the position was fundamentally challenged in the case of McCondichie (2003) and confirmed in Donaldson (2004) and (2005). In both cases the courts reevaluated the meaning of the word 'person' in light of the European origin of the

Regulations and decided that it did not afford protection to visitors who are not on premises as a consequence of their employment.

- Employed visitors. The definition of 'workplace' in regulation 2 encompasses employed visitors as it refers to, "any premises or part of premises which are not domestic premises and are made available to any person as a place of work". It is not necessary that the place used by an employee should ordinarily be used as a workplace; it becomes their workplace when they go to work there. This was explicit in the case of Clark (1998) who tripped over a bag of salt left on a footpath at an unmanned sewage works and was implicit in the case of Campbell (2004) who fell down an embankment. Campbell's case was dismissed because he could not prove the embankment was a floor, not because he failed to prove that the embankment was a workplace, albeit a temporary one.

Forseeability and the magnitude of the risk.

Does the risk of a slip or trip have to be 'foreseeable' to be the subject of regulation 12?

When considering a claim by McGhee (2002) Lord Hamilton said:

'The notion of risk imports a prospect and a prospect involves some measure of forseeability. What that measure is (or how in words or figures it should be expressed) may be debatable; but it appears to me to lie somewhere between a prospect of adverse affect to health or safety which is so remote as may be properly discounted and a likelihood in the sense of something which has more than even chance of coming to pass....'

In Marks and Spencer (2001) the court also considered the level of risk that was required to bring the case within the scope of the Regulations. LJ Waller stated: 'Taking in to account all the relevant factors in this context; that is to say the nature of the risk (i.e. here that the weather strip is by a door, that it is only 8- 9.5 mm high, that it is next to some steps that if the weather strip were tripped over a person may fall down the steps outside the door). But at the same time the assessment would hold that the weather strip was obvious, that it was in a place to be expected, and indeed this lady knew of it and there had been no complaints at all despite the number of exits that had taken place.'

Later he went on to say: 'The assessment would take into account the nature of the persons who are exposed to the risk. This lady, for example, was 63. The evidence was that she did not always walk picking her feet up, as perhaps she should have done, and the presumption must be that there would be a number of employees in Marks and Spencer such as this lady. But again the assessment would be that persons such as this lady had managed to exit without any difficulty.'

Lord Justice Schiemann stated: 'In law, context is everything. The context here is a shop, with it being expected that many people of varying degrees of physical mobility, in varying footwear and varying degrees of tiredness and attention, with varying amounts of bags and so on their person, will use this floor to walk on. But one has to bear in mind that these will be people who live, by and large, in the ordinary world, who walk on ordinary roads and who live in ordinary houses and move about in a way that we all do. The sort of slight rise which we have here occurs everywhere. One can hardly move for more than a few minutes without being exposed to whatever threat to health and safety such a rise may be said to constitute. The ordinary person

would not.... regard his ordinary walking about in the course of an ordinary day on such a floor as that with which we are presently concerned as exposing him to a risk to his health and safety.'

Marks and Spencer's appeal against the award of compensation was upheld.

The fact that no previous accident has occurred does not prove that there is no hazard, and this point was made in Brioland Limited (2005). Key differences between Marks and Spencer (2001) and Brioland (2005) relate to familiarity with the floor and the size of the trip hazard. Mrs Palmer (Marks and Spencer 2001) was familiar with the premises as an employee of 10 years, had used the exit on many previous occasions and the height of the weather bar was 8-9.5mm whereas Mrs Searson (Brioland 2005) was unfamiliar with the premises and the threshold was 27mm high. Mrs Searson's claim for compensation was upheld.

Warning signs

Warning signs were displayed at the entrances to the Shibboleth installation advising patrons of the risk of falling. Their presence was evidence of the duty holder's awareness of the hazard and therefore that there was a risk of injury. The use of warning signs has featured in a number of cases and the courts have made some relevant comments.

In the case of the Home Office (2004) the court stated that the presence of a warning sign did not discharge the burden imposed by the regulations, or relieve the defendant from liability for the breach of the regulation. It is not sufficient to warn people of the presence of a hazard and do nothing to remove the hazard. Lord Wheatley (Nisbet, 2002) referred to the use of signage in his judgement, saying:

'When there is an evident and obvious danger then certain duties of care will arise automatically and in effect contemporaneously with the appreciation of the danger. I can see no reason why the janitor should not be charged with a duty of immediately placing any available cones and warning signs around a wet floor, alerting those within the room from the outset as to the danger, as soon as he was aware that the floor was in a slippery condition.'

The judge's comments in Nisbet (2002) were made in respect of how the failure to warn of the hazard might be reflected in a judgement of negligence and any compensation awarded. In contrast the Home Office case (2004) dealt with a breach of statutory duty and the judge's comments make it clear that it is the employer's responsibility to remove hazards and not just warn people of their existence. The presence of such a warning may go some way to mitigate liability for a negligence claim.

How the law might apply to Shibboleth

Only the courts can give an authoritative interpretation of the law but responsible duty holders and EHPs make initial judgements about hazards, risks and compliance.

When duty holders and EHPs are seeking to achieve Sensible Risk Management it is important to consider the purpose of the criminal law. In McGhee (2002) Lord Hamilton stated that the primary purpose of the Regulations was the avoidance of harm to workers by the taking of measures in advance. This is in contrast to the function of civil law, which is the compensation of people following an accident. When duty holders and EHPs are considering how to address a prospective risk, the imperative is to prevent it and it is a criminal offence to expose people to the hazard, whether or not the harm arises. It is commonly expected, and easier to justify intervention or enforcement action following harm, but not beforehand. It is when duty holders

or EHPs take preventative action in respect of risks perceived (by some) as being minimal that the perception of health and safety as being bureaucratic is raised.

Criminal law and the Shibboleth

In the Turbine Hall, where Shibboleth was exhibited, employees were protected by sections 2 and 4 of the Health and Safety at Work Act 1974, regulation 12 of the Workplace (Health Safety and Welfare) Regulations 1992 and regulation 3 of the Management of Health and Safety at Work Regulations 1999 (risk assessments). Members of the public were protected by the duties imposed by section 3 and 'risk assessments'.

The court indicated in Marks and Spencer (2001) that regulations 12(1) & (2) should be taken together when considering the constructional suitability of a floor.

Regulation 12(1) requires the floor to be of such construction that it is suitable for the purpose for which it is used. The floor of the Turbine Hall is constructed from a power floated concrete which slopes down from the western entrance for about 50 metres with the remainder being level. Without the crack the floor would comply with the requirement as it was of sound construction, had adequate strength and was suitable for pedestrian traffic. However, the crack had been designed into the floor and was an integral part of its construction. It is not something that has arisen from a defect or from wear. Regulation 12(1) is written in a strict sense, in that it is not subject to being "so far as is reasonably practicable". Taken at its simplest the floor is either suitable or it is not.

Inevitably it will be in determining what is 'suitable' that legal argument will arise as in Marks and Spencer (2001) and Ellis (2007).

Is 'suitability' influenced by the tasks people are engaged in when walking on the floor? The Approved Code of Practice and Guidance on the Regulations – L24 (HSE, 1998) and a number of decided cases suggest that this is the correct approach to take (Marks and Spencer 2001 and Ellis 2007), so the suitability of the floor must relate to the underfoot needs of the user engaged in activities that can be reasonably foreseen.

Regulation 12(2) deals with holes in floors among other hazards. Floors should be free from any hole that exposes a person to a risk to his health and safety. How big does a hole have to be to present a risk taking into account the foreseeable use of the floor? A shallow hole may be sufficient to expose a person to a risk if it could cause a fall, for example, during manual handling. In the Shibboleth the crack was of such a size (100 mm wide and 300 deep) to present a hazard to pedestrians.

The fact that only a small number of staff were exposed to the hazards or that they had received training and instruction has no bearing on compliance with Regulation 12 (1) & (2). Compliance rests with the construction of the floor and not on other means of reducing the risk which might be argued under regulation 12(4).

Therefore duty holders and EHPs must address the question – "Is the floor suitable for the purpose for which it is being used?" Although Shibboleth was the focus of the installation, the floor in which it was installed was still part of a 'workplace' and public pedestrian area and should have complied with statutory requirements. If the Shibboleth crack was in a local shopping mall, the issue of suitability would be easier to determine. It is suggested that no one would accept the floor as being suitable in those circumstances and thus could be subject to a

Prohibition Notice as it would present a risk of serious personal injury from falling. Yet we hesitate to adopt this approach to the same hazard and risk when it is presented as being art.

Is suitability related to the number and type of people who use the floor? It must be a relevant factor in determining the likelihood of the risk materialising. The use of any area by members of the public brings a new set of risk factors such as a lack of familiarity with the area and disability (Marks and Spencer 2001). The public visited Shibboleth in their thousands and were therefore exposed to the hazard presented by the crack. Although the number of staff exposed to the hazard was significantly smaller, they were entitled to the protection of regulation 12.

Those attending the Shibboleth went with the specific purpose of seeing and experiencing the crack in the floor of the Turbine Hall. This must have a bearing on the way in which the "suitability" of the floor is considered. However the Regulation 12 requirement that the floor be suitable cannot be met by simply relying on the fact that everyone knows that there is a crack in the floor.

From an EHP's perspective Shibboleth exposed people to a real risk to their health and safety and therefore breached regulation 12 (1) and (2) Workplace (Health Safety and Welfare) Regulations 1992 and sections 2 and 3 of the Health and Safety at Work Act 1974.

Civil law and Shibboleth

Breach of statutory duty

Evidence that a floor was in breach of regulation 12 cannot be used to support a civil claim for breach of statutory duty unless that person was in employment (McCondichie 2003). A floor that complied with regulation 12 and was suitable for employees in a workplace should also discharge an employer's duties towards non employees under section 3 Health and Safety at Work Act.

None of the cases reviewed involved a claim for breach of statutory duty under the Management of Health and Safety at Work Regulations 1999 or under section 3 Health and Safety at Work Act 1974, yet both of these provisions specifically afford protection to non-employed persons.

Common law occupiers liability

It does not follow that a finding of breach of statutory duty will also result in the court finding in the plaintiff's favour for negligence at common law or under occupiers liability (Mackenzie 2007). There appear to be two reasons why this is so.

First, the statutory duty may not be applicable to that particular appellant (McCondichie 2003) and second, the courts appear to take a pragmatic approach as demonstrated in Jaguar Cars (2004).

If a finding were made in favour of the appellant, then the degree of 'contributory negligence' has to be assessed. Each situation is unique but it is likely that the mitigating factors outlined below would carry weight in favour of a higher level of contributory negligence being attributed to plaintiffs.

The courts may consider the following factors as being contextually relevant to the Shibboleth:

Aggravating factors

- The dimensions of the crack would have presented a significant hazard. It is not the sort of unevenness that people encounter in their everyday lives. [Marks and Spencer 2001]
- Very large numbers of people attended the installation and were exposed to the hazard.
- People were injured.
- Visitors were members of the general public with all the varieties of age and physical ability that accompanies them. [Marks and Spencer 2001]
- Public were unfamiliar with the building. [Brioland 2005]
- There must have been a real risk of people being seriously injured. (High likelihood of serious injury) [McGhee 2002]
- Natural curiosity predicts that people would try to insert feet into the crack. People do not look where they are going. [Anderson 2002]
- Risk assessment had identified the hazard, warnings were displayed but no other physical methods to prevent injury were implemented.

Mitigating factors

- People specifically visited the Gallery to view Shibboleth and were aware of the presence of the crack.
- A risk assessment had been undertaken and the hazard identified.
- Warnings were displayed. [but refer to Home Office 2004]
- Stewards were employed within the Turbine Hall.

What could have been done to prevent falls at the Shibboleth?

Was there any reason why standard approaches to trip risk reduction could not have been utilised at the Tate Modern, especially after it was known that people had been injured? The answer should be No, but again the 'artistic' dimension of the situation presents itself, as some of the possible interventions would have interfered with the artistic integrity of Shibboleth and the ability of people to interact with it.

The most obvious remedy for a crack in a floor would be to fill it in – but for obvious reasons that was not going to happen at the Shibboleth; however other possibilities were recognised by the Gallery including higher levels of control of entry, barriers or demarcation lines and Perspex bridging over certain sections (Times, 2007).

The Sensible Risk Management debate is not restricted to duty holders and EHPs. Members of the public have a view as they are affected by the decisions taken either because they are injured or their freedoms are curtailed by not being able to do something. Two responses to the Shibboleth debate were posted on the Times On Line website (Times OnLine, 2007) and highlight how 'health and safety' can be perceived as unhelpful:

'It also makes a comment on how people need to be coddled with safety warnings and guard rails everywhere. Common sense severely lacks today. If adults can't be responsible for themselves or their children, they shouldn't leave the house – where injuries can still happen'. Misha, Montreal, Canada.

‘Surely the fact that there is a man stood at the door handing out leaflets reminding visitors to 'watch their step', along with the fact that these people have turned up specifically to see the crack, is enough of a safety measure. The leaflet also asks parents to keep children under control. Anyone who then suffers injury as a result of some kind of negative interaction with the art should really not be allowed out in public.’ Matthew Gay, London.

Conclusion

- Shibboleth presented a long deep crack in the floor of the Turbine Hall at the Tate Modern. It was a work of art but also a real hazard to employees and visitors. Regulation 12 (1) & (2) Workplace (Health Safety & Welfare) Regulations 1992 sets the health and safety standard for the construction of floors with respect to employed persons, while members of the public were afforded protection under the general duty of care under section 3 of the Health and Safety at Work Act 1974.
- Considering all the circumstances of the exhibition, and having regard to the way that the courts have interpreted the law in civil cases, it is the author’s opinion that the floor breached regulation 12 (1) & (2) of the Workplace Regulations and Sections 2 & 3 of the Health and Safety At Work Act 1974.
- As members of the public were injured visiting Shibboleth, the Tate Modern could face litigation for possible failings under the Occupiers Liability Acts or at common law, but not in respect of breach of statutory duty under the Workplace (Health Safety & Welfare) Regulations 1992.
- EHPs deal with breaches of the law on a daily basis but not all result in formal action such as improvement notices, prohibition notices or prosecution. EHPs exercise considerable discretion and apply common sense with support by enforcement policies and protocols in ensuring a ‘sensible approach to risk management’.
- There is no doubt that in any other circumstances a floor presenting with a crack the size of the one in the Shibboleth would not have been tolerated, but because it was presented as a ‘work of art’, the appropriateness of the usual approaches adopted by duty holders and EHPs seem to have been thrown in to question.
- The purpose of the Health and Safety at Work Act 1974 and Regulations is to prevent exposure to hazards and subsequent injury. The hazard was evident and 15 people were reported as having been injured.
- The situation should not have been permitted and other measures to manage the risk should have been implemented by the duty holder. Where duty holders are reluctant to discharge their responsibilities, EHPs should take appropriate enforcement action. It is important to note that EHPs are not the final arbiters of health and safety; this responsibility lies with industrial tribunals and the courts and in contentious situations such as the Shibboleth, these bodies should be utilised more willingly to obtain an independent perspective on Sensible Risk Management .

The views expresses in this paper are personal and do not necessarily reflect the policy of the London Borough of Bromley nor is any criticism implied of any duty holder or EHP involved with the Shibboleth installation.

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Prevalence of the Hydatid Disease-causing tapeworm Echinococcus granulosus amongst stray dogs in south east Wales, United Kingdom - Simon D Swanton1 BSc (Hons) MSc FRSH MCIEH MRIPH MInst.LM and John D. Wildsmith2 MSc CMIOSH MCIEH

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Abstract

Hydatid Disease is the name given to the condition caused by the zoonotic tapeworm *Echinococcus granulosus*. The tapeworm spends most of its adult life in the intestine of its definitive host, namely canids and in particular the dog. The tapeworm eggs become voided in the canids' faeces and as a result of ingesting the eggs, infection passes to the intermediate host, commonly herbivores while grazing. However, humans can become accidentally infected and hydatid cysts may develop throughout the body.

In the United Kingdom, Hydatid Disease is endemic within the sheep farming communities of south Powys, Wales. In view of the levels of infection in the region, a scheme involving the worming of farm dogs was introduced in 1983 until 1989, when it was replaced with an education programme. As a result of the termination of the worming programme, recent research indicates a re-emergence of *E. granulosus* infection in farm dogs in the region and also bordering areas in south east Wales.

While the levels of infection amongst farm dogs have been monitored, the level of infection among non-farm dogs has largely been ignored. Of public health concern is the potential role of non-farm dogs in the transmission of infection, particularly stray dogs. This is because such dogs could have access to infected material, their faeces could contaminate the environment and they are unlikely to have been regularly wormed.

Between May and December 2006, faecal samples were collected from 857 stray dogs impounded by councils in south east Wales, which represented the largest sample of stray dogs for *E. granulosus* infection in the United Kingdom. The samples were laboratory tested for *Echinococcus* coproantigens using a sandwich ELISA method, and where necessary a specific PCR assay technique.

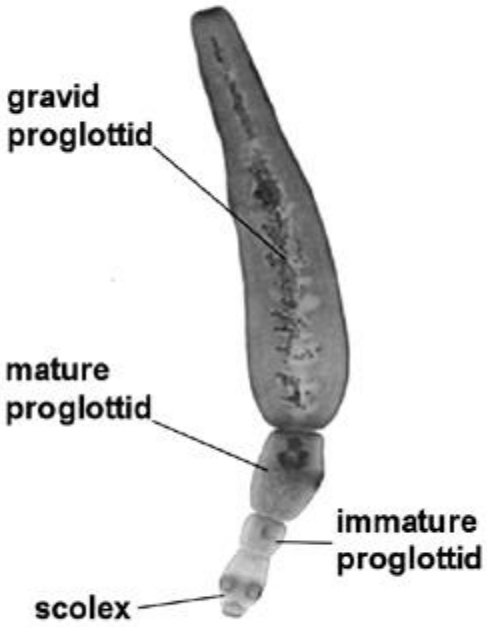
The findings of the research suggest that stray dogs do not appear to play a role in the transmission of *E. granulosus* in south east Wales.

Key words: Dogs; *Echinococcus granulosus*; echinococcosis; environmental health; G1 genotype; Hydatid Disease; hydatidosis; sheep; Wales.

Introduction

Cystic echinococcosis (CE) or cystic hydatidosis is the name given to the condition caused by the zoonotic endoparasitic tapeworm, *Echinococcus granulosus* (Subclass Eucestoda; Order Cyclophyllidea; Family Taeniidae). It is a small cestode of approximately 2-7mm in length

(Figure 1.0). As with all members of the Family Taeniidae, *E. granulosus* requires two mammalian hosts for completion of its life cycle: a definitive (final) host which is always a carnivore and where the adult worm develops in the small intestine, and an intermediate host which is often a herbivore, where the cystic metacestode usually develops in the visceral organs (Thompson & McManus, 2001).



As *E. granulosus* has a low intermediate host specificity, infections have been reported from domestic and wild ungulates, particularly bovids, as well as primates, leporids and macro-pod marsupials (Meymerian & Schwabe, 1962; Thompson & McManus, 2001). In view of this, currently nine different host-adapted genotypes (G1 – G9) have been identified using mtDNA sequences, the majority of which are known to be zoonotic apart from the buffalo strain (G3), horse strain (G4) and lion strain (G9) (Thompson, 1995; Thompson & McManus, 2001; Eckert & Deplazes, 2004). In the definitive host, specificity appears to be far greater than at the intermediate host level although it is often the dog and other canids who act as the definitive host, apart from the G9 lion strain which only involves felids (Thompson, 1995).

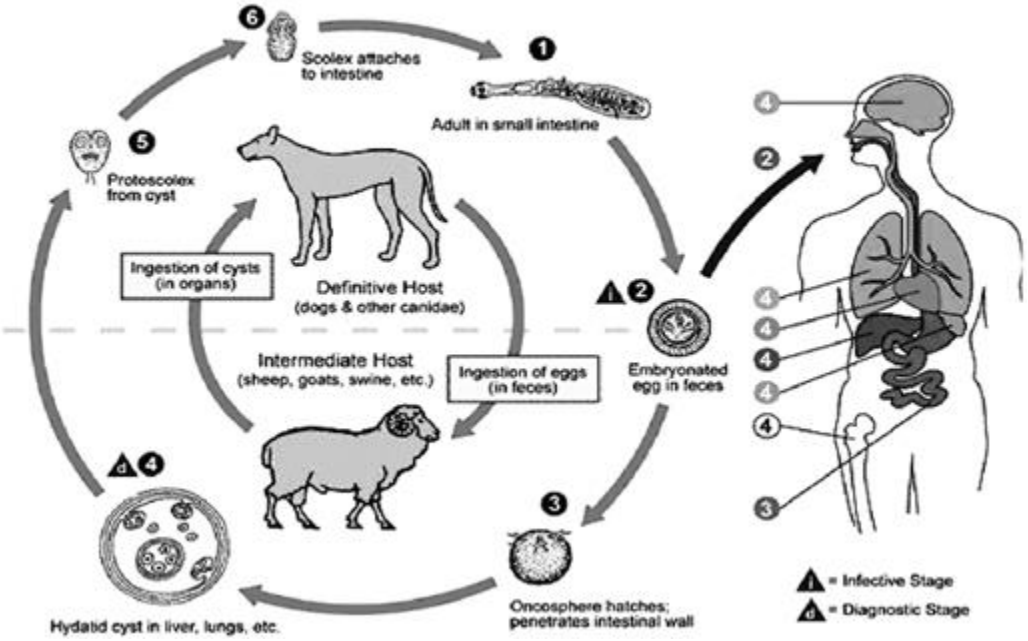
Although considerable research has been undertaken in relation to the factors responsible for the differences in definitive host specificity, the dynamics are still not completely understood (Thompson, 1995; Buishi *et al*., 2005a).

It is suggested that the gut microtopography (e.g. crypt and villous size) between species of the definitive host may be more suited to certain species or genotypes of *Echinoccocus*, and that the composition of bile between host species may also influence host specificity (Smyth, 1964; Thompson, 1995). Furthermore, it is also hypothesised that biochemical and nutritive factors as well as physiochemical and immunological characteristics play an important role in host specificity. To this end Thompson & Kumaratilake (1985) established that considerably more

worms initially parasitised Australian dingoes than domestic dogs even though these canids are closely related definitive hosts, thus indicating that the metabolic or physiological needs of this strain were better catered for in the dingo (Thompson & Kumaratilike, 1985; Thompson, 1995). Similar findings have been described by Walters & Clarkson (1980) who reported that research in south Wales determined that sheepdogs experimentally infected with the sheep strain (G1) of *E. granulosus* were more susceptible to infection than beagles (Thompson, 1995).

Further research also suggests that male canids are more likely to be infected with *Echinococcus spp*. than females (Budke, 2004), and that immunosuppressed definitive hosts are more susceptible to infection (Sato & Kamiya, 1990). Recent data also indicates that naturally-induced protective immunity may occur as a consequence of infection, thus resulting in considerably lower worm burdens in older Simon D Swanton and John D Wildsmith definitive hosts than those younger hosts who have not yet acquired any immunity (Lahmar *et al*., 2006).

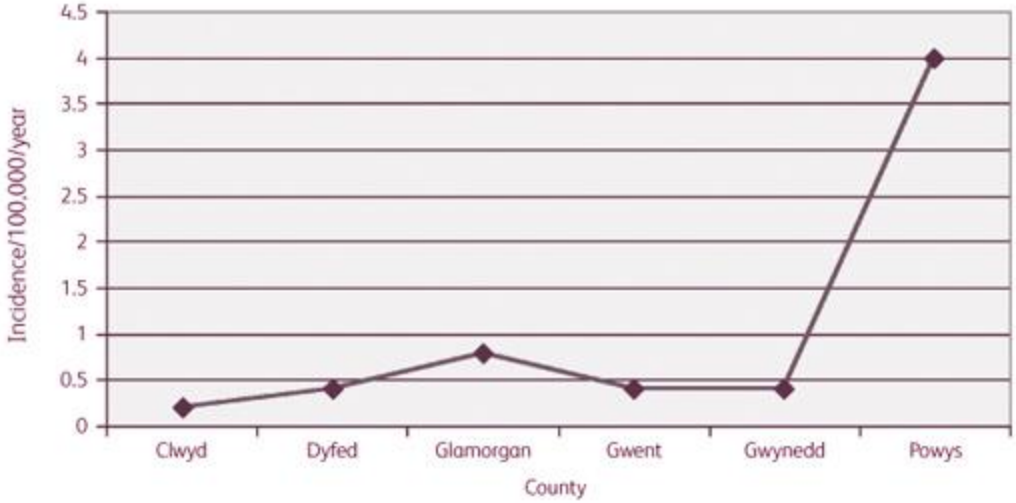
Although *E. granulosus* has sylvatic cycles, often involving wild carnivores and ungulates, it is the domestic cycles that usually involve dogs and farm livestock that are the most common and pose the greatest risk to human health. This is particularly true of the sheep-todog cycle involving the G1 genotype and there is clear evidence that communities involved in sheep farming harbour the highest infection rates of human Hydatid Disease owing to man's susceptibility to this strain (Gemmell *et al*., 2001; McManus *et al*., 2003; Craig & Larrieu, 2006). Humans become accidentally infected as aberrant (or accidental) intermediate hosts as illustrated in Figure 2.0 and cysts such as those shown in Figure 3.0 may develop throughout the body particularly in the liver and lungs, giving rise to the condition known as human Hydatid Disease or human cystic echinococcosis (CE) (Schantz *et al*.,1995; Anderson, 1998).



Human infection occurs because of the ingestion of tapeworm eggs present in canine faecal matter, after handling dogs or allowing dogs to lick the face following faecal/oral grooming behaviour. Thus, children through their playing habits are at particular risk from being infected by those tapeworm eggs present on the dog or those eggs present in the environment. Cysts have a variable growth rate ranging from 1mm to 31mm per year (Bell et al., 1988; Noble et al., 1989; Romig, 2003) and human infection may go unnoticed for a period of 10 years or longer, particularly as physical symptoms may not be apparent for up to 20 years.

Human Hydatid Disease impacts on health not only in terms of mortality but also morbidity (Ammann & Eckert, 1995). In view of its public health significance, human Hydatid Disease has been the subject of considerable research throughout the world and is considered by The World Health Organisation (WHO) as: "…. not only one of the most widespread parasitic diseases, but also one of the most costly to treat and prevent in terms of public health". (Eckert et al., 2001b, p.ix).

Within the United Kingdom two genotypes of E. granulosus are known to be present, namely the zoonotic G1 sheep strain and the G4 horse strain, which is not a known zoonosis. Human Hydatid Disease involving the G1 strain is endemic within two sheep farming communities: the Hebrides Islands of north west Scotland and the south Powys area of Wales. The heightened levels of infection in south Powys, as highlighted in Figure 4.0, resulted in the introduction of a voluntary hydatid control programme between 1983 and 1989.

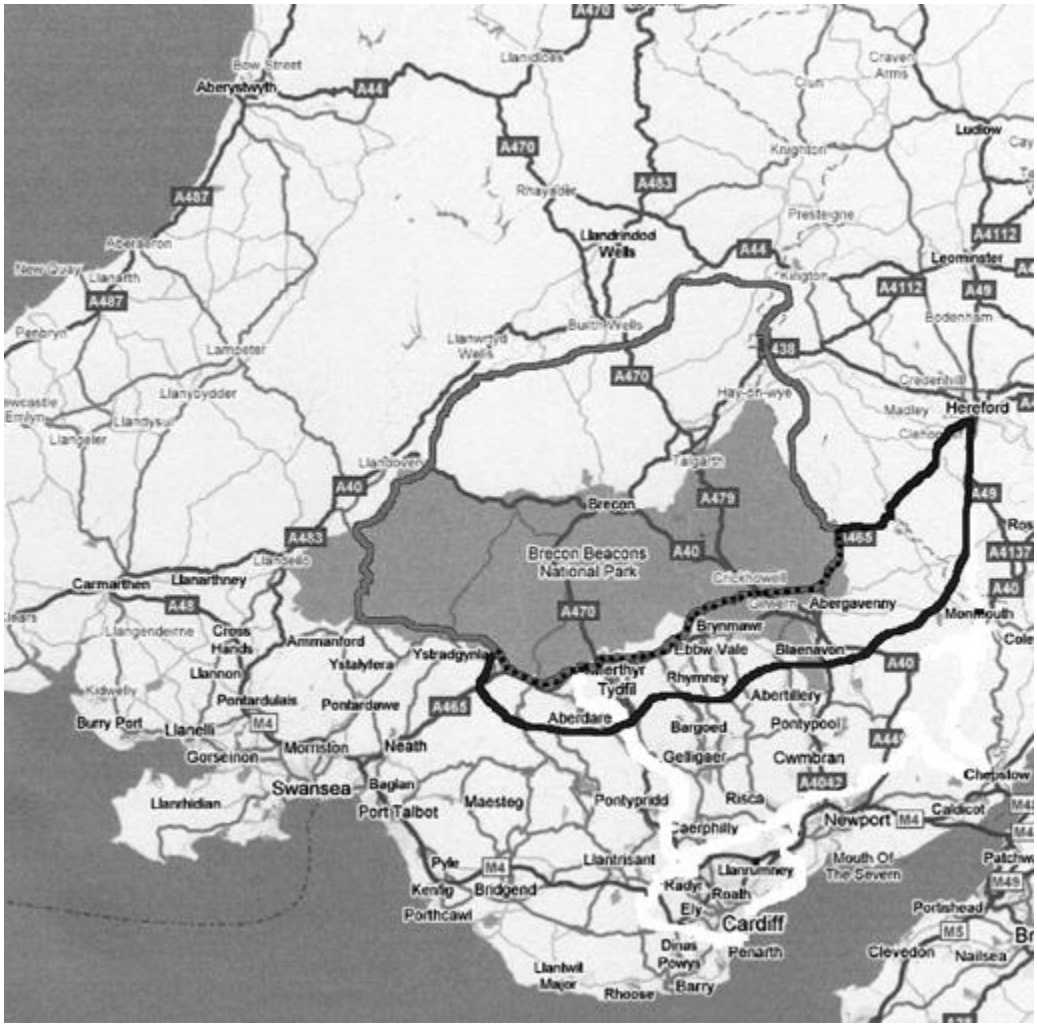


Regular worming of farm dogs with the anthelmintic medication Praziquantel (which readily destroys the worm within the canine host, thus breaking the lifecycle) was undertaken voluntarily by farmers who were provided with worming medication free of charge by the then Ministry of Agriculture Fisheries and Food (MAFF).

However, because of a lack of funding from the then Welsh Office, the programme was terminated and replaced with a health education programme (Lloyd et al., 1991; Craig et al., 1996; Buishi et al., 2005b). Recent research has suggested that following the termination of the control programme E. granulosus infection has re-emerged in dogs, with 6% of farm dogs in the previous intervention area and 24% of farm dogs in the non-intervention areas bordering south Powys positive for infection (Lloyd et al., 1998; Buishi et al.,2005b).

In addition to this, using sentinel lambs Lloyd et al., (1998) found that 5% of lambs in the former intervention area and 10% of lambs in the nonintervention areas were infected with E. granulosus, indicating that pastures were recontaminated. In light of these findings it is considered that the termination of the hydatid control programme was premature and the health education programme has largely failed to prevent re-emergence of transmission (Buishi *et al*.,2005b; Craig & Larrieu, 2006).

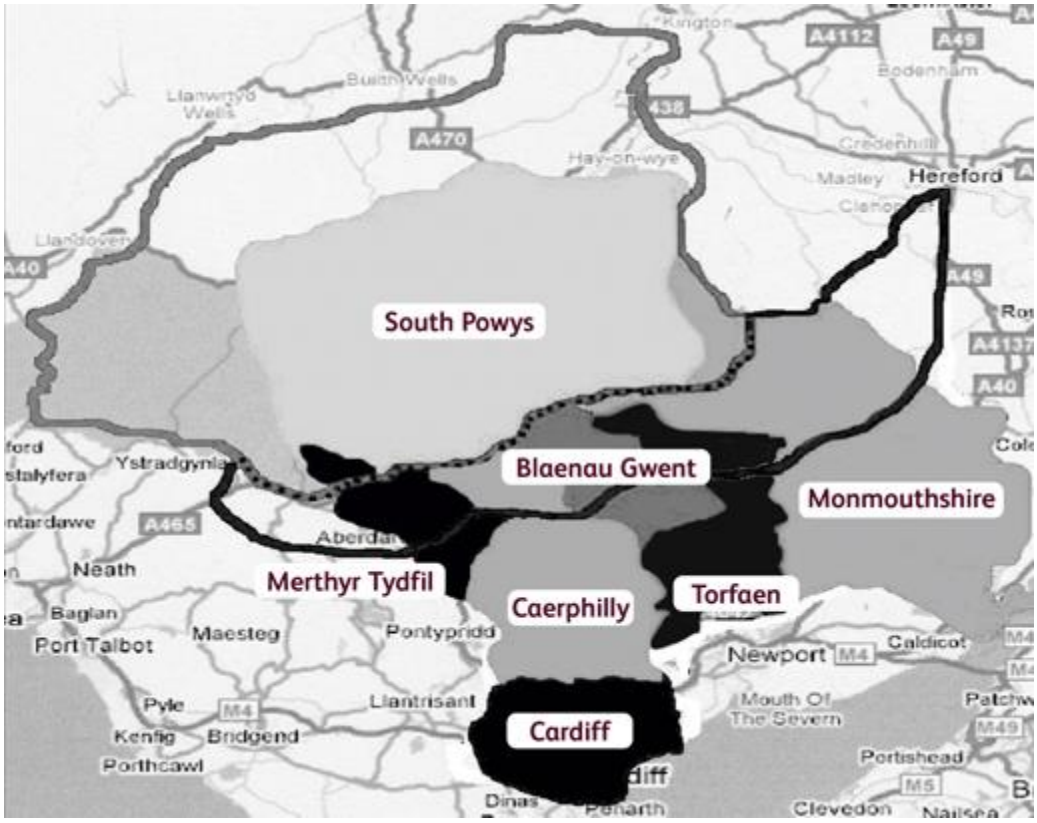
Furthermore, the research also identified a new focus of human echinococcosis for the period 1984 – 1990 in those areas of south east Wales which border the previous intervention area (Lloyd et al.,1991; Palmer et al., 1996; Buishi et al., 2005b). This highlights that human Hydatid Disease, although endemic in two specific areas of the United Kingdom, has the potential to emerge throughout the country, a concern identified by Edwards et al. (2005, p.782), who stated that “although the risk may be greatest in the sheep-rearing areas of mid and south Wales, infection could also be transmitted to other areas of Britain by the movements of infected sheep or dogs”.



In view of the potential for an upsurge in the prevalence of the disease in south east Wales, the Welsh Assembly Government has recently introduced a Hydatid Disease Eradication Campaign. However, while the re-introduction of a suitable control regime is necessary to address this public health problem, it must be based upon surveillance data that describes the occurrence and distribution of infection in all epidemiologically important hosts. This data is of fundamental importance as it establishes the importance of echinococcosis within a region and provides base line information for formulating a suitable and cost effective control policy (Gemmell & Schantz, 1997).

This is of particular importance in relation to canine hosts, as dogs and in particular stray dogs, have been identified as epidemiologically important hosts in other regions of the world. In light of this, control programmes initiated throughout the world that have not succeeded often cite the failure to effectively tackle canine infection as an important factor (Conchedda *et al*.,1997; Jiménez *et al*., 2002; Oku *et al*., 2004; Craig & Larrieu, 2006). The importance of determining infection levels among dogs is perhaps best summarised by Schantz (1997, p.79) who states *"because the infected dog is the direct or indirect source of infection for humans, the prevalence of canine infection is the most reliable indicator of the potential danger to humans. Surveys on the prevalence of canine echinococcosis are essential to define transmission patterns and to monitor the success of intervention measures designed to prevent infections in dogs"*.

Although surveillance of livestock infection through veterinary/abattoir monitoring is undertaken and human infection levels are obtained as a result of hospital reporting, data relating to canine infection has been scant. While considerable research has been undertaken in the south Powys area regarding the dog–sheep relationship, it has been focused on farm dogs owing to their access to infection through contact with sheep carcasses and/or through consuming infected offal as a result of home slaughter practices (Palmer *et al*., 1996; Buishi *et al*., 2005b). Thus, apart from a very small-scale survey in May 1996 which involved two dog pounds, no research had been undertaken in relation to levels of infection among non-farm dogs and in particular stray dogs. The levels of infection among the non-farm dog population were largely unknown and the role of such dogs in the transmission dynamics of this disease in the United Kingdom had not been quantified. The introduction of a control programme that has not been informed by a surveillance study to establish infection rates within the definitive host population is likely to be significantly compromised.



Accordingly, it was considered that the screening of stray dogs would provide valuable information regarding the levels of *E. granulosus* infection in non-farm dogs. Levels of infection in these dogs could be viewed as a 'worst case scenario' as they were unlikely to have been regularly wormed, may scavenge for food (which could include infected ovine material) and have unfettered access to public places where their faeces are not removed, and therefore, if infected, pose a significant risk to public health.

Methodology

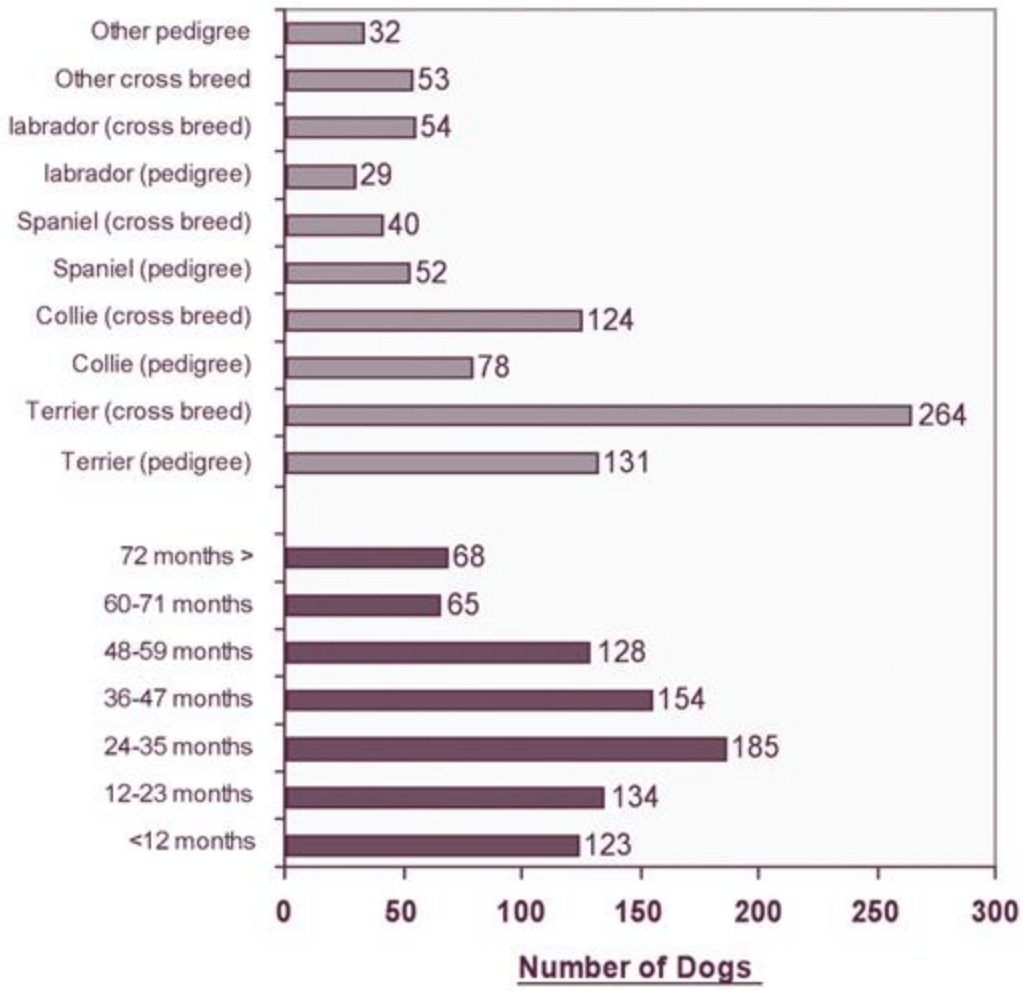
In order to assess infection levels of *E. granulosus* among stray dogs, considerable attention was paid in determining the most appropriate method of achieving this. Historically diagnosis of *E. granulosus* infection in definitive hosts has proved difficult because the eggs of all *Echinococcus* and *Taenia* species are morphologically indistinguishable from one another,

and the characteristic small segments of *Echinococcus spp*. may be absent from the faeces or can be easily overlooked (Craig, 1998; Eckert *et al*., 2001a). In view of this, two major diagnostic methods have been used in dogs, namely purgation with arecoline hydrobromide or arecoline acetarsol and necropsy of the small intestine (Eckert *et al*., 2001a).

Local Authority	Blaenau Gwent	Caerphilly	Merthyr Tydfil	Monmouth-shire	South Powys	Torfaen	Cardiff
Number of canine samples collected	127	216	56	64	29	132	233

Diagnosis in the canine definitive host has traditionally been accomplished through the administration of arecoline hydrobromide (2mg/kg) or arecoline acetarsol (3mg/kg) as a solution or tablet, and the identification of adult cestodes in the fluid faecal matter discharged after purging (Eckert *et al*.,2001a; Craig, 1998). Although this method is 100% specific, it is extremely cumbersome requiring veterinary attendance to administer arecoline, and in the event that a dog fails to purge, further dosing is necessary (Eckert *et al*., 2001a; Zhang *et al*., 2003). Schantz (1997) highlighted the disadvantages of inducing the purgation of dogs. In his Tunisian study only 68% of the dogs purged after the first arecoline dose and 12% of the dogs failed to purge after a second dose. A further limitation is that the arecoline test should not be used on pregnant bitches, young puppies or aged dogs, and occasionally fatalities have been reported following penetration of the intestine with previously consumed splinters of bone, which cause the intestine to rupture as a result of the force of the purge (Economides & Christofi, 2000).

Direct observation of the intestinal contents of the definitive host may be undertaken after necropsy, including a search for adult worms, which are best identified morphologically with a dissecting microscope (Ouhelli *et al*., 1998). However, intestinal examination is somewhat difficult when worm numbers are low (i.e. <50 worms), when tapeworms are immature and because the worm attaches between villi, resulting in only the posterior region of the worm being visible (Deplazes *et al*., 1994; Craig, 1998). Although this method remains a reliable and specific technique and has satisfactory sensitivity, it requires the dogs to be killed, which was considered rather extreme for the purposes of this study. Immunodiagnosis has progressed significantly in recent years and offers an alternative testing technique. It consists of two main approaches; namely serum antibody detection and the detection of parasite antigens in faeces which are known as coproantigens. Infection in the definitive host through serum antibody detection is a technique that has been the subject of considerable research. This method relies on the intimate contact between the scolex of the cestode and the mucosal layer of the small intestine of the definitive host, which was first highlighted by Smyth (1964). As a result of the interaction between the scolex and the mucosal layer an immune response in the form of hypersensitivity reactions may occur, which can be detected in vitro using an *E. granulosus* protoscolex antigen preparation in enzyme linked immunosorbent assay (ELISA) (Gasser *et al*., 1988; Gasser *et al*., 1993; Craig, 1998). This technique requires veterinary assistance in order to liberate samples from the dog and was not considered the most appropriate approach to determine current infection levels owing to the residual nature of antibodies (thus producing false positives) and the possibility of non or low responders to the test (Craig, 1998; Eckert *et al*., 2001a).



Coproantigen detection by ELISA has the advantage over serum antibody detection because of the high probability of correlation with current infection. To achieve this, definitive host faecal samples are obtained in vitro and analysed in the field or in a laboratory setting. Detection of specific *E. granulosus* antigens (coproantigens) in the faecal samples, which are a result of degradation products from the tapeworm, is obtained using the sandwich ELISA (Craig, 1998; Abbasi el al., 2003; Zhang *et al*., 2003). Although this technique has a specificity of approximately 97% when worm burdens are >100 worms, sensitivity levels are subject to some debate with suggested sensitivity levels for natural canine *E. granulosus* infection ranging from 60% (Deplazes *et al*., 1994; Jenkins *et al*., 2000; Abbasi *et al*., 2003) to 100%, where the number of parasites detected was in excess of 100 (Buishi *et al*., 2005a; Zhang *et al*., 2003). Notwithstanding this, as the technique exhibits a high probability of correlation with current infection and is capable of detecting patent and prepatent infections to a reasonably high level of specificity and sensitivity, it is considered a reliable tool for epidemiological investigations (el-Shehabi *et al*., 2000; Eckert *et al*., 2001a; Zhang *et al*., 2003).

After carefully evaluating the various techniques available to assess levels of canine E. granulosus infection, the research team opted for the collection of canine faecal samples for subsequent coproantigen analysis. In making this determination, consideration was paid to the cost, not only in monetary terms but also resources; avoiding the need for veterinary input; ease of sampling; viability of the samples collected, particularly in terms of storage (which in this instance could be stored frozen for over 12 months); availability of an appropriate analytical

procedure to test the samples and the robustness of the subsequent analysis. In the United Kingdom responsibility for the control and collection of stray dogs rests with local authorities. In light of this, local authorities employ the services of a dog warden whose duties involve the seizure and subsequent temporary kennelling of such dogs.

The power to seize stray dogs is laid down in Section 149(3) of The Environmental Protection Act 1990 (as amended) which states that: "Where the officer has reason to believe that any dog found in a public place or on any other land or premises is a stray dog, he shall (if practicable) seize the dog and detain it, but, where he finds it on land or premises which is not a public place, only with the consent of the owner or occupier of the land or premises.

" In order to avoid ambiguity and to provide a robust definition of a stray dog, for the purposes of the study a stray dog was defined as a dog found in a public place or on any other land or premises and was unaccompanied. Local authorities provide kennelling facilities (either inhouse or on a contractual basis with a privately owned kennels) as temporary accommodation for stray dogs and these afforded an excellent location for screening stray dogs for E. granulosus infection. Letters were sent to those local authorities located in south east Wales which encompassed both the previous intervention area and bordering non-intervention areas where there is a new focus of infection, seeking permission to sample stray dogs. For comparative purposes Cardiff Council was also contacted to provide a control sample from an urban area which was not considered to have heightened levels of E. granulosus infection. All of the local authorities contacted agreed to participate in the study.

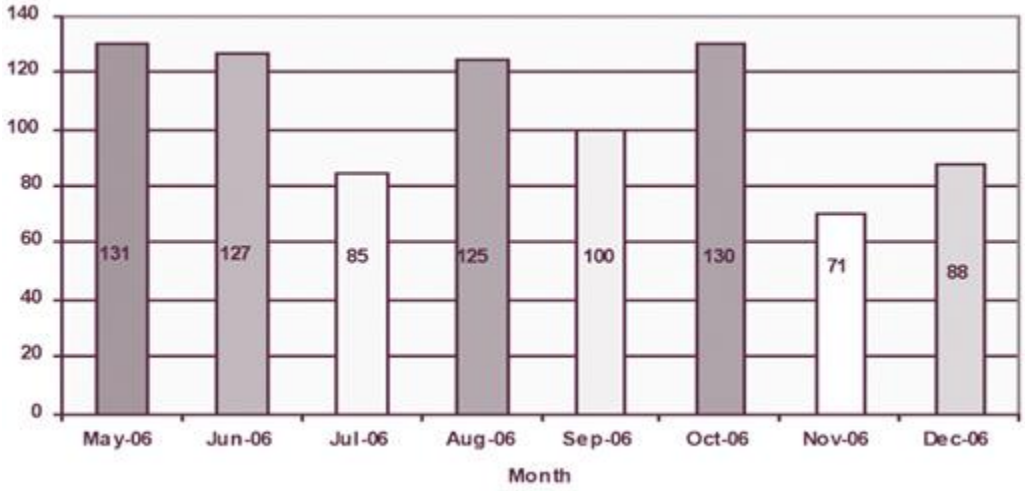
In order to effectively carry out the sampling it was determined that the kennelling facility staff would be required to undertake the faecal sampling as it was not viable for the authors to visit each kennelling facility on a daily basis. A payment of £1 per sample was offered as an incentive to kennel staff and the research team provided a freezer, which would remain the property of the facility at the conclusion of the study, and a monthly payment of £10 for electricity costs relating to the operation of the freezer was proposed.

Each kennel facility agreed to undertake the sampling. Although there are several commercially available ELISA kits for the detection of coproantigens in the field (Eckert et al., 2001a; Abbasi et al., 2003; Zhang et al., 2003), it was determined that the most appropriate method for subsequent analysis of the samples should be laboratory based. In reaching this decision consideration was taken of the authors' lack of expertise in such analysis, the robustness of the results obtained and the potential for bias.

The Cestode Zoonoses Research Group Laboratory at Salford University, Salford, UK agreed to undertake the specialised analyses of the samples for a nominal fee, using the sandwich ELISA technique and also to subject possible positive samples to a more sophisticated polymerase chain reaction (PCR) test to confirm or exclude an infection. During April 2006 a sampling protocol and sampling data sheets were designed and subsequently tested for ease of use, robustness, clarity and information content. As a result of this process, several amendments were made to the sampling protocol and data sheets, which were finalised and distributed to the kennelling facilities two weeks prior to the commencement of the sampling programme.

In order to facilitate the collection of faecal samples from the stray dogs, the following items were supplied to each kennelling facility and replenished on a monthly basis: Fecon© 27ml sterile faecal specimen containers, disposable gloves, antibacterial handwash, marker pens for labelling the specimen containers, and sampling data sheets. The sampling was undertaken by

the staff of the kennelling facilities for the period 2nd May 2006 to 31st December 2006. This involved the collection of 857 canine faecal samples, which is the largest published study to date of stray dogs for E. granulosus infection in Wales and in the United Kingdom. Each stray dog was assigned a unique number (with a three letter code for each local authority area) by the dog warden for local authority purposes and this was also assigned to each sample, which facilitated tracking of the stray dog records.



During the cleaning out process of the kennel, a 12-15g sample of the dog's faeces was collected into a Fecon© 27ml sterile faecal specimen container, using the integral fixed spoon. The integral fixed spoon type specimen container was purposely selected and provided to the kennelling facilities in order to minimise the likelihood of cross contamination of samples and to ensure that utensils were not contaminated with faecal matter. Once the sample was collected, the sample data sheet was completed and the corresponding local authority code and unique stray dog number were written on the label of the sample container before being placed into the freezer and frozen at -18°C. Previous research has suggested that susceptibility to E. granulosus infection and worm burden counts among the definitive host population may vary in relation to factors such as age, sex and breed. In view of this, the dog's age, sex and breed was recorded for each sample collected using the sampling data sheet.

During the first month, weekly visits were made to each kennelling facility to check that the sampling procedure was being undertaken correctly and to address any initial problems. To ensure the robustness of the sampling programme, regular auditing of the sampling data sheets and stored samples using the local authority stray dog records was undertaken where possible and did not reveal any discrepancies. On a monthly basis, the samples were collected from each kennelling facility and subsequently transported in ice boxes using a courier service to the Cestode Zoonoses Research Group Laboratory at Salford University, Salford, UK.

On arrival at the laboratory, the samples were initially stored frozen at -20°C until tested. Before testing approximately 2g of each faecal sample was thawed and mixed with an equal volume of 0.3% phosphate buffered solution (PBS)- T20 by hand shaking until a slurry was achieved, then centrifuged at 500 x g for 10 minutes at room temperature. Faecal supernatants were tested for Echinococcus coproantigens using a sandwich ELISA method that used a capture antibody against E. granulosus adult somatic antigens as had been used in previous studies (Palmer et al., 1996; Buishi et al., 2005b) to investigate canine echinococcosis in south Wales. In order to ensure the validity of the analysis, two of the wells on the ELISA plate contained blank samples

and two of the wells contained samples known to be E. granulosus positive. The ELISA plate was then read at 630nm using a Multiskan

Ascent™ plate reader manufactured by Lab Systems™, which provided optical density readings of each well of the plate. An optical density cut-off value of 0.125 was applied to the samples, above which samples were considered as possible positives for *E. granulosus*. Those samples which tested as possible positives using the ELISA technique were identified within the freezer and later subjected to the PCR assay technique developed by Abbasi *et al*. (2003) which amplified a target repeated sequence (EgG1 Hae III) identified in the G1 genome of the common sheep strain of *E. granulosus*, in order to confirm or exclude infection. On a regular basis, results of the analysis were forwarded electronically to the authors in Microsoft Excel™ format.

Results

Data from the sampling regime and subsequent laboratory analysis was inputted using Microsoft Excel™. In order to ensure that the number of samples collected in each local authority area represented a true reflection of stray dog numbers in that particular area, the stray dog records held by each authority for the preceeding two years were audited where available. This revealed that the percentage of stray dogs sampled when compared to the number of stray dogs impounded by each local authority per year ranged from 16% (south Powys) to 41% (Blaenau Gwent) with a mean value of 34.1%. As can be noted from Figure 7.0, unfortunately only 29 stray dogs were sampled in the south Powys area, which was not considered a true representation of the stray dog population in this region.

However, in contrast to the low sample frequency in south Powys, the number of samples collected in Cardiff was large and a decision was made to terminate the sampling regime in this region with effect from 31st October 2007. With the exception of south Powys, it was considered that the number of samples collected represented a true reflection of stray dogs impounded by each local authority. However, the number of stray dogs collected may not indicate the true level of stray dog numbers in a given authority area as this is dependant upon the resources and manpower allocated to this function. Thus, a local authority that invests considerable resources into the collection of stray dogs may *appear* to have considerably more stray dogs than an authority that simply does not collect a majority of strays. However, as there are no definitive records of the actual number of strays in any given area, this was not possible to determine.

The information obtained confirmed that the samples collected provided a representative sample of the impounded stray dog population both in terms age, sex and breed. In particular 63% of the dogs were male, which are considered more likely to be infected than females; 51.6% of the dogs were aged <36 months and thus more likely not to have acquired immunity to the parasite and therefore if infected would have higher worm burdens compared to older dogs, and 23.6% of the dogs sampled belonged to the collie breed, which are suggested to be more susceptible to G1 genotype infection than other breeds.

The eggs of *E. granulosus* are able to withstand extremely wide variations in temperature and therefore can remain viable throughout all possible weather conditions within the United Kingdom. Notwithstanding this, as can be noted from Figure 9.0, the collection of samples was evenly distributed throughout the sampling period ensuring that a representation of each month was achieved, thus avoiding any climate-related sampling bias.

Of the 857 samples collected, 14 were considered possibly positive for *E. granulosus* infection as a result of the ELISA process. However, owing to the borderline nature of the spectrometer

readings, the faeces were subsequently subjected to the more sensitive PCR process. This procedure determined that none of the samples was positive and therefore the laboratory analysis of the canine faecal matter determined that 100% of the stray dogs sampled for *E. granulosus* infection in this study were negative.

Discussion

This study aimed to determine the prevalence of *E. granulosus* infection among the stray dog population in the previous hydatid intervention area and those bordering areas of south east Wales where research suggests there is a new focus of infection. This was considered of particular importance as only very limited research had been undertaken in relation to non-farm dogs and therefore infection levels amongst this cohort had not been ascertained. The research would provide invaluable information on the distribution of infection among such dogs and would assist The Welsh Assembly Government's Hydatid Disease Eradication Campaign scheduled to commence in January 2008.

This was considered particularly important as it is essential to ascertain infection levels among all epidemiologically important hosts prior to, and during any eradication programme, for failure to do so has been cited as a contributing factor in those control programmes initiated throughout the world which have been unsuccessful. Although a large number of samples was collected in this study, the small number of samples collected in south Powys was not representative of the stray dog population in this area and as such, this is considered as the principal limitation of the sampling programme.

This is of particular concern as south Powys is known to have heightened levels of infection and it is suggested that stray dogs in this rural area have the greatest opportunity to scavenge on infected ovine material. In view of this, it is essential that further sampling of stray dogs in this area is undertaken to determine levels of infection. However, with the exception of south Powys, the samples collected in this study provided a representative sample of impounded stray dogs in the region both in terms of age, sex and breed.

Furthermore, the samples collected were evenly distributed throughout the eight-month sampling period, which ensured that any climate-related sampling bias was avoided. The subsequent laboratory coproantigen analysis of the samples, utilising the ELISA method and where necessary PCR technique, determined that 100% of the samples obtained were negative for E. granulosus infection.

Although there is some debate as to the specificity and sensitivity of the ELISA technique, particularly when worm burdens are low (>100 worms), of the Echinococcus species only the zoonotic E. granulosus genotype G1 and the non-zoonotic equine G4 genotype are known to be present in the United Kingdom. In view of this and in light of the results obtained, the specificity of the analysis was considered appropriate for the purposes of this study.

The findings of this study suggest that farm dogs remain the principal definitive host in the lifecycle and therefore particular emphasis must be focused upon the regular anthelmintic treatment of such dogs as well as ensuring these dogs are denied access to infected ovine material. While stray dogs have been cited as epidemiologically important definitive hosts in other regions of the world where E. granulosus is endemic, most notably Cyprus, Turkey, Sardinia, Uruguay, Chile and the African continent, it is suggested that the basis for the lack of positive cases in this study can largely be attributed to the following reasons:

- Unlike many regions of the world (particularly undeveloped countries) stray dog numbers in the UK are relatively low and the control of such dogs is adequately managed through the legislative mechanism and hence local authority control;
- The number of stray dogs in the UK that are homeless and therefore rely entirely on scavenging as a food source is low;
- Stringent controls within the UK ensure that home slaughtering practices and the disposal of ovine material is adequately controlled, unlike those undeveloped regions of the world where stray dogs have access to, and are fed, discarded ovine material which is unlikely to have been inspected for infection;
- As an island nation those abattoir, veterinary and public health controls set in place for the management of stray dogs, meat inspection and onfarm management are not compromised by an adjacent territory where stray dogs may encroach.

However, little research has been undertaken in relation to those dogs involved in rural pursuits, such as fox hounds and hunting dogs. This is particularly concerning as such dogs are regularly fed raw meat and offal, which in the case of hunt kennels can be an approved method for the disposal of fallen livestock including sheep. The staff of such premises may not be sufficiently knowledgeable or may lack the diligence to identify ovine hydatidosis, particularly in light of similar parasitic infections which may be manifested as very similar lesions. While pet or companion dogs are not considered as epidemiologically important definitive hosts within the United Kingdom, emphasis should be placed upon educating dog owners of the risks associated with and those steps that should be taken, to minimise the likelihood of the transmission of hydatidosis.

Conclusions and practice recommendations

Stray dogs do not appear to play a role in the transmission dynamics of *E. granulosus* in the south east Wales region of the United Kingdom, with the exception of south Powys, where further sampling of stray dogs is necessary. It is essential that farm dogs are regularly treated with a suitable antiparasitic worming medication and farmers are educated about the risks and those steps necessary, to minimise the likelihood of the transmission of hydatidosis.

Sampling of those dogs involved in rural pursuits such as fox hounds and hunting dogs should be undertaken in order to ascertain infection levels among this cohort. While pet or companion dogs are highly unlikely to be epidemiologically important definitive hosts within the United Kingdom, dog owners should be educated to ensure the transmission of disease is minimised. This should emphasis that: dogs are not fed raw ovine meat or offal; dogs are not allowed to stray or “roam”; wash hands after handling dogs; discourage dogs from licking their owners etc., and particularly the face; worm dogs on a regular basis with an antiparasitic wormer containing Praziquantel – better known by the brand names Droncit™, Drontal™ and Drontal Plus™ among others.

Local authorities responsible for the collection and impounding of stray dogs should consider the worming of all such dogs with an antiparasitic wormer prior to repatriating the dog with its owner or re-homing. The random sampling of pet or companion dogs should be undertaken to confirm or exclude this cohort of definitive hosts as epidemiologically important.

Acknowledgements

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Molecular identification of the bacterial burden in Sahara Dust samples - Dr Edu B Suárez1, Dr Jaime Matta2, Miss Magda Rolón2, Miss Lucianette Maldonado1, Dr Yasmin Detrés3, Miss Alina de la Motta3, Dr Maria Gelado4, Dr Juan Ramos2 and Dr Roy Armstrong3

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Abstract

The Canary Islands are exposed to dust originating in the Sahara and Sahel regions. Saharan dust (SD) aerosols also cross the Atlantic and affect the Caribbean, Central America, and the south-eastern United States and the north-eastern Amazon basin. SD includes bioaerosols that act as vectors of a variety of micro-organisms (fungi, viruses and bacteria) and their biologically associated products (e.g. spores, mycotoxins, endotoxins).

These are potentially pathogenic to terrestrial and aquatic organisms, as well as to humans. Dust loads transported into the atmosphere have been estimated to range between 500 million tons and 1 billion tons annually. Classic methodology used for the identification of these organisms in SD samples includes the culturing and isolation of viable specimens followed by biochemical analyses. Most recently, molecular biology techniques such as DNA extraction, PCR, and DNA sequencing have complemented this methodology.

Still, these approaches depend on the culturing viability of the micro-organisms that are in the collected samples. In this study, we developed a new method that overcomes this limitation. By utilising as a model for environmental testing SD samples collected in Gran Canaria at two different dust cloud intensities, we effectively include the cloning of heterogeneous DNA to the experimental scenario. Our results suggest that the diversity of bacterial species seems to be related to the intensity of the dust cloud event.

We report the bacteria: Morganella morganii, Rahnella aquatilis, Corynebacterium mucifaciens, Staphylococcus kloosii/carnosus, Propionibacterium acnes, Serratia fonticola, and Shigella flexneri (not previously identified in SD samples) and confirm previously reported genera: Pseudomonas, Bradyrhizobium, Sphingomonas, and an Arctic Sea-origin bacterium. This is the first report describing this methodology for bacterial identification from air-collected samples, containing more than a single bacterial species. This work addresses the air quality at which countries located within the SD trajectory are exposed to, by using a new methodological tool and from a non-conventional environmental/biological standpoint. We expect that a better understanding of SD bacterial burden will contribute to the development and implementation of more efficient management measures, in order to decrease public health issues presented during SD events.

Key words: Bacterial identification; environmental health; environmental sampling; public health management; Sahara Dust.

Introduction

Because of the proximity of the Canary Islands to the African continent, this archipelago is exposed to the presence of African dust throughout the year. However, the maximum frequency of dust events in this region occurs in the winter months (November-February) and it accounts for over 35% of the total annual dust flux (Dorta et al., 2005). Saharan dust (SD) aerosols rapidly (7-10 days) cross the Atlantic Ocean and impact on the Caribbean, Central America, and the south-eastern United States primarily between the months of May and October, and the northeastern Amazon basin from February to April (Swap, 1992; 1996). Dust loads transported into the atmosphere have been estimated to range between 500 millions tons to 1 billion tons, annually (Moulin et al., 1997; Taylor, 2002). Currently, there exist many efforts directed towards the identification and reduction of ambient concentrations of particulate material as a mechanism for improving human health. However, the biological burden present in SD has the potential of spreading a wide variety of microorganisms (fungi, virus, and bacteria), and their biologically associated natural products (spores, mycotoxins, endotoxins). These can be pathogenic to plants (Nagarajan, 1990), marine environments (Shinn, 2000; Mos, 2001; Garrison et al., 2003; Weir-Brush et al., 2004) and humans (Griffin et al., 2001; Kellogg et al., 2004). The National Institute of Allergy and Infectious Diseases have identified airborne dust as the primary source of allergic stress worldwide. Interestingly, areas such as the Aral Sea and the Caribbean, where SD exposure is common, are associated with the highest incidence rates of asthma in the world (Bener, 1996; Howitt, 2000).

Previous studies have utilized a broad range of technical approaches to identify the micro-organisms, transported by SD. These methods include, the culturing of viable specimens, microscopic analyses, and a combination of DNA extraction, polymerase chain reaction (PCR) of the cultured colonies, and DNA sequencing testing (Culturing-PCRSequencing method: CPS). Fungi, bacteria, and viruses, which can be pathogenic to humans, have been isolated and identified in cultures and by means of the CPS technique (Griffin, 2001 and 2003; Kellogg et al., 2004). However, it has been postulated that the species present in SD that can be identified through currently available methods contributes to less than 1% of the total or real burden comprising the tested samples (Eilers et al., 2000; Griffin, 2001).

Some of the limitations of the CPS methodology include the relatively large amount of sample required for obtaining sufficient initial culture material. The sampling of the fine particulate matter with a diameter of 2.5 (PM2.5) or 10μm (PM10.0) usually results in the recovery of small concentrations of dust. The amount of dust necessary from each sample for starting a culture in the different selective growth media is usually not achieved in a single collected filter. Another limitation encountered when using the CPS method is that in order to grow, the organism needs to be alive and viable.

The identification of fungal species is also time consuming; it can take several weeks to grow cultures. Finally, it has been suggested that not all the culture media provide the nutritional supplements required by all the species existent in a sample. To overcome some of these limitations, we developed an innovative method termed PCS, to assess the identity of the most common fungal and bacterial species present in SD samples. PCS involves sequentially performing of DNA extraction, PCR, cloning, and DNA sequencing. The PCS method is performed by using DNA extracted directly from a collection filter, which is normally contains a

heterogeneous mixture of SD micro-organisms. The PCR product obtained by using universal primers is cloned into a plasmid vector. Positive clones are purified and sequenced, and the obtained sequences are submitted to the NCBI BLAST database for confirmation of identity.

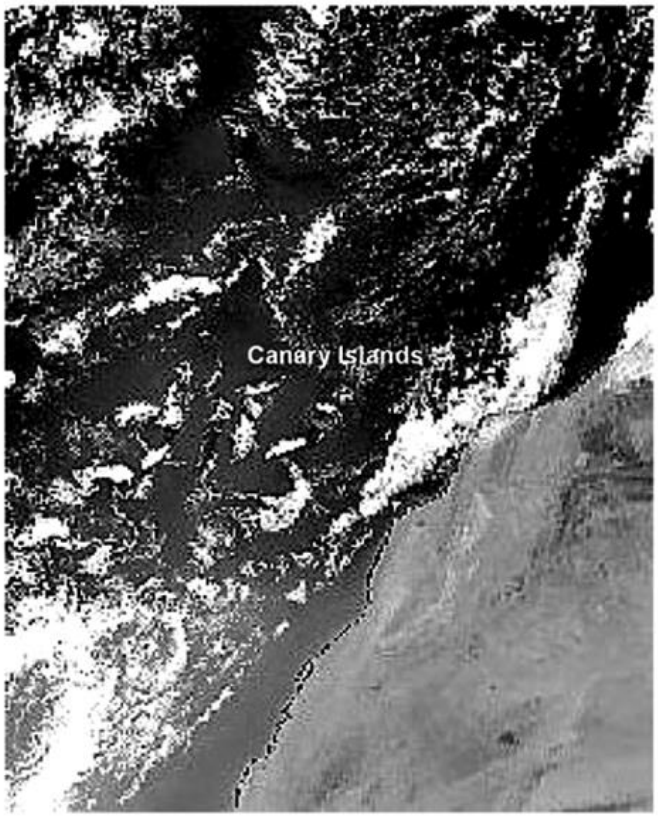
The use of heterogeneous DNA and the cloning step allows the assessment of more than one kind of DNA per PCR reaction. This is expected to correspond to the presence of the species in the collected sample. In this pilot study, we used the PCS approach to identify bacterial species present in SD samples from the island of Gran Canaria. Methods Sample collection The Canary Islands are an archipelago of seven islands located 115 km off the northwestern coast of Africa. SD samples were collected at the Pico de la Gorra air-sampling station located at 1,930 m of altitude on the island of Gran Canaria (28°06'N, 15°24'W). The Island of Gran Canaria, located in the Atlantic Ocean at approximately 100 km off the African Coast, is frequently exposed to dust plumes originating in the Sahara and Sahel regions. A high volume pump model CAV-A/M (MCV, S.A.) set at 60m3/hour was used to collect particles of 10µm or less, during a 12 hours sampling period.

The samples were collected in 8" x 10" Whatman filters (GF/A) that were stored after the completion of the sampling in a sterile bag and frozen at -20ºC until DNA extraction. The filters, labelled as SD#15 (3rd June 2002) and SD#7 (1st March 2003), correspond to a low dust concentration (35.72µg/m3) and an intense dust event (4492.9µg/m3), respectively. The occurrence and intensity of the events were confirmed using satellite images (SeaWiFS). The ICoD Dust Regional Atmospheric Model (ICoD/DREAM) and the National Oceanic and Atmospheric Administration (NOAA) Hybrid Single-Particle Lagrangian Integrated Trajectory (HySplit) model were used to determine the surface dust concentration over the Canary Islands and backward trajectories of particles, respectively. DNA extraction of SD samples DNA extraction of SD samples was performed by placing one-half of the filters in a sterile 15ml Falcon tube with 5ml of ultra pure, molecular grade, autoclaved water. The samples were incubated at 37°C for one hour with continuous shaking.

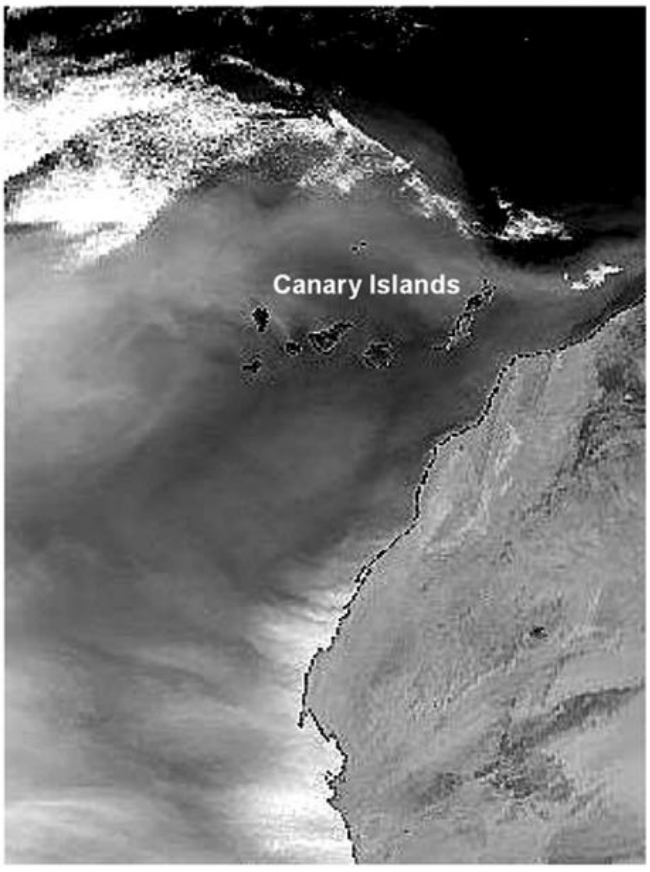
The total DNA extraction was carried out from 500µl of the eluted sample using Epicentre's SoilMaster™ DNA Extraction Kit, following the manufacturer's instructions. PCR amplification and electrophoresis The microbial PCR amplification from the SD DNA samples was performed using the bacterial universal 16S primers: P4 (5'- AACGCGAAGAACCTTAC-3') and P5 (5'-CGGTGTGTACAAGGCCCGGGAA-CG-3'), with a Triple- Master® PCR Kit (Eppendorf AG, Hamburg, Germany) in a PCR reaction volume of 20µl. Each reaction contained 3.2µl of 10X High Fidelity PCR Buffer, 0.4µl of each 10mM DNTP; 0.5µl of each primer (10.0µM), 0.3µl of TM enzyme (5U/µl),10.1µl of water and 5µl of extracted DNA. PCR was performed in an Eppendorf Gradient Mastercycler® (Eppendorf AG, Hamburg, Germany) following these steps: denaturation for 5 min. at 94°C and 35 cycles of amplification using a step programme of 20 sec. at 94°C, 20 sec. at 54.0°C; 5 min. at 72°C; a final extension of 10 min. at 72°C; and a hold step at 4°C.

Positive and negative controls were included in each reaction using Escherichia coli bacterial DNA and water as templates, respectively. Electrophoresis of the PCR products (9µl) was performed in a 3% agarose gel with TAE buffer at 100 volts for 90 minutes, stained with ethidium bromide, and visualized under UV light. PCR product cloning, plasmid purification, and DNA sequencing The obtained amplicons were cloned using the TOPO TA Cloning® kit (Invitrogen Corp., Carlsbad, CA), following the specified protocols. The E. coli 5F' competent cells were chemically transformed according to the manufacturer's specifications (Invitrogen Corp., Carlsbad, CA), and plated on Luria-Bertani (LB) plates containing 100µg/ml of ampicillin. Ampicillin-resistance and -galactosidase bluewhite screening was used to identify white,

recombinant colonies. Twenty-one (21) recombinant colonies were individually picked from SD#7 and SD#15 transformations. Colonies were grown overnight with constant shaking at 37°C in 5ml of LB media containing ampicillin (100µg/ml). Plasmid purification was performed using the (QIAGEN Inc., Valencia, CA), following manufacturer's instructions. The DNA sequencing was performed at Florida State University using the Big Dye Terminator protocol with the M 13 Forward and Reverse primers. E. coli DNA (control reaction) was included for sequencing, in order to verify the accuracy of the generated sequences. Sequence alignment, editing, and species identification The obtained DNA sequences were aligned with the P4 and P5 16S rRNA universal primer sequences and edited by using BioEdit software. Edited sequences were submitted to NCBI-BLAST (www.ncbi.nlm.gov/BLAST/) for bacterial identification. The sequences were analysed by terms of individual matches and the percentage of homology with any existing sequence in the database and were submitted to the GenBank database.



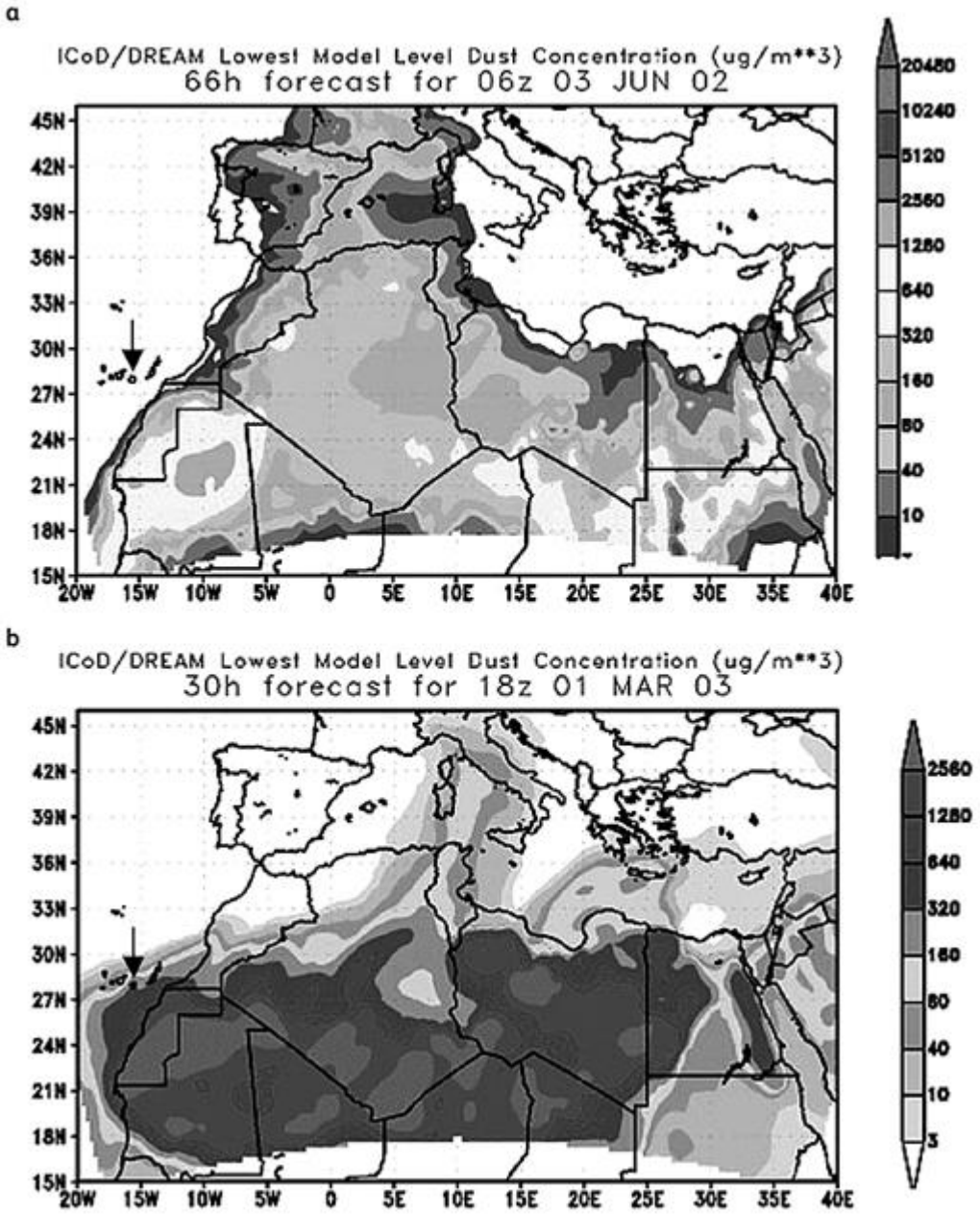
a



b

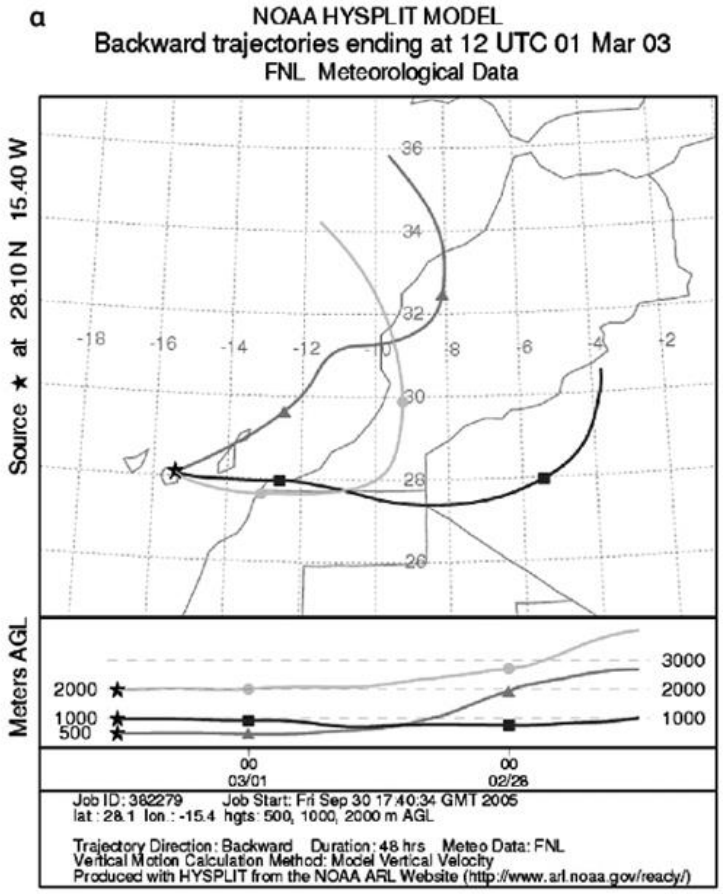
Results The Sea-WiFS images (Figures 1.0a and 1.0b), as well as the ICoD DREAM models (Figure 2.0a and 2.0b) of dust concentrations, confirmed the differences in the intensity of the dust loads affecting Gran Canaria during the sampling dates of this study. The origin of the sampled particles is different, as shown by a backward trajectory analysis of dust particles travelling at 500, 1000, and 2000 (Figures 3.0a and 3.0b). The PCR fragments obtained from the amplification of the heterogeneous DNA collected in the filter, showed products of variable length when visualised in the agarose gel analysis (data not shown).

The cloning step allowed us to obtain more than 21 colonies per sample, but we selected randomly only 21 colonies of each sample for our purposes. In theory, each one of the selected clones has the potential to represent a different 16S rRNA identity. The PCR products, which ranged from 433-445 bp, were confirmed as revealed by the DNA sequencing of each clone (42). The obtained sequences were assigned with the accession numbers DQ453569-DQ453603 (Table 1.0) at the GenBank database. Thirteen genera were identified from the 21 clones selected from the SD #7 sample transformation (Table 1.0). As well, five genera were identified from the 21 clones of SD #15 (Table 1.0). The percentages of homology for SD #7 vary from 93% the lowest to 100% the highest. All the positive clones of the SD#15 showed 99 % homology with the corresponding matches in the database with the exception of one clone that showed a 98% homology (DQ453597). However, eight clones from the SD#15 resulted as false positives for the DNA insert, a phenomenon not observed in the SD#7. Discussion Because of their proximity to the African Continent, the Canary Islands are exposed to intense Saharan dust storms throughout the year.



The mass concentration of dust particles in the filter from 1st March 2003 was 128X higher than the mass of dust particles concentration measured in the filter on 3rd June 2002. In addition to the differences in the intensity of the two dust storm events, an important observation is that it is also suggested that the origin of the two sampled dust particles is different (Figures 3.0a and 3.0b). A backward trajectory analysis of dust particles travelling at 500, 1000, and 2000 m confirmed the African origin of the dust sampled on 1st March 2003. However, the origin of the particles sampled on 3rd June 2002 appeared to be oceanic. We selected two different events in order to identify temporal variations in the microbial diversity spread by SD. A 68% higher diversity of bacterial species was observed in the SD#7 sample (Table 1.0), which corresponds to a large dust storm that passed over the island of Gran Canaria (Figure 1.0b).

a


NOAA HYSPLIT MODEL
Backward trajectories ending at 12 UTC 01 Mar 03
FNL Meteorological Data
Source ★ at 28.10 N 15.40 W
Meters AGL
3000
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1000
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00
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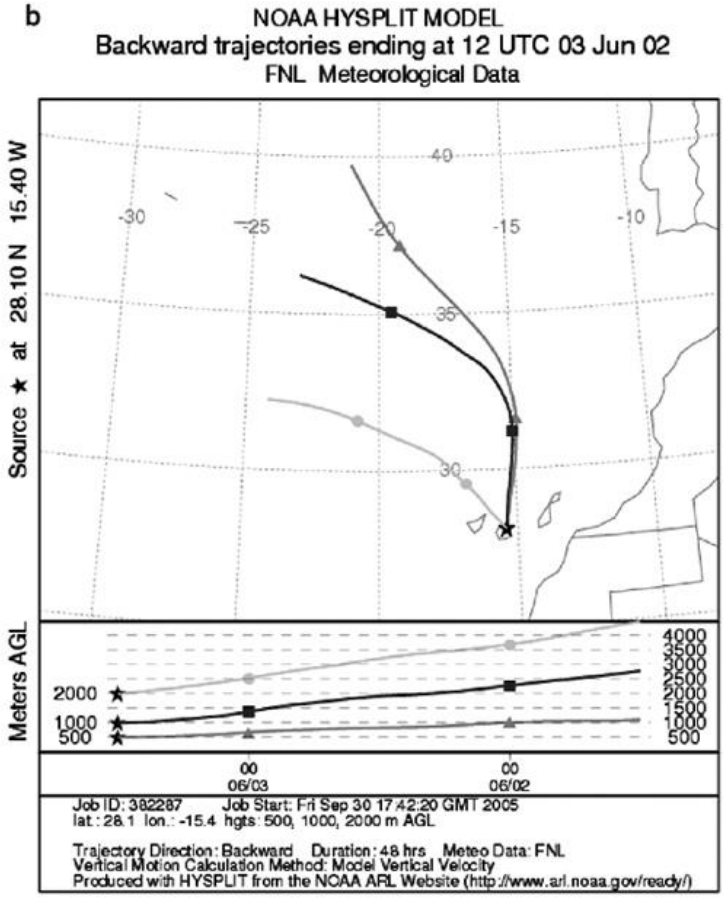
02/26
Job ID: 382279 Job Start: Fri Sep 30 17:40:34 GMT 2005
lat : 28.1 lon : -15.4 hgts: 500, 1000, 2000 m AGL
Trajectory Direction: Backward Duration: 48 hrs Meteo Data: FNL
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

b


NOAA HYSPLIT MODEL
Backward trajectories ending at 12 UTC 03 Jun 02
FNL Meteorological Data
Source ★ at 28.10 N 15.40 W
Meters AGL
4000
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2000
1000
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06/03
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06/02
Job ID: 382287 Job Start: Fri Sep 30 17:42:20 GMT 2005
lat : 28.1 lon : -15.4 hgts: 500, 1000, 2000 m AGL
Trajectory Direction: Backward Duration: 48 hrs Meteo Data: FNL
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

The number of species found in SD #15 was lower than that of SD #7 (5 and 13, respectively) and showed two species with a higher number of clones per species: Staphylococcus kloosii/carnosus (6) and Bradyrhizobium sp. (4) (Table 1.0). We suggest that the high number of clones per species, identified in SD#15, represent lower diversity. In contrast, in SD#7, we identified a lower number of clones per species, but the representative genera was richer. In conclusion, the number of clones per species was inversely proportional to the identified bacterial diversity. Fifty percent (50%) of the bacteria identified in SD#7 are associated with human health issues. These include: Pseudomonas, Rahnella aquatilis, Serratia fonticola, Sphingomonas, Shigella flexneri, and Corynebacterium mucifaciens. In contrast, only one of the species, Corynebacterium mucifaciens, identified in SD #15 is pathogenic to humans. The other four species identified from SD#15 are part of normal or resident microbiota of animals (Staphylococcus kloosii; Propionibacterium acnes), soil (uncultured soil bacterium) or plants (Bradyrhizobium). Interestingly, by comparing the identified species, it is clear that all the species identified in the light dust event sample (SD#15) were also present in the heavy dust event sample (SD#7).

Sahara Dust Sample #7			
No. of Clones	Matching organism(s)	GenBank Accession number	% homology
1	Arctic sea ice bacterium ARK9973/Marine sediment bacterium OC-12ª Bradyrhizobium sp.	DQ453581	99 a
2	Corynebacterium mucifaciens	DQ453573, DQ453583	99
1	Modestobacter sp. Ellin 165 a	DQ453589	99
1	Morganella morganii	DQ453582	97 a
2	Propionibacterium acnes	DQ453569, DQ453572	100
2	Pseudomonas sp.a	DQ453576, DQ453579	98
1	Rahnella aquatilis isolate k	DQ453577	99 a
1	Serratia fonticola	DQ453570	100
1	Shigella sp/Escherichia sp	DQ453578	99
1	Sphingomonas sp.	DQ453585	100
4	Staphylococcus kloosii/carnosus	DQ453571, DQ453584, DQ453586, DQ453588	97-99
3	Uncultured bacterium clone MP104-0/	DQ453574, DQ453575, DQ453580	99
1	Sphingomonas sp°	DQ453587	93 a
Sahara Dust Sample #15			
No. of Clones	Matching organism(s)	GenBank Accession number	% homology
4	Bradyrhizobium sp.	DQ453590, DQ453598, DQ453601, DQ453593	99
1	Corynebacterium mucifaciens	DQ453596	99
1	Propionibacterium acnes	DQ453597	98
6	Staphylococcus kloosii/carnosus	DQ453594, DQ453599, DQ453600, DQ453592, DQ453602, DQ453603	99
1	Uncultured bacterium clone mw5	DQ453595	99
8	No Insert	False Positives	-

These results may represent a shared or common bacteria burden between these two regions or normal microbial inhabitants of these sites. These data can also be useful to identify the bacterial contribution from different North African geographic areas to a dust cloud crossing the Atlantic Ocean and reaching the western hemisphere. This type of strategy would provide insights about the final bacterial complexity of the dust clouds that arrive at the western hemisphere. The importance of the identification of the bacterial build-up as the final dust cloud is formed has been a constant concern. However, the viability status of the bacteria had always been presented as a methodological limitation for this purpose. With the PCS method, this limitation is overcome because the bacterial DNA can be extracted and analysed independently of the bacterial viability status. The possible existence of a bacterium with an Antarctic origin (marine sea ice brine or ponds) was not surprising.

Similar to the arctic sea bacterium identified in the SD#7 sample (DQ453581), Kellogg et al. (2004) previously reported Kocuria and Planococcus genera in a sample collected at an African dust event in Mali. It is hypothesised that as a result of changes in the Hadley circulation (past glacial periods), tropical dust (including Saharan) has been transported to the Polar Regions (Chylek et al. 2001).

Conclusions

By using the PCS method, we overcame some of the limitations of the current methods used for the identification of fungal and bacterial species. The identification can be performed independently of the viability status, using small amounts of initial material, and in a relatively brief period of time. In this pilot project, we effectively utilised the cloning of heterogeneous DNA collected from environmental samples at two different intensities of Sahara Dust clouds events. Our results indicate that the diversity of species seems to be related to the intensity of the event. This new method provides an innovative tool for the assessment of species that might not be viable or cultured. In addition, by using this method we can estimate the prevalence of the species in a given sample by identifying the number of clones per species. The identification of additional species can be achieved by increasing the number of selected clones.

* One limitation that we encountered was the false positive results (no insert) in sample SD#15. However, this might represent a technical issue (cells viability or lack of technical experience in the transformation process), rather than a questioning of the applicability of the technique per se.

* It would be beneficial to conduct a sampling in different regions and of dust events with different geographic origins because this would contribute to the elucidation of the bacterial contribution of each region to the final dust cloud. The PCS method can be employed in the characterisation of fungal and viral organisms as well.

* This work addresses the air quality to which countries located within the SD trajectory are exposed. By using this new methodological tool and from a nonconventional environmental/biological standpoint, we expect to provide a better understanding of the SD bacterial burden.

* Our findings could be used to study the presence of these organisms and their correlation with the public health issues at specific geographical regions or sampling sites during a SD event. It might also contribute to the development and implementation of more efficient management measures (e.g. medical prophylaxis for specific biological agents, scheduled vaccinations, use of protective cloth) that will decrease public health issues related to the occurrence of a SD event.

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Spatial distribution of particulate air pollution in Nigerian cities: implications for human health - S I Efe1 Ph.D

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Abstract

This study examines distribution of ambient particulate pollution and its possible health implications in Nigerian cities. A total of 102 high-volume (HV) samplers were used in 17 Nigerian cities to draw a known volume of ambient air at a constant flow rate through a size selective inlet and through filters for a six-year period (2001-2006). Particles in the PM_{10} size range were then collected on the filter during a 24-hour sampling period to get a daily average ambient PM_{10}. The data were subjected to paired t-test, ANOVA and multiple regression statistical analyses. The results showed that the urban corridors of over 70% of Nigerian cities are sites with a high rate of daily mean/annual mean ambient PM_{10} of over 120µg/m^3, while < 30% of Nigerian urban centres had mean annual ambient PM_{10} value of 119.2µg/m^3. Similarly, significant differences exist in PM_{10} concentrations across different land-use types, between the built-up areas and those of the surrounding rural areas. The high concentrations of PM_{10} in most Nigerian urban environments have resulted in significant prevalence of cough, catarrh, eye infection, asthma, chronic bronchitis etc. The study therefore recommends the following: the introduction of an emissions standard; road pricing for automobiles during the hours of 7.45 am-9.45 am; 1.45-2.45 pm and 3.45-5 pm; industries involved in ambient particles pollution should set up chambers to control emissions from industrial sites; the incineration of refuse in market areas should be stopped and replaced by the regular collection and processing of waste at government approved sites far away from residential areas; the gas flaring in the refineries should be stopped because of the increased ambient PM_{10} (> 139µg/m^3) values recorded within the foci of gas flaring areas.

Key words: Air pollution; environmental health; Nigeria, particulate matter, PM_{10}; urban areas.

Introduction

Particulate matter encompasses the small solid or liquid substances that are released into the atmosphere through many activities. For instance, nearly all industrial processes, as well as the burning of fossil fuels, release particulate matter into the atmosphere (Varney and McCormack, 1971, Smith, 1975, Miller, 1994 and Botkin and Keller, 1998). Botkin and Keller (1998) stressed that much particulate matter is easily visible as smoke, soot or dust, and other particulate matter is not easily visible. Included within particulate materials are constituents such as airborne asbestos particles and small particles of heavy metals such as arsenic, copper, lead, and zinc, which are typically emitted from industrial facilities such as smelters.

It was observed that about 10% of the mass of all pollutants is emitted as particles and liquids compared with 90% from gaseous compounds (Miller, 1994 and Botkin and Keller, 1998). Particulate matter embraces a wide range of solid and liquid particles extending from more than 10m in diameter (Varney and McCormack, 1971). Most of the smaller particles, approximately 10µm or less in diameter, are of smoke and are produced by incomplete combustion of fossil fuel (Smith, 1975). Miller (1994) however differs in his explanation. He asserts that suspended

particles (oil smoke, 0.8 – 1μm), combustion nuclei (0.01 – 0.1μm), photochemical smog (0.01 - 4μm), metallurgical dust and fumes (0.001 - 100μm), cement dust (0.6 - 100μm) and coal dust (1 - 100μm etc) are found in a wide variety of types and sizes (as indicated above). Smaller particles are more properly referred to as 'aerosols' and exist in the urban tropospheric area for perhaps a week before breaking up and, if introduced into the less turbulent conditions of the stratosphere, this type of particle may persist for years (Junge and Werby, 1985 and Mamane *et al.*, 1982).

Ambient aerosol composition is one of the most noticeable nuisances in polluted urban regions that needs to be monitored, but only a few studies have been reported in literature (Katze, 1961; Giever, 1976; West, 1976; Yaalon and Ganor, 1979; Mamane et al., 1982 and, Pope et al., 1995). The neglect over the years may be because their measurements are considered to be erratic, selective, non-predictable and usually not replicable (Giever, 1976 and Pope et al., 1995). Giever, (1976) and Pope et al., (1995) therefore called for the regular monitoring and analysis of aerosol in cities to enhance effective information necessary for urban planning and management (United States Global Change Research Programme [USGCRP], 2002). Aerosols are good precursors of condensation nuclei that can lead to heavy downpours, which may result in destructive urban floods.

The urban environments of Nigeria are characterized with increased particulate matter (PM10). Most commuters and urban dwellers are constantly exposed to the hazard of particulate matter, most especially motorbike (Okada) riders and their passengers, and those who live close to the traffic clogged areas. Thus, urban inhabitants are typically plagued by a series of complaints including eye irritations and respiratory problems. To cope with this hazard, most commuters now resort to covering their nostrils and mouth with handkerchiefs at major junctions; and some drivers wind up their car windows in these areas. The effects of particulate matter on vertebrate animals include impairment of the respiratory system, damage to eyes, teeth, and bones, increased susceptibility to disease, pests or other stress – related environmental hazards, and reduced ability to reproduce (Smith, 1975, NAPAP, 1990; Injuk et al., 1995; Pope et al., 1995; and Blake and Rowland, 1995). Similarly, other effects of suspended particles have been noted (see Smith, 1975; Miller, 1994; NAPAP, 1990; and Botkin and Keller, 1998 and Efe, 2005). For instance, (Miller, 1994) stressed that suspended particles aggravate bronchitis and asthma. Particulate matter associated with large construction projects may kill organisms and damage large areas, changing species composition, altering food chains and generally affecting the ecosystem (Botkin and Keller, 1994). It should be noted that these problems are not unique to Nigerian cities. In London, United Kingdom during 1952, atmospheric pollution and smog resulted in between 3,000 and 4,000 deaths; caused 20,000 other inhabitants to be sick, and shortened the lives of thousands more (Botkin and Keller, 1994 and Efe, 2005 and 2006).

In Nigeria, the effect of particulate matter on human health has been noted by several scholars, for instance Ossai *et al.*, (1999), Okecha (2000) and Efe (2005) asserted that high rates of respiratory diseases occasioned by increased PM_{10} concentrations were experienced by residents of most urban areas. Specifically, Efe (2005 and 2006) noted that residents of Refinery Road, commercial areas, traffic-clogged areas and high-density residential areas in the Warri metropolis were the most affected, with over 15% of the cases recorded among infants and schoolchildren in Benin City, Ibadan, Kano and Port Harcourt, etc. Generally, these scholars believe that particulate matter in urban areas of Nigeria has the following health implications:

- The oxides of sulphur and nitrogen combined with water vapour in the atmosphere cause acid rain in cities. When these acids are consumed, they cause acidosis in human body. Excess accumulation in human body can lead to death.
- Gaseous pollutants stimulate coughing in patients suffering from chronic bronchitis, and those patients with heart and lung disease may fatally succumb to sulphur IV oxide; more commonly referred to as sulphur dioxide.
- Particulate matter that enters the lungs may lodge there and result in chronic respiratory problems including emphysema, pneumonia, bronchitis asthma and respiratory tuberculosis, etc.

Other consequences include widespread acid rain, pollution of surface and sub-surface systems, destruction of vegetal cover, and endangered human lives (health) among others. It is on this note that Okecha, (2000) and Efe, (2006) joined with Smith, (1975); Miller, (1994); Moore, (1995) and Botkin and Keller, (1995) in calling for regular studies on air particulate pollution and its possible health effects in urban environments around the world as well as highlighting the need for appropriate policy development if the threat is to be mitigated. It is on this premise that this pioneering study covering 17 Nigerian cities was embarked upon. This was undertaken with the aim of examining the spatial distribution of PM_{10}, its health implications and possible management measures in Nigerian cities. These cities have a population of over 50,000 each, with high rates of industrial activity that have encouraged rapid urban development over the years. In fact, they are the nerve centres of the Nigerian economy.

Methods of data collection

A stratified sampling technique was adopted where each of the cities was divided into six homogenous groups based on land-use types. The population in these areas is homogeneous across each of the six groups. A total of 102 high-volume PM_{10} samplers (HV PM_{10}) (locally known as pumps) were used for the six years (2001-2006). The HV PM_{10} was used to draw a known volume of ambient air, at a constant flow rate, through a size-selective inlet and through one or more filters. Particles in the PM10 size range were then collected on the filter during 24-hour sampling period. The researcher, with 16 of his trained research assistants, used the HV PM_{10} sampler to obtain the air particles as recommended by Giever (1976) and the Federal Ministry of Environment in each city in Nigeria, on an hourly basis from Sundays to Saturdays for the six-year period 2001-2006. In each of the six zones, air particulate matter samples of four distances (20m, 50m, 100m, 200m and 500m) were taken and averaged for the 24 hours duration to get the daily mean PM_{10} particles (WHO, 2005 and Efe, 2006). The daily PM_{10} concentrations were then averaged to get monthly and annual values. These distances according to Okacha (2000) and Efe (2006) were adopted for spatial coverage and to avoid a point specific measurement. Efe (2006) has adopted the same distances in a similar study in Warri and achieved significant results. The PM_{10} is determined using this model:

T.S.P. = Ms - Mo/V - - - (1)

Where T.S.P. = Particulate matter

Ms = mass of filter paper after sampling

Mo = mass of filter paper before sampling

V = volume

Therefore, concentration per unit time = $\mu g/m^3$/Hours - - - (2)

The Mo value was derived by weighing each sample filter before sampling and Ms was done by weighing each sample filter after sampling. The difference in weight between them gives the net weight (mass) gain of the collected PM_{10} The sampled volume was corrected to standard conditions of 25ºC, 760m Hg or 101kPa (Efe, 2006). The annual and monthly means of the ambient air particulate matter were then calculated and used for the study. A survey of three major hospitals in each city was also carried out. Case files of patients treated for airborne diseases (bronchitis, asthma, cough/catarrh and eye infection, etc) were obtained and the number of cases treated for each disease was recorded for the period of study from January to December 2006 and used for the study. To determine the level of variation or differences among the PM_{10} in the various land-use types, the analysis of variance (ANOVA) statistical technique was adopted. In addition, the paired t-test was used to compare the level of the differences, which exist between the PM_{10} collected from the built-up areas and the surrounding rural areas. The paired t-test was also used to compare the differences that exist between the ambient PM_{10} during the weekdays (Mondays-Fridays) and those of the weekends (Saturday-Sunday), as well as the difference that exists between the urban corridors and the surrounding rural areas of Nigeria. On the other hand, the multiple regression analysis was used to test the level of effect of PM_{10} on the occurrence of disease in Nigeria cities. This was denoted with:

$y = a + bx1 + bx2 + bx3 + bx4 - - - - - bxn + e$

Where

- y = PM10
- X1 = bronchitis
- X2 = cough
- X3 = asthma
- X4 = cardiovascular diseases
- X5 = eye infection
- X6 = skin infection

These statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS). These statistical techniques have been employed by Ayeni (1994) and Efe (2005 and 2006) and they achieved significant results.

Results and discussion

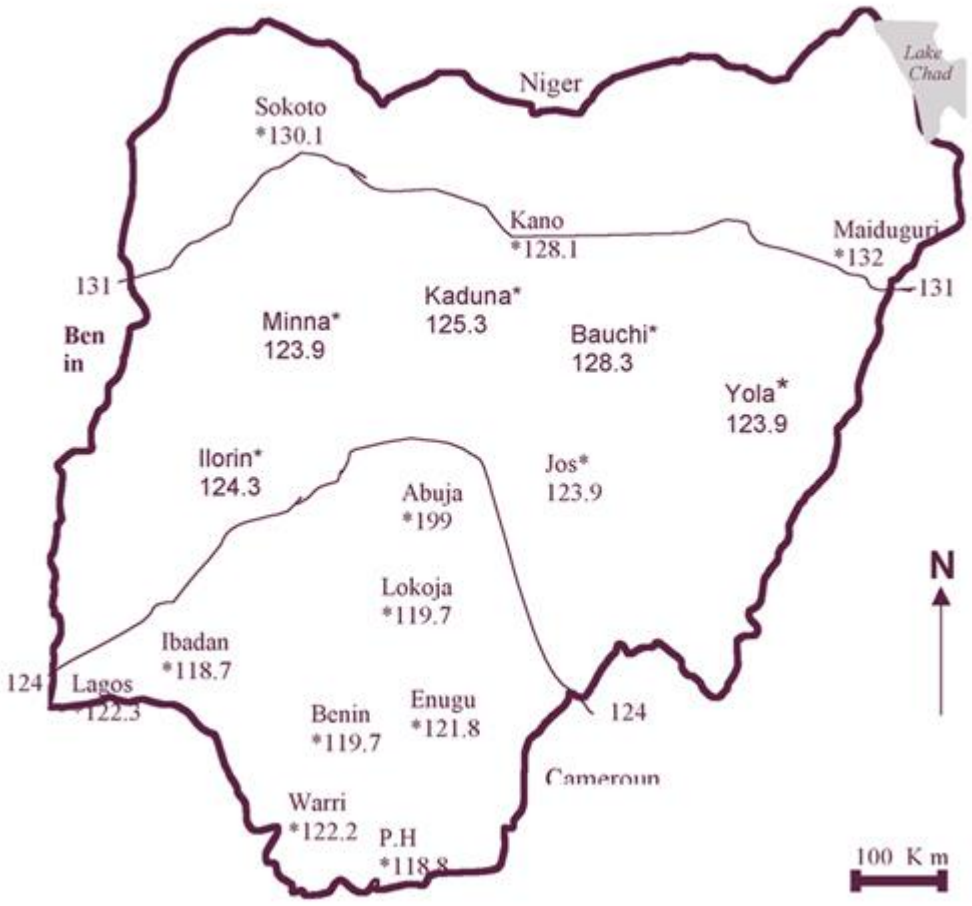
The data collected for the study are presented in Tables 1.0 – 3.0 and discussed below.

Cities	PM_{10} (μg/m³)	WHO 2005 unit (μg/m³)
Kano	128.1	20
Sokoto	130.1	''
Maiduguri	132.0	''
Bauchi	128.3	''
Kaduna	125.3	''
Jos	123.9	''
Minna	123.9	''
Yola	123.9	''
Ilorin	124.3	''
Abuja	119.0	''
Lokoja	119.7	''
Benin city	119.2	''
Enugu	121.8	''
Ibadan	119.7	''
Warri	122.2	''
Port Harcourt	118.3	''
Lagos	122.3	''
Mean	**123.6**	''

Table 1.0 shows the annual mean ambient particulate air pollution in seventeen cities in Nigeria. Generally speaking, Nigerian cities are characterized with high levels of PM_{10}, with an overall annual mean value of 123.6μg/m³. It also shows that the northern cities have generally higher concentrations of PM_{10}, with annual mean of 132μg/m³ at Maiduguri, 130μg/m³ at Sokoto, 128.3μg/m³ at Bauchi and 128.1μg/m³ at Kano respectively while the southern cities recorded values that span 118μg/m³ at Port Harcourt to 122μg/m³ at Warri and Lagos. The middle belt area has values of 123.9μg/m³ at Yola, Minna and Jos to 124.3μg/m³ at Ilorin. Thus, PM_{10} values in the northern cities are over 8% higher than those in the southern cities. Other cities in the middle areas are Abuja and Lokoja, which had annual mean 119μg/m³ and 120μg/m³ respectively.

Cities	A	B	C	D	E	F	Urban Mean	G	Mean	WHO 2005 unit ($\mu g/m^3$) per annum
Kano	143	127	145	36	127	159	140	60	128	20
Sokoto	150	129	150	137	127	157	142	61	130	"
Maiduguri	151	129	151	146	127	158	144	62	132	"
Bauchi	146	127	150	141	126	149	140	59	128.	"
Kaduna	145	126	140	136	126	146	137	58	125.	"
Jos	143	125	138	135	125	144	135	57	124	"
Minna	142	124	138	135	127	143	135	58	124	"
Yola	142	124	132	131	127	144	133	57	122	"
Ilorin	143	123	137	136	120	144	134	58	123	"
Abuja	130	106	136	130	126	146	129	59	119	"
Lokoja	129	124	132	129	121	147	130	56	120	"
Benin city	128	122	131	129	122	148	130	55	119	"
Enugu	128	121	140	135	124	149	133	55	122	"
Ibadan	130	120	140	137	109	146	130	56	120	"
Warri	138	126	139	140	120	140	134	52	122	"
Port Harcourt	139	116	139	138	100	141	129	55	118	"
Lagos	140	125	146	139	99	150	133	57	122	"
Mean	139	123	140	136	121	148	135	57	124	"

This increase was occasioned by the deposition of particulates or dust raised during the Harmatan season, wind movement of dry particulates and aerosols from the Sahara desert into the northern states, and burning of anthropogenic substances etc. Generally speaking, the concentration of ambient air particulate matter over Nigerian cities is about 500% higher than the 20µg/m^3 threshold of WHO (2005) (See Figure 1.0).

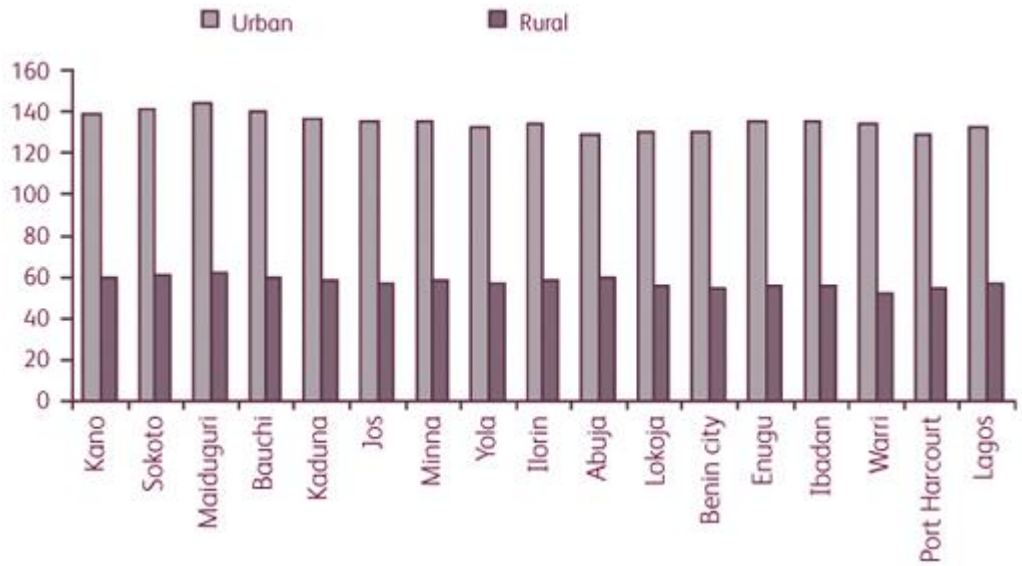


A critical examination of the spatial distribution of the ambient air particulate matter over Nigerian cities revealed that the traffic-clogged areas had the highest concentrations with mean annual values of 147.7μg/m^3. Traditional areas which also formed part of the cities, had the lowest mean ambient PM_{10} with 121.2μg/m^3 over the six years of study. This showed a difference of 26.5μg/m^3 which indicates that ambient PM_{10} concentrations in the traffic-clogged areas are about 22% higher than those in the traditional areas (see Table 2.0). This increase is occasioned by the deposition of particulate from increased vehicular movement, dust raised during the Harmatan season, wind movement of dry particulates and aerosols from the Sahara desert, and burning of anthropogenic substances.

The other land use types showed the following concentration of annual mean ambient PM_{10} in decreasing order: 140μg/m3 (industrial area); 139μg/m3 (high-density residential, 136μg/m^3 (commercial areas) and 123μg/m^3 at the low-density residential area respectively. The result of ANOVA analysis performed on the annual mean ambient PM_{10} collected from the various land use types showed that significant differences exist among the ambient PM_{10} values recorded from the various land use types, with calculated F value of 4.18 that is P>0.05 (see Table 3.0). This difference is greatest between the trafficclogged areas and the traditional areas.

	Sum of Square	DF	Mean Square	F	Sign.	Remark
Between	596.3	5	119.274	4.184	0.071	Significant difference exist
Within	142.537	5	28.507			
Total	738.909	10				

In another vein, cities with the highest concentration of PM_{10} in their urban corridors also recorded a concomitant increase in ambient PM_{10} concentrations in their surrounding areas over other cities with lower values of PM_{10}. For instance, Maiduguri recorded the highest concentration of ambient PM_{10} (144μg/m^3) in her urban corridors and 62μg/m^3 in the surrounding rural areas, while Abuja and Port Hartcourt had the lowest value of 129g/m3 at her urban corridors, and 59μg/m^3 and 55μg/m^3 respectively at thier rural landscape (see Table 2.0 and Figure 2.0).



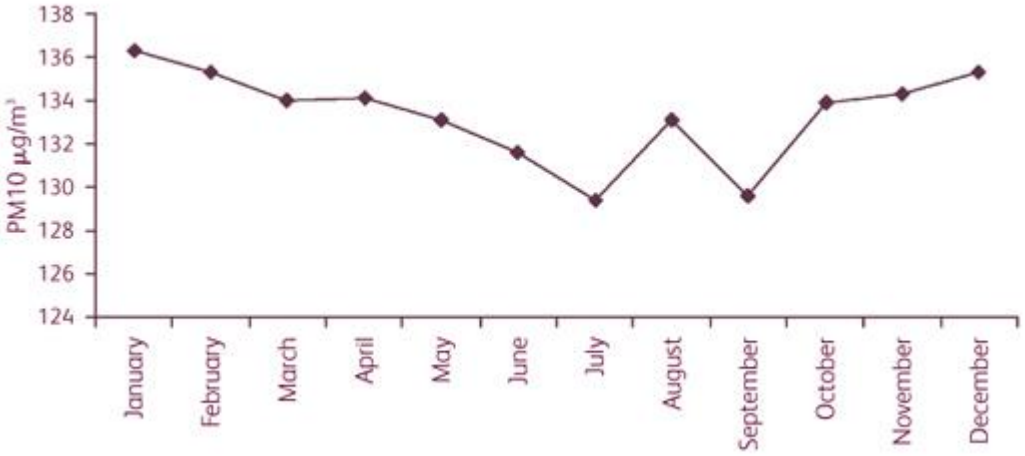
Comparing these values with those of the surrounding rural areas showed that ambient PM10 concentrations in the rural areas were generally lower than those of the urban areas (see Figure

2.0). The urban environment had mean annual ambient PM10 that span 129μg/m^3 to 144μg/m^3, with an overall mean of 135μg/m^3, while the surrounding rural areas recorded mean annual mean ambient PM_{10} value of 57μg/m^3 (see Figure 2.0), indicating over 136% difference between the two landscapes. When these values were compared with the aid of paired t-test statistical analysis, results revealed that a significant difference exists in the ambient PM_{10} concentration between the urban corridors and the surrounding rural areas of Nigeria. This is evident from the calculated t- value of 67.88μg/m^3, which is significant at P>0.05. Similarly, the result from the analysis also showed that the urban landscapes of Nigeria correlated strongly with the concentration of PM_{10} over the past six years, with a correlation coefficient (r) value of 0.72. This indicates that human activities and burning of anthropogenic substances in the urban areas are 52% responsible for the concentration of PM_{10} in Nigerian cities.

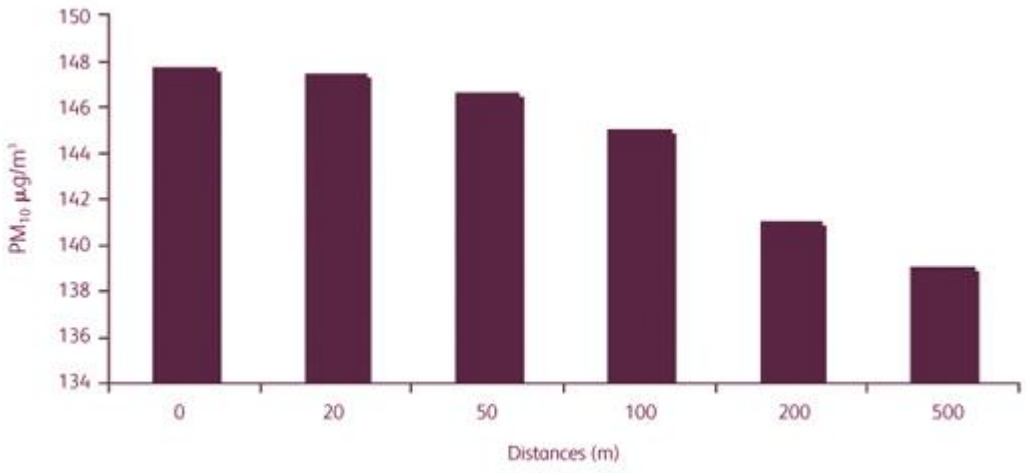
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Mean	WHO 2005 unit (μg/m^3)
January	134	142	141	138	133	133	133	136	50
February	133	140	139	138	133	132	132	135	"
March	133	137	137	137	132	131	131	134	"
April	132	136	138	137	134	132	130	134	"
May	131	137	133	135	133	132	131	133	"
June	128	132	131	135	133	131	131	132	"
July	127	132	130	130	130	129	128	129	"
August	130	137	136	134	132	133	130	133	"
September	126	132	130	130	130	130	129	130	"
October	129	138	140	134	132	132	132	134	"
November	130	140	139	135	132	132	132	134	"
December	132	141	140	135	133	133	132	135	"
Mean	130	137	136	135	132	132	131	133	"

Table 4.0 shows the mean seasonal and daily distribution of PM_{10}. Generally, the dry season recorded higher values of mean ambient PM_{10}; these are January (136.3μg/m^3); December and February (135.3μg/m^3); November (134.3μg/m^3); and March (134μg/m^3). The wet months had mean ambient PM_{10} concentrations that span 129.4μg/m^3 in July to 134.1 μg/m^3 in April. Figure 3.0 gives a better view of this distribution. It is clear from Figure 3.0 that there was a general recession or decrease in monthly mean ambient PM_{10} from January with a value of 136.3μg/m^3 to 129.4μg/m^3 in July, thereafter an increase in August to a value of 133.1μg/m^3 and a fall to 129.6μg/m^3 in September. The increase in the month of August is associated with the little dry spells that precipitate particulate matter during this period. There is also a gradual increase in PM_{10} from 129.6μg/m^3 in September to 135.3μg/m^3 in December.

The general increase in PM10 concentration during the dry season is a confirmation of the earlier view that the deposition of particulates or dust raised during the Harmatan season, wind movement of dry particulates and aerosols from the Sahara desert into the northern states, and burning of anthropogenic substances, etc are the major factors that are responsible for this increase.



From Table 4.0 the mean daily distribution of PM_{10} showed that higher concentrations were generally recorded during the working days than at weekends. There is a general decrease in PM_{10} from 137µg/m^3 on Mondays to 130.4µg/m^3 on Sundays, indicating a decrease of 6.6µg/m^3 between the working days and the weekends. The peak level of 137µg/m^3 occurs on a Monday. However, the working days (Monday-Friday) had an average value that decreased to 134.4µg/m^3 while those of the weekends (Saturday and Sunday) showed an average of 130.7µg/m^3 indicating a difference of 3.7µg/m^3. This is significant with r value of 0.73 significant at P>0.05. For instance Mondays had the highest mean ambient PM_{10} values of 137µg/m^3, and Tuesday had 136µg/m^3; this, however, decreases gradually to 132µg/m^3 on Fridays throughout the year, while Saturdays and Sundays had the lowest mean values of 131µg/m^3 and 130µg/m^3 respectively (see Table 4.0). These mean ambient daily PM_{10} values are higher than the 50µg/m^3 threshold of WHO (2005). For instance Sundays and Mondays with the lowest and highest ambient PM_{10} values (130g/m^3 and 137g/m^3 respectively), are 160% and 174% higher than the WHO (2005) threshold respectively. The mean daily concentration in the urban landscape of Nigeria recorded gradual decease in ambient PM_{10} as distance increases from the traffic-clogged area (see Figure 4.0). This decreases from 147.7µg/m^3 at the traffic-clogged areas to 139µg/m^3 at 500m away from the source of the ambient PM_{10}. On the other hand mean daily distribution of ambient PM_{10} in the industrial area decrease from 140.5µg/m^3 at the industrial site to 132.5µg/m^3 at 500m away from the industries. These indicates about 6% decrease from the traffic clogged area and the industrial area to 500m. At the industrial area this is more typical of refinery industry at Warri, Port Harcourt and the Niger Delta environment where gas is being flared, cement industries and road construction industries (during construction exercises in the dry season) in the country. It is clear that road traffic, the refinery and cement industries made significant contributions to ambient particulate concentrations owing to meteorological factors (wind) which helps to spread the ambient PM_{10} concentrations to areas of other land use. Other land uses only decrease by 2µg/m^3, indicating a 1% decrease within these land uses (high and low density residential, commercial and traditional areas). This is quite different from the rural areas, which decreased from 57.4µg/m^3 at road junctions to 56.7µg/m^3 at a distance of 500 m, showing a 0.7µg/m^3 reduction or 1% decrease.



Health implications and policy measures

The study revealed that Nigerian cities have been characterised with high levels of air particulate pollution over the period of the study. Certainly, this has strong health implications for the urban dwellers over these years. For instance, studies in the developed countries have linked particulate air pollution with the prevalence of respiratory diseases in cities (see Botkin and Keller, 1998; US Environmental Protection Agency, 2002; Shprentz, 1996 and Efe, 2006). They opined that increased particulate pollution above the WHO threshold may result in changes in lung function and respiratory illness. The US Environmental Protection Agency, 2002 and Shprentz, 1996 further stressed that particulate matter also resulted in increased hospital admissions for respiratory diseases and heart disease, increased school and job absence from respiratory infections and aggravation of chronic conditions such as asthma and bronchitis. This view has been noted by the Union of Concerned Scientists (UCS, 1989). The UCS in their studies of PM_{10} pollution and health stressed that 2% to 8% of total human mortality in cities is attributable to a 50µg/m^3 increase in PM_{10} pollution in these cities. Risk of mortality is approximately 15% to 25% higher in cities with the highest levels of PM_{10} pollution, compared to cities with lowest level. This coincides with the view of Efe (2006) that over 31% of respiratory diseases in Warri and environs are significantly related to the prevalence of ambient air particulate pollution. The result of this study revealed that the prevalence of respiratory diseases in Nigerian cities correlates significantly with PM_{10} concentrations. This is evident from a correlation coefficient (r) value of 0.98 which was performed with the SPSS software, indicating that the ambient PM_{10} is responsible for 96% occurrence of respiratory diseases in Nigerian cities with $P>0.05$. An evaluation of PM_{10} on the occurrence of individual diseases in Nigerian cities showed that cough and catarrh had the highest correlation value of 0.93, suggesting that PM_{10} is responsible for 86% occurrence of this disease, while cardiovascular diseases had the lowest r-value of 0.63 indicating 40%. Other diseases showed r-values of 0.86 (eye infection); 0.85 (skin diseases); 0.83 (asthma) and 0.80 for chronic bronchitis. It also showed strong rvalues of 0.99 among land uses, with traffic-clogged areas 0.87, industrial areas 0.75, commercial areas 0.67, high density residential areas 0.65 and G.R.A. areas 0.22. With the exception of the G.R.A. areas with r- value of 0.22 indicating no significant effect [$P<0.05$] of PM10 on the prevalence of airborne diseases in the area, diseases in other areas correlated significantly with the distribution of PM10 [$P>0.05$].

Conclusion and recommendations

Built-up areas of Nigerian cities are characterised with high levels of annual mean ambient air particulate pollution of over 120μg/m^3, with northern cities of Maiduguri, Sokoto experiencing higher concentrations of PM10 than Lagos and Warri, their southern counterparts. In addition, the trafficclogged areas and industrial areas generally have the highest annual mean ambient PM10 values of over 140μg/m^3, and the low-density residential areas generally have annual mean ambient PM10 values of over 120μg/m^3.

The surrounding rural areas had annual mean ambient PM_{10} values of 57.4μg/m^3, which is also above the 20μg/m^3 safe limit of WHO (2005) global guidelines. The monthly mean ambient PM_{10} values showed that the dry season recorded higher values of mean ambient PM_{10}; these are January (136.3μg/m^3); December and February (135.3μg/m^3); November (134.3μg/m3); and March (134μg/m3). The wet months had mean ambient PM_{10} concentrations that span 129.4μg/m^3 in July to 134.1μg/m^3 in April. The urban landscapes of Nigeria correlated strongly with the concentration of PM_{10} over the past six years, with a correlation coefficient (r) value of 0.72, indicating that human activities and burning of anthropogenic substances in the urban areas is 52% responsible for the concentration of PM_{10} in Nigerian cities. Thus, significant differences exist in PM_{10} values recorded among the land use types, and also between the built-up areas and those of the surrounding rural areas. High concentrations of PM_{10} in most Nigeria urban environment in 2006 have resulted in significant health implications for the urban dwellers. This is evident from the calculated correlated coefficient (r) value of 0.98, indicating that PM_{10} is responsible for the prevalence of airborne diseases. These diseases are cough and catarrh, eye infections, skin diseases, asthma, chronic bronchitis and cardiovascular diseases.

It is recommeded that an emissions standard for Nigerian cities should be introduced. Road pricing for automobiles using cities should be considered. This could be done by charging to enter a designated region of cities where congestion and high ambient PM_{10} was noticed. Concurrently, improvements should also be made to public transport provisions such as the introducton of car sharing and the provision of park and ride facilities. Commercial bus services should be provided for commuters in the busy routes during the hours of 7.45am-9.45am; 1.45-2.45pm and 3.45-5pm when private cars and motorbikes will be off the road. Freer flowing urban traffic will result in slightly lower particulate emissions.

The existing ban on the import of cars and motorbikes that are more than five years old by the Federal Government of Nigeria is a welcome development but this approach has experienced implementation issues since older and more polluting vehicles are still being imported without enforcement of the appropriate sanction, because of the nature of the people involved. In the same vein, the activities of smugglers to bring in older and more polluting cars have also been on the increase. Though the Nigeria Customs Services have declared war against the activities of the smugglers, which led to the seizure of some of the cars, there is the need for the government to further equip the Customs Services with modern facilities to curb this menace.

There should be regular environmental education provided on the need to do the following: keep car and other engines properly tuned and avoid using engines that smoke; avoid extended periods of engine idling; whenever possible use a car pool, public transport or walk; combine errands to reduce the number of trips taken by car; reduce or eliminate fireplaces and wood stoves; avoid burning leaves, trash and other materials – instead, mulch or compost leaves and yard waste.

Residents of affected cities should plan strenuous exercise activities for when particulate concen trations are forecast to be lower and they should reduce the amount of time spent at vigorous activities or choose less strenuous activities such as going for a walk instead of jogging. There should be moral persuasion (that is, persuading people through publicity and social pressure), direct control, including regulations, market processes that affect the price of goods and services, and include various kinds of subsidies and grants. This policy should also be applied to industries and all those that pollute the environment. Industries emitting significant ambient particulate pollution should set up chambers or collectors to control emissions of coarse particulates from power plants and industrial sites. This will provide a mechanism that causes particles in gas to settle out in a location where they may be collected for disposal in landfills

The gas flaring in the refinery should be stopped because of increased ambient PM_{10} recorded in areas associated with gas flaring. For instance >139µg/m^3 ambient PM_{10} values were generally recorded within the foci of gas flaring areas in Warri and Port Harcourt. Alternatively, the flared gas should be converted to industrial raw materials for the production of domestic gas.

The incineration of refuse in market areas should be stopped. The Local Government Authority should engage in regular collection and processing of waste at approved government depots on the outskirts of the city, far away from residential areas. This could be done through the reintroduction of monthly environmental sanitation collections. Cloud seeding that will enhance rainfall should be periodically carried out to clear off most of the suspended particulate matter. This should be done with the provision of good drainage systems in Nigerian cities to channel inundated water (if any) to rivers and the Atlantic Ocean for coastal cities.

Effective urban planning is a necessity.

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CIEH funding for research projects

The CIEH sets aside a budget each year to support environmental health research. If you would like further information and/or to apply for support for a research project, please contact John Guild on 0207 827 5842 or fill in the email form.

The criteria for applications are as follows:

Procedure and conditions of grant applications

1. CIEH members only are eligible for research grant aid.
2. Applications in an agreed format are to be made in advance.
3. Eligible costs include legitimate expenses, but exclude tuition and course fees.
4. Payment will be made on receipt of invoices or written evidence of expenditure.
5. Grant instalments will be paid, up to a maximum of 75% of the total grant, before receipt of the completed research paper offered for possible publication in JEHR. The balance will be paid on publication or at such other time as agreed.

Assessment criteria

Each case will be judged on its merits. The awarding body will wish to consider:

- The extent to which the research is likely to contribute to the knowledge-base of environmental health;
- Value for money in relation to the proposed expenditure;
- Whether the methodology is appropriate and robust;
- The proposed timescale; and
- Any other relevant matter.

Book Reviews

Books reviewed this issue are:

- Toxicity testing in the 21st Century: a vision and strategy
- Introduction to Global Health
- Environmental Epidemiology: Principles and Methods

Toxicity testing in the 21st Century: a vision and strategy

NATIONAL RESEARCH COUNCIL of the National Academies, 2007.

ISBN 13: 978-0-309-10992-5 (hardback)

$36.00

This book constitutes the final report of the Committee on Toxicity Testing and Assessment of Environmental Agents. The committee, a group of 23 relevant specialists, was convened in response to a request from the US Environmental Protection Agency to the National Research Council to develop a long range vision for toxicity testing and a strategic plan for implementing the vision.

The book commences with a summary, and six chapters and an appendix, which provides biographical information about all members of the committee, follow this. The first chapter, Introduction, sets the scene by providing a brief historical perspective and a discussion of the limitations of whole animal studies to determine apical end points as a basis for future risk assessments and subsequent regulatory control. The second chapter, Vision, considers what sort of testing approaches we might take in the future bearing in mind both the limitations identified in chapter 1 and the need to protect public health and the environment against a background of ever increasing chemical complexity. The committee recommends that we should seek to move from the in viva ‘whole animal' testing strategy of the past towards an in vitro approach, using human cell lines to identify toxicity pathways and biomarkers dependent on molecular or cellular changes which are likely to indicate increased risk of harmful health effects. The committee acknowledges that initially traditional testing will be required in parallel with these new approaches to enable public and governmental confidence in the new approaches to develop. It is therefore predicted that reduction of animal testing programmes will occur only gradually. The third chapter, Components of the vision, considers the steps that will be needed to enable the approach outlined in the vision to become effective and the complications that will have to be overcome. In the latter case the difficulties associated with the identification and assessment of risks associated with metabolites is considered in some detail. Chapter 4, Tools and technologies, introduces tools and technologies that might be used to apply the vision. It is emphasised that these will evolve and develop over time and are likely to include sophisticated population studies and computer modelling. Chapter 5, Developing the science base and assays to implement the vision, stresses the amount of work that will be needed if the vision is to become reality. The final chapter, Prerequisites for implementing the vision in regulatory contexts emphasises the roles of non-scientists in funding the research and developing the necessary regulatory frameworks. It is stressed that much time and resources will be needed if the vision is ever to be achieved and it will therefore be necessary for scientists to convince politicians and the public of the merits of their case.

In summary, the book represents a scholarly thesis on a very complex and important topic. It outlines the many deficiencies of the established protocols for toxicity testing, proceeds to consider how things might be improved and how new improved approaches might indeed be established. I enjoyed reading it and it helped to clarify my views on a number of issues. I would certainly recommend it to anyone interested in developing toxicity testing programmes. However, given the visionary nature of the book, I would not recommend it to any of my undergraduate classes. The book is mainly focused on the situation in North America and while geographic location seems unlikely to have any significant effects on the efficacy of toxicity testing as such, the same can't be said for the accompanying political and economic pressures. There are already claims that the REACH regulations, recently introduced by the EC, are inhibiting rather than fostering the development of alternative testing measures. It seems unlikely that the EC will be willing to embrace such an innovative new programme so soon after establishing its own approach. However, whether the vision is ever fully realised or not, the book does us all a service by promoting the ambition to develop a much better approach than the one we are currently using.

Dr Bill Byers Senior Lecturer in Health Sciences, University of Ulster

Introduction to Global Health

Kathryn H Jacobsen, 2008. Jones and Bartlett Publishers International, Barb House, London, W6 7PA

ISBN 13: 978-0-7637-5159-3 (paperback) 483 pages

£29.99

In the preface to an introduction to Global Health, the author Kathryn H Jacobsen tells you that you may read about a lot of things you've never heard about that affect the lives and health of millions of people each year. For many readers this will be very true and indeed even for well informed public and environmental health professionals, this most readable book provides a useful and at times inspiring source of information.

The book also claims to give you the vocabulary and knowledge base to understand the language of global health. The clear writing style with concise definitions for the technical and jargon words certainly delivers this claim.

Each chapter is prefaced by a list of key points and the text is peppered with those words in bold type that are intended to provide you with the essential vocabulary of global health.

The enormity of the challenges in securing health for the world's population are well illustrated by the many relevant graphs and tables used throughout the book. The 14 chapters, seven appendices and a comprehensive index allow the casual reader to dip profitably into an area of specific interest, but for the greatest benefit, reading the complete volume and then reinforcing your expanded vocabulary and knowledge by revisiting those chapters of greatest interest is a better option.

Some environmental health professionals may be disappointed if they immediately turn to their specialism covered in Chapter 10, as they will find little technical information, although many may be surprised at the data concerning indoor air pollution – showing it to be a bigger global

killer than TB or malaria. Hopefully they will be impressed by the range of health stressors that they are acknowledged to tackle.

Clinicians may feel they are neglected as the book is focussed on public health, not individual health and covers the various stressors and interventions. The benefits of early interventions to obviate the need for expensive clinical remedies are well demonstrated. Many assertions are made, often with some noticeable passion, such as the claim that pharmaceutical products may be of little value if the patient is unable to read the label. Purists may demand the gold standard of double blind trials to provide evidence, but perhaps the approach suggested by the late Xavier Bonnefoy should be followed. When advocating the need for evidencebased data to provide convincing arguments, he would ask: why demand research when the answer is so blindingly obvious? How many different ways can it be stated that poverty is the greatest cause of ill health?

The development of the arguments in support of public health in its broadest context is well made and will provide health activists, politicians and economists with succinct quotes to arm them as advocates for public health.

This is particularly true for the chapters on global health payers and players and the penultimate chapter on global health priorities, which even draws on Bill Gates for quotes.

It must be remembered that this is an introductory text and it is therefore most welcome to see the final chapter entitled Learning more about global public health. In less than 30 pages this useful chapter provides a 'how to' guide for reading abstracts and finding reliable articles, as well as tackling epidemiologic study designs, clinical trials, research ethics, interpretation and validity of data in a manner that is understandable even to those without any background in statistics.

There will be few readers who fail to be stimulated by this book and do not follow up one or more of the things that they had never heard of before. This is not a weighty tome to be placed on a library shelf, but a good read to be thrust in front of those embarking on a career in public health, or those movers and shakers who with the knowledge and vocabulary that it provides could make a difference to the health of countless millions.

Les Milne CIEH Trustee and IFEH representative

Environmental Epidemiology: Principles and Methods

Ray M Merrill, 2008. Jones and Bartlett Publishers International, Barb House, London, W6 7PA

ISBN 13: 978-0-7637-4152-5 (paperback) 483 pages

£29.99

Environmental epidemiology is the study of distribution and determinants of health related states or events in specified populations that are influenced by physical, chemical, biological, or psychosocial factors in the environment. It also involves the application of this study to prevent and control health problems. Historically, environmental epidemiology had initially focused on disease-causing infectious agents or pathogens and factors such as water quality, waste disposal and food safety. Increasing life expectancy in many parts of the developed world

has subsequently driven a change in emphasis from infections to chronic disease. Environment epidemiology also examines the effects of social disorder such as war, conflict, terrorism, and natural disasters on disease and death.

This publication provides an in-depth user-friendly guide to these topics. The layout will be particularly popular with undergraduate and graduate students as each chapter contains learning objectives, a summary of key issues, exercises and study questions. All readers will appreciate the clarity of language and logical progression of the subject matter. This makes it particularly useful as a reference guide for professionals in the public health protection field.

Section I of the book deals with the concepts and basic tools of environmental epidemiology by initially discussing study design and then expanding on how specific studies into various environmental hazards can be elaborated. The section dealing with monitoring environmental justice is particularly interesting and raises issues that would merit further consideration closer to home. Chapter 5 provides a model of clarity in explaining the various statistical methodologies available to environmental epidemiologists.

Section II is very much a 'hands-on' guide to investigating disease clusters and appropriate responses from public health professionals. The examples provided of appropriate statistical tools for assessing disease clusters and carrying out times series studies are both comprehensive and informative.

Section III provides an array of specific examples of environmental epidemiological studies carried out to examine the health implications of air quality, soil and food, water quality, and radiation. Chapter 14, which deals with the issue of climate change and health, provides an excellent overview of this complex issue.

The book is rounded off with a series of useful appendices on data sources, selected statistical tests, and answers to study questions. While most of the data and examples in the book are based on US data sources, these are sufficiently diverse and authoritative to have wide application to readers from further afield.

Martin Fitzpatrick Associate Editor, JEHR