

EUROHEIS ASSESSORS' REPORT 2003

In accordance with the agreement between the EUROHEIS consortium and the EC, three independent assessors have evaluated the EUROHEIS project, giving their view in three separate reports below.

The attached reports are written by Dr Ed Jessop, representing public health aspects of the project, Dr Christine Dunn, representing the Geographic Information Systems point of view and Ms Dea Carlsson, giving her views on the project from an environmental aspect.

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Dr Ed Jessop, Public Health

E G Jessop DM FFPHM

Formerly Director of Public Health

West Surrey Health Authority

Edmund.jessop@doh.gsi.gov.uk

[Disclaimer: Edmund Jessop is currently working at the UK Department of Health. Opinions expressed in this report are the author's and not necessarily those of Her Majesty's government. They may not be cited as official policy.]

REPORT ON THE EUROHEIS PROJECT

INTRODUCTION

The EuroHEIS partners have successfully completed a project to develop systems in a number of European countries which will allow assessment of environmental influences in health. A key to this has been the development and dissemination of a rapid inquiry facilities, together with a number of technical and statistical development and adaptations to local circumstances and datasets. Overall I judge this project to be a remarkable success.

In reporting on the EuroHEIS project, it is worth recalling the events which led to the setting up of the Small Area Health Statistics Unit in England, and the development of its Rapid Inquiry Facility. As the name implies, speed of response is an important part of managing public concern.

On Tuesday 1st November 1983, Yorkshire Television broadcast a programme with the title "Windscale: the nuclear laundry". The television reporters announced that they had discovered a cluster of childhood leukaemia near to the Sellafield plant of British Nuclear Fuels Ltd in Cumbria, England. Radiation is a known cause of leukaemia, and the Sellafield plant was a known source of radioactive discharge to the local environment. Not surprisingly this programme caused considerable public alarm.

The first scientific response, analysing incidence, was published four weeks later in the Lancet (Craft 1983). This response came from a Regional Cancer Registry. It was a matter of good luck that Sellafield is in a Region which had for many years maintained a high quality register of childhood cancers. The same group were able to set the Seascale cluster in context the following year by publishing a list of other clusters in the Region. Data from a national mortality database were published three months after the programme (Gardner 1984); again there was an element of good fortune in this response from a group which had developed an atlas of cancer mortality for the whole country not long before.

It took several years for a national team to investigate fully the epidemiology of the Seascale cluster (Gardner 1987a, Gardner 1987b, Gardner 1990a Gardner 1990b).

The UK government established an advisory group to report on the apparent increase in incidence of leukaemia in the area (Independent Advisory Group 1984). The group noted that initial epidemiological analysis of the claims of the television programme had been slowed by the need to assemble all the datasets specifically for this investigation. The other problem was that there was no context against which the Seascale cluster could be viewed: we knew there was a cluster at Seascale near to a nuclear facility, but we didn't know where other similar clusters were located, nor conversely what was happening in the vicinity of other nuclear facilities.

Because of these difficulties, one recommendation from the expert group was that the Department of Health should establish a unit which could analyse small area data throughout the United Kingdom. Over the next few years the Small Area Health Statistics Unit was created, initially at the London School of Tropical Medicine and Hygiene and now at Imperial College .

All of this may seem obvious now, but at the time the high quality scientific response to the public concerns seemed somewhat fortuitous. Had the cluster not been cancer, or had it not been in the Northern Region of England, the response would not have been so prompt nor so accurate. The RIF was designed to ensure a response over as wide a range of disease as possible (constrained by existing datasets), anywhere in England: specifically the response was to set concerns about a potential cluster in a context of national and local rates of disease, adjusted for confounding by age, sex and deprivation.

DENMARK

Denmark has chosen not to implement the RIF, because it doesn't need to. The basic structure of a RIF study is ecological: area rates of disease are calculated using numerators attributed by place of residence and denominators counted at census.

In Denmark the availability of personal identifiers, linked to address and updated daily, allows the denominator to be expressed as person-years of residence. (It should be noted that even with this method problems remain: for example people may spend all or part of a day at a workplace far from their home; some people have second or 'weekend' homes; students and others may spend many weeks away from their recorded 'home' address.)

Nevertheless the availability of precise data on where people have lived, and for how long, is a huge strength of Danish studies. Dunstan's simulation (E07)¹ showed that 10% migration per annum of the resident population would lead to 40% loss of power to detect a true effect of exposure on outcome. This is particularly relevant given that most ecological studies of environmental exposure using RIF and similar methods have proved negative: we cannot tell how many were due to loss of power rather absence of effect on health. Governments will not implement central population registers simply for the benefit of epidemiologists: but we should recognise that countries with such registers have a powerful advantage when testing hypotheses.

Where residential histories are not available, they can be constructed in case-control studies, as was done for example in the Seascale studies (Gardner 1990a, Gardner 1990b). Such studies may be necessary to supplement RIF, but a negative RIF study would make it more difficult to justify the resources needed for a case-control or cohort study.

¹ References in this format are to the proceedings of the EUROHEIS / SAHSU conference held at Ostersund Sweden 30 – 31 March 2003.

Even when denominator population at risk has been counted as person-years, problems of exposure classification remain. In most studies there is no exact measure of exposure. Exposures are assigned to individuals from area estimates of environmental hazard. In Poulstrup's example (E13) of dioxin exposure, the area estimate is derived from a mathematical model of air dispersion. In other RIF examples, an exposure value is assigned according to proximity to a source (e.g. a factory or a river). These methods assign exposure with varying degrees of precision.

A different problem arises if the main exposure is not at the home address. Exposures to airborne pollution, particularly if acute, may be greater at a place of outdoor recreation than inside a home – to take an extreme example, exposure to airborne Legionella bacterium at a flower festival.

A poster presentation from Peru [E31] described the use of personal recording devices (for carbon monoxide). Although personal monitors are commonly used by radiation workers, they are rarely used to monitor exposure in the general public. Undoubtedly people would not wear monitors continuously for many years, but there may be scope for creative ways to measure personal exposure more accurately.

FINLAND

Investigations in Finland included a study of cancers in farmers near a river contaminated with dioxins (E17), and the geography of acute myocardial infarction and diabetes mellitus in childhood (E09) , and of amyotrophic lateral sclerosis (E46).

The study of cancers in farmers near the River Kymijoki has a number of interesting features.

The authors comment that environmental levels of dioxins and furans 'are among the highest in the world'. This provides a good scientific rationale for the study. In general RIF studies respond to public concern in a locality – thus

we do not pick the best place to answer the scientific question about exposure and health effect. Perhaps this is one reason why so many RIF studies are negative.

Verkasalo et al concluded that their results are suggestive of increased cancer risk among farmer who live close to the river. They are appropriately cautious about this conclusion. One feature of RIF or equivalent studies is that huge numbers of comparisons are made – in this example 3 age bands, 2 time periods, three proximity bands and at least 14 cancer types. In these circumstances, tests for statistical significance can be very unreliable guides to interpretation. Few contributors to the EuroHEIS project discuss this at length, but it is a major problem. The problems of multiple significance testing are well recognised in the medical literature. Methods such as those of Bonferroni or Holm (Aickin 1996) have been developed to reduce (but not abolish) the problem.

The other feature of the Kymijoki river study is that the exposure measure is proximity to a river and not a point location such as a waste tip or river. It would be almost impossible to analyse proximity to this type of exposure without some form of GIS. The problems of using concentric circles in point source investigation were discussed by James (E40).

Two special features of the country are worthy of note. Firstly, the population in some areas of Finland is very sparse. This led to some special problems of data display, neatly solved by mapping only inhabited squares (see EuroHEIS final report).

Secondly, farming is important enough to form a separate category in socio-economic analyses – and note this in a socioeconomic, not a job, classification scheme: the other categories are upper and lower clerical, skilled and unskilled and 'other'. I am not familiar with socioeconomic classifications other than those used in the United Kingdom and the USA, but I imagine that few countries have 'farmers' as a separate category. This illustrates the difficulty that may occur in applying results from one country to

another, and also the need for country-specific measures if socio-economic status is likely to confound analysis of health status. The Irish EuroHEIS partner addressed this issue.

From a public health point of view the studies of diabetes mellitus in children and of amyotrophic lateral sclerosis are perhaps of more interest than the study of acute myocardial infarction. We know how to tackle coronary heart disease – and indeed one of the most famous campaigns in the world took place in Finland (Tuomilhto 1986). Thus the slight influence of water contaminants, though interesting intellectually, carries little practical implication. With diabetes mellitus and amyotrophic lateral sclerosis (ALS) the position is different. Diabetes is a major public health challenge because it is common, serious and its cause is unknown. The incidence in children is increasing at a rate which suggests environmental influence. Thus any study which might point to a cause is legitimate. Similarly ALS is a rare disease of unknown cause and so identifying areas of high or low incidence, or time-space clusters is worthwhile.

IRELAND

Full details are not yet available on the project in Ireland.

It is however clear from the analysis of urban-rural variation in injury deaths (E15) that geographical coding systems in Ireland are still at a very early stage of development. This will severely limit the development of RIF systems in that country.

One focus of the work in Ireland has been the development of socioeconomic classifications. Certainly analyses of environmental influences on health can be seriously in error if no account is taken of the type of people who live in different areas. Davies showed how failure to account for this led to a mistaken belief that high mortality from stomach cancer in Worksop could be attributed to high levels of nitrate in drinking water (Hill 1973, Davies 1980).

Some thought need to be given to the theory of deprivation or social status which underpins new socio-economic classifications. In England, the system used by the Registrar General throughout the twentieth century was based on the concept that a man's job was a good indicator of his position in society, and hence also of his wife's and children's position. This system worked well for most of the twentieth century. But by the 1990s society had changed so much that a man's job no longer indicated his position in society, let alone that of his wife and offspring. Newer classifications based on home and car ownership were developed. In the National Health Service Jarman selected items for his widely-used measure of deprivation (Jarman 1983) on the basis of the opinions of other London general practitioners. The social scientist Townsend pointed out that this index measured neither wealth nor income and proposed an alternative (Townsend 1988). The approach in Ireland is empirical: to identify 'as subset of socioeconomic variables that best discriminates between high and low mortality or morbidity rates on a small area basis'.

Nevertheless the Ireland partner has identified an important issue. In many RIF studies, deprivation will confound analyses of the effect of environmental influences on disease incidence; so a numerical indicator of deprivation is required. If none is available one must be constructed, and the data available to do this will vary from country to country. For example, no information on household income is collected in the UK census, whereas it is in the USA. Hence income can be used as a measure of deprivation in ecological studies in the USA but not in the UK.

The structure of society may also vary considerably from country to country – as noted above a special socio-economic category for farmers is thought to be necessary in Finland.

ITALY

In Italy the effects of air pollution were studied. There were two unusual features of the study: firstly, the concept of a 'counterfactual' was used to

describe the likely effect of reductions of different magnitude in air pollution. This concept is increasingly used in epidemiology to give clarity about assumptions on which analyses of cause and effect are based (Greenland 2002).

Secondly the effect was described as a change in life expectancy. This has some benefits but intrinsically gives greater weight to effects in young people than in old people. It may be desirable to value young life more highly than old life but this feature of the method needs to be made explicit to all concerned.

The Italian study appears to have used each city as the unit of analysis. Geographically this is very different from the concept of the RIF. It is however worth pointing out that public health action is ultimately political action. Hence analyses which match political boundaries are relevant for public health. Furthermore the results are presented in terms (gains in life) which are more easily understood than the usual relative risks of RIF analyses, and the Monte Carlo simulations allow credible intervals for effects to be estimated. All of these features remind us that the end point of analysis is a decision: to act or not. If analyses can be expressed in terms which are not only valid but also relevant to decision makers, so much the better.

NETHERLANDS

The Netherlands partner studied the effect of noise around Amsterdam Schiphol airport. It is unlikely that routinely available data – mortality, cancer, congenital malformations – will reveal much about the effects of noise. The novel feature of this study, then, was the special collection of data by questionnaire survey among more than 13,000 inhabitants. It is likely that influences on mental health will only be detectable by questionnaire survey. Once this methodology has been established a number of other possibilities open up – for example small area studies of exercise habits and their relationship to local human and physical geography. Large sample sizes will be needed to provide statistically stable estimates from small areas.

SPAIN

In Spain a number of technical enhancements were made to the RIF. Functionality was added to cope with the problem of attributing area levels of hazards (such as levels of magnesium in drinking water supplies), and routines to deal with missing data [E30].

The performance of the RIF was tested against formal statistical investigation with more detailed methods in three test cases: this is important work since we need some form of validation for the RIF. The results of these comparisons were encouraging.

An extended set of tests for cluster detection were also tested. This is important if the RIF and similar systems are to be used pro-actively, to seek out clusters, rather than as now in purely reactive mode when local communities express concern. It is however clear that mathematics of cluster detection are highly complex. Kelly et al [E21] provided a critique of a commonly used cluster detection technique which is freely available for download from the World Wide Web.

SWEDEN

Sabel [E28] looked at the distribution of cardiovascular disease in Stockholm. As noted above we already know enough to take successful public health action against coronary heart disease. Often, however, public health action is targeted geographically – we have to focus available resources on particular neighbourhoods. It then becomes interesting to try to estimate the effects of neighbourhood attributes such as physical assets. This would might weight to campaigns to build more leisure resources such as sports halls or to reduce alcohol and fast food outlets. There is a huge literature about the influence of social capital on health, and also huge debate (Egolf 1992, Baum 1999, Whitehead 2001). The work on context versus composition must thus be seen as exploratory.

UNITED KINGDOM

The Small Area Health Statistics Unit in the UK continues to fulfil its original brief of response to local concerns about environmental influences on health. Two examples were mentioned at the Ostersund conference: investigating kidney disease near a chemical plants at Runcorn [E08], and the effects of high levels of bromate in drinking water in Hertfordshire.

The facilities of the RIF have also been exploited in other ways not related to environmental influences on health. Thus Aylin was able to examine the outcome of paediatric cardiac surgery in different hospitals in England (Aylin 2001). This particular study had no spatial dimension but took advantage of the holding of national datasets on patients admitted to hospital.

Another obvious application of the RIF would be to regard the health services as an area effect: for example the datasets would allow mapping of access rates to specialised services. Or the classification of 'avoidable methodology' might be used to examine avoidable deaths and relate this to health service jurisdictions or administrative areas. In this way the performance of health services in preventing avoidable death could be mapped. Such analyses would be more complex where health services overlapped – for example surgical services in some metropolitan areas – and GIS would be need to identify the dominant health service in a particular area. A number of the EuroHEIS partner countries and institutions have experience of area analyses of avoidable mortality (Barry 1992, Treuniet 1999, Westerling 1993).

OTHER COUNTRIES

Other countries, most obviously the USA, have used GIS to examine environmental influences on health.

The Centres for Disease Control are setting up a tracking network [E06]. There is a strong emphasis on stakeholder participation. Collaboration between local health agencies and universities is evident in many of the

EuroHEIS projects, but it is not so explicitly part of the process of constructing surveillance networks. This is perhaps a weakness in systems which are publicly funded and which originated as a government response to public concern.

In the EuroHEIS partners, communicable disease has not been a high priority. Wartenberg [E02] remarked that control of Lyme disease is helped by integrating climate, environmental and ecological data to map habitat suitable for the vector ticks. Lyme disease is also prevalent in Europe. Another example might be the mapping of bovine tuberculosis in relation to human disease, particularly if allied to molecular DNA typing of bacterial strains.

California has established a pesticide use database. In this agricultural state, some people live in close proximity to what is in effect a chemical industry – modern farming. Nuckols [E03] mapped pesticide use and also linked types of land use (e.g. wine growing). Most countries in Europe do not have reporting requirements for pesticide use and studies of health effects have to rely on partial and inaccurate records to reconstruct this information retrospectively.

CONCLUSIONS

Overall the participants of the EuroHEIS project are to be congratulated for their work.

In future four considerations may become increasingly important.

(1) Firstly, the economics of RIF are interesting. Considerable resources are required to set up an RIF. Spatial datasets in particular can be extremely expensive. Once the system is set up, however, it is cheap to run: the marginal cost of an inquiry is very small. The clear implication is that RIF become more cost-effective if they are used intensively. Also it is more cost effective to run a large RIF than a small one – ‘large’ in public health referring to the population coverage (over 50 million people in the UK RIF). In general RIF are built around existing datasets, but collaboration would plainly bring economies of scale. That said, public health action depends on political structures so collaborative efforts would need to respect political boundaries.

As noted above once the assets for an RIF have been assembled it makes sense to exploit the system for uses other than investigation of environmental influences on health. This will also improve the return on investment in RIF.

(2) On the other hand we need to ensure that RIF resources are used for problems best answered by spatial data sets. Remembering the saying 'To a man with a hammer, everything looks like a nail', we should avoid the temptation to regard all problems as susceptible to spatial analyses.

(3) We do not yet know how best to use RIF systems for surveillance, that is, systematic monitoring of places for unusual disease occurrence. In general we use RIF to respond to local concern – apparently high rates of disease are detected by other data systems (including the collation of anecdote by newspaper reporters). This is unsatisfactory. As guardians of public health we should detect high incidence of disease before local people become alarmed.

But no examples were given in the EuroHEIS project of investigations prompted by data surveillance at the RIF centre. We need – though this is a formidable task - to develop new methods which will give adequate sensitivity and specificity for the countless analyses possible with geographic information systems.

(4) Finally we need to remember the 'public' in 'public health'. Our aim is to serve the public, by identifying environmental threats to health, or by providing reassurance that economic and other activities confer no detectable risk of harm. RIF systems are highly technical but we must not allow ourselves to become divorced from the people we serve. 'How are we involving the public in this research or investigation?' should be a standard question.

Related to this is the need for RIF systems, and indeed all investigation of influences on health, to match political systems. Ultimately we need to act on our findings must lead to a decision – to act or not to act, and any such decision will be political. Thus analyses must be expressed in terms that politicians can understand, and must be based on geographies that match political realities. Also organisations which host RIF systems, or carry out similar research, must have political backing, either through the governance of the organisation (its board or equivalent) or through the research contract specification.

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Dr Christine Dunn, GIS

Senior Lecturer
Department of Geography
University of Durham
Durham
UK
C.E.Dunn@durham.ac.uk

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EUROHEIS: External evaluator report: a GIS perspective

Project aims, approach and management

The EUROHEIS project has a set of clearly formulated objectives and appears to have been generally well conducted and organised. The project is extensive, although at the same time the component parts are largely manageable in scope. More specifically the project aims 'to improve health information and analysis in order to assess relationships between environmental pollution and disease, and to respond rapidly to health threats, improving knowledge and understanding of health risk management'. The project aims are appropriate in the sense that the intention is to both analyse spatially-referenced health data and to include an assessment of risk. Development of the Rapid Inquiry Facility (RIF) is a specific example of an output from the project which seeks to incorporate the two key elements of data integration and risk assessment.

The investigators have clearly succeeded in meeting their objective of enhancing information bases, and spatial and statistical analysis of health-related datasets. Specific findings have also emerged in terms of exploring associations between sources of environmental contamination and ill-health. The second part of the statement of aims cited above is more ambitious and makes links to health policy and practice in terms of utilising information systems to help improve management and response to public health threats. This statement is also incorporated in the intentions for the RIF in terms of 'utilising the system within the context of improving public health, preventing human illness and diseases, and obviating sources of danger to health'. This is a laudable part of the context in which the project operates although its success is perhaps more likely to become clearer in the longer-term.

From a GIS perspective one of the most potentially valuable aspects of the project is the focus on developing *integrated* systems for disease and exposure mapping. This is a difficult aim to fulfil completely since there are inevitable problems in defining an 'integrated' GIS and particularly so in the field of environment and health where some of the complexities outstrip the capabilities of a spatial information system. GIS is therefore not a panacea and an important balance needs to be struck between, on the one hand,

incorporating relevant variables into a spatial analysis and, on the other, recognising the limitations of GIS and the value of alternative approaches to analysing spatially-referenced health data. The investigators have largely acknowledged this through use of other approaches such as statistical modelling. It remains of critical importance, however, to ensure that user documentation for the RIF is explicit in clarifying the constraints of the system.

A sensible approach has been adopted in terms of a staged development of the GIS-related work from a feasibility study for the RIF in Phase I, implementation in Phase II, through to utilisation of a series of case studies in partner countries in the final phase. The project also benefits from the existence of an already well-established historical set-up in terms of GIS work in the partner countries. A strong network of research contacts has been established and built upon. In addition there are good examples of the core EUROHEIS project forming a springboard from which further collaborations have been initiated (eg. the Spanish partner's alliance with a number of other organisations in Spain; requests to the Swedish partner to implement the RIF beyond Stockholm; and work with staff at the University of Southampton in the UK which has led to a request for them to become a formal partner).

Activities and achievements

System development and implementation

The system should be sufficiently flexible to allow addition of new features and modules, notwithstanding the need to recognise the limits of GIS functionality. The project has achieved this by employing widely used proprietary software for the RIF, namely ESRI's ArcView 3.2 with Avenue as the programming language, and Oracle. The reasons for incorporating a separate database management system (Oracle) coupled to the GIS are documented in Project Report 22 February 2001 and are entirely appropriate.

With ESRI's upgrade to ArcView 8.x, however, there have been changes to the programming language and I understand that the investigators intend to re-code the system using Microsoft Visual Basic (VB). In many ways this was unavoidable although it remains unfortunate that valuable time will need to be spent re-coding the system. That said, this also presents an opportunity to make further improvements, eg. to the running and efficiency of the system. Further, there are facilities to assist in the conversion of Avenue code to VB through 'Avenue Wraps' wraparounds. It is also, perhaps, an indication of the degree of control which large software vendors can exercise over their users although this disadvantage is outweighed by the benefits afforded by the strategy adopted here.

Some partners have implemented the UK RIF in its entirety, some have elected to adapt it to their own requirements in the light of data characteristics, and others have developed additional modules. This use of different approaches to implementation is entirely appropriate given the different needs and circumstances of the set-up in each partner country. The approach taken

by the Finnish partner, for example, to adopt the most successful aspects of the RIF and of SMASH seems eminently sensible. Similarly work by the Spanish partner to evaluate the power of the basic RIF system in comparison to advanced statistical approaches is to be commended as an effective benchmark for the limitations of RIF.

Data collection and organisation

The researchers have adopted an ordered and professional approach to the collection and organisation of data. For some partner countries this has been a relatively straightforward task but for others it has proved to be a major undertaking. The project has used mainly routinely-collected datasets and this is appropriate given the constraints on time. It would be useful, though, to have an indication of whether the subsequent analyses have been able to generate ideas about improved methods of collecting and organising geographically based health datasets.

There are only limited examples of data exchange between partner countries and although this is perhaps to be expected for an initial project it would be valuable for any further work to consider this aspect more seriously. In addition it appears that necessary data were supplied to the Irish partner rather late in the project which prevented them from presenting a full set of findings at the evaluation stage.

Data Quality

The project clearly recognises the fundamental importance of data quality issues. Inevitably different partner countries have access to datasets not only of different quality, availability and consistency, but also for different geographical scales. Efforts have been made to determine the degree of variation in data across the partner countries through appropriate methods (questionnaire and follow-up discussions) and to document brief descriptions of the major datasets (Appendix 2, Project Report 22 February 2001). It is important to ensure that access to this metadata is provided to users eg. RIF users and that published work fully acknowledges the limitations of the data and subsequent implications for results.

Type of spatial analysis should be matched to the spatial resolution and accuracy of the data such that, for example, if data are available at individual level (as in Denmark) this should be exploited. Even at this scale, however, factors such as daily movements of individuals (eg. to the workplace, school etc) can complicate environment-health relationships. Where individual level data are available only for restricted case areas within a partner country (eg. specific cities in Italy) it is encouraging to see that the potential is recognised for exploiting these through trial analyses in order to demonstrate what may be possible for larger geographical areas. The value of highly specific datasets (eg. CJD in Valencia, Spain) is also not to be underestimated.

Spatial analysis

The RIF was designed to be used as an *exploratory* tool. Its merits include the fact that results are achieved both rapidly and in a visual format. As acknowledged by the project investigators the intention of the RIF is to provide a preliminary step in disease-exposure assessments before more in-

depth investigations are carried out. The importance of highlighting to potential users that the RIF allows primarily a quick perusal of the data cannot be over-emphasised. The project documentation includes a set of broad recommendations for follow-up studies and this is a useful inclusion. The use of Bayesian statistical modelling is suggested as one such recommendation and this has been used in the project as a partial solution to situations where areally-based data are too crude in scale terms to allow analysis at small area level.

There has been something of a focus, particularly with the RIF, on putative *point* sources and this reflects the research experience of the investigators. Although there are examples of case studies using linear sources (eg the Finnish partner's work on river sediments) any further phase should perhaps consider non-point sources more concertedly, particularly as project objective 3 specifies systems for 'point/area/line source investigations'. The Spanish partner has made efforts to address this issue since many of their case studies cannot be analysed in terms of a point source based approach.

Currently it appears that several uses of the RIF select specifically-defined radii for buffers centred on putative point sources (2km and 7.5km). The user has the flexibility to define bands of widths other than these two distances but it may be useful to ensure that supporting documentation warns about the need to consider data quality and resolution. It would be misleading, for example, to define a relatively low distance value where the data resolution does not warrant such analysis. Whilst the documentation provides some justification for choice of these specific distance values as a compromise situation, there remain a number of inherent weaknesses in an approach which relies on rigid concentric circles as estimates of zones of exposure and there is potential for users subsequently to misinterpret the findings. In addition it would be useful to have a comment on some of the specific implications of data accuracy, eg. converting unit postcodes to a spatially-referenced geocode; and the robustness of the results to minor changes in the distance bands. The authors acknowledge many of these limitations but it is important to document them fully in order that future developments of the RIF are targeted appropriately.

The project acknowledges the importance of confounding variables and the RIF incorporates measures of socio-economic status (level of deprivation) as a means of partially accounting for area influences on health status. The use of socio-economic status in this way is a reasonable strategy, not least on pragmatic grounds since these data are more readily available than data relating to other, more specific, confounders. Socio-economic status expressed for instance as an aggregate indicator can also provide a *crude* proxy for more specific variables (eg. occupation, lifestyle and behavioural factors such as smoking habits etc.). That said, deprivation indicators remain problematic both in terms of meaning of component variables and in relation to their attempts to represent the intricate complexities of social, cultural and economic characteristics of individuals or groups. They therefore need to be used with a 'health warning'.

Because a deprivation index is something of a 'catch all' some acknowledgement of the limitations of the approach is important. Work by the Irish partner which reviews some of the difficulties involved in attempting to 'measure' deprivation and their work to develop appropriate measures is therefore significant. The emphasis on performance and discrimination of the different deprivation index components is encouraging.

It would also be useful for the investigators to consider how the complexities of representing socio-economic status as an indicator might be documented for system users in the same way that Prof Briggs has provided a critique of environmental health indicators. The notion of indicators as 'use-specific', rather than generic, tools is particularly salient.

Although it accounts for population deprivation, the basic RIF approach does not take into account a number of other potential confounding factors in health-environment relationships. Some inroads have been made elsewhere as part of EUROHEIS eg. using individual level data in Denmark and, using simulated data, the conference paper by Dunstan explored the potential effects of migration on environment-health associations and on the power of detection of an effect. Dunstan rightly called for the need to develop improved models which take into account migration effects and it would be beneficial if any further phases of EUROHEIS were to take this on board. Population migration data are available, for example, for flows within and between small areas in Britain through the Census of Population's Special Migration Statistics.

One of the more significant challenges in assessing environment-health relationships is the definition of environmental exposure. Obtaining high quality environmental data is notoriously difficult and in a European-wide investigation these difficulties are magnified as data availability and quality varies. Environmental data are often collected in a piecemeal fashion and their reliability can be questionable particularly when dealing with historical datasets. The inadequacies of exposure assessment are acknowledged by the project. Use of a spatial information system such as GIS usually implies allocation of areal values of exposure although use of overlay procedures allows estimated exposures at individual levels to be imputed. The zones as represented in the RIF signify simplified geographical areas of exposure based on proximity of residence to a putative hazardous installation. Dispersal of atmospheric pollutants, for example, is, however, more complex than implied by a set of concentric circles, depending on such factors as wind speed and direction, atmospheric conditions, topography, characteristics of pollutant type and source (eg. chimney stacks) etc. Indeed, some of the work presented as part of the project has demonstrated the need to incorporate estimates of exposure based on, for example, air quality dispersion models (eg. the work by Poulstrup, Hodgson and Larsson). The extent to which a system such as the RIF should take on board these issues depends partially on the intended future for the system. From the documentation it appears though that the RIF has the flexibility to import variously defined study areas, eg. through environmental modelling.

Some consideration has been given to the issue of the spatial units themselves. The project recognises that administrative areas tend to vary in shape and size, and over time. The specific definition of these boundaries is often the result of political or administrative decisions and, from an environmental health perspective, is essentially arbitrary. These units also contain within-unit variation eg. in terms of population distribution. Simple choropleth maps which are based on these units can therefore be misleading both from a visualisation point of view and in terms of subsequent analysis. Sweden's 'reasonably homogeneous' base units appear to offer potential although even here there will be intra-unit variation in terms of environmental and socio-demographic factors.

An associated problem relates to the fact that data for different variables are often available for different sets of areal units. Exploring potential relationships between such variables therefore necessitates application of some form of areal interpolation. Here the work by Cockings (UK) and Poulstrup (Denmark) is valuable in its use of automated zone design to define purpose-specific zones for specific epidemiological investigations and to explore sensitivity of results to the modifiable areal unit problem (MAUP). Using empirical examples from the two partner countries, this is to be commended for two specific reasons. First, work on the design of the basic areal building blocks underpins much of the EUROHEIS endeavour. Work such as that on sensitivity of results to changes in boundary definition is critical and, indeed, is a stated objective of the project. Further phases should therefore seek to implement mechanisms rapidly to communicate innovative technical or conceptual ideas to other partners. Second, the work forms a genuine example of data sharing and collaboration. It is recommended that any further phase of EUROHEIS gives priority to further examples of this type of joint alliance through data exchange. These alliances facilitate advances in a number of ways, not least more efficient development of methodologies.

Cross-partner work

Many, although not all, of the findings thus far seems to be based around individual country partners, with less in the way of cross-partner collaboration. Commendable examples of genuine joint alliances include the work by the UK and Danish partners (referred to above) and that led by the Irish partner to review protocols for metadata exchange and to explore relationships between health and socio-economic status for participating countries. At this stage the relatively limited amount of joint-partner investigations is perhaps expected although specific inter-partner work should be given a high priority in any further research. There are, however, limitations to the extent to which this can take place where, for example, inter-country comparisons of findings may be limited by, for example, different definitions of socio-economic deprivation. That said, subject to data quality issues there should be possibilities in terms of focused inter-country comparisons of findings relating to specific conditions eg. congenital malformations. The Irish partner has already worked on this kind of data and it is available in the UK and potentially to the Spanish and Danish partners.

In a European-wide setting work by the Irish partner indicates justification for lack of analysis using data for NUTS areas and comments on difficulties of making inter-country comparisons in relation to definitions of deprivation. Given this background, future work which gives a more detailed judgement and recommendation as to the feasibility for comparisons of findings in a European-wide context will be useful.

An important potential benefit of large European projects is exchange of expertise. The documentation alludes, for example, to potential for the Spanish and Swedish partners to fill some of the gaps in their in-house GIS expertise by drawing on UK capability. Similarly the Italian partners note the potential to benefit from adoption of UK expertise in exploring relationships at local level, based on address-based data.

It is encouraging to see that there has been inter-country exchange of expertise through a number of specific training sessions on statistical modelling. Any further phases of the project should consider extending this notion to other aspects of the research. Training amongst partner countries, even at a fairly basic level, should not only aid wider understanding and therefore further improve the quality of research activities and outputs, but also help staff to consider the project as a truly holistic and inter-disciplinary research endeavour.

Organisational issues and users

It is particularly pleasing and, indeed, entirely fitting and correct, that the project investigators have considered the role of political, organisational and economic issues around implementing the systems in partner countries. These factors are equally, if not more important, than the more tangible technical and methodological issues relating to implementation. The Danish partner in particular has given specific consideration to these issues. It is encouraging to see that the newest partner, the Netherlands, also explicitly states development of an organisational framework as one of their aims for developing the RIF. Factors relating to the contexts in which the systems might be operationalised, who will use them, what kind of support will be provided and how training needs will be met, remain crucial to project success since these factors may well differ from those under which the system was initially developed. Project documentation is encouraging in its recognition of the importance of on-going involvement of the data providers and other key agencies, and of the cost implications of support in the post-implementation phase.

The generic user base for the system at this stage remains fairly clear and this has been incorporated into the system design. It is therefore fairly straightforward for a user such as an epidemiologist with little or no previous knowledge of GIS, for instance, to utilise the RIF for a rapid inquiry. Work on user-friendly manuals, initiated by the Spanish partner, is important both in the context of system use and understanding of results. Such documentation should be made available in a number of languages.

In any future phase, there may need to be more specific exploration of potential users in a wider range of settings, considering issues such as control over specific user groups, training needs etc. A strategy based on different categories of user with different levels of access and authorisation may be appropriate. The Danish partner documents plans to implement this approach through a web-based information system subject to security caveats. The focus on professional users is appropriate.

Location of the Spanish partner's version of the RIF in a regional health authority's department of epidemiology represents a sensible approach with directed use of a two-pronged approach to installation setting (standalone PCs and satellites to a central database).

Plans to disseminate the RIF worldwide as freeware need to take seriously the 'health warnings' and considerable thought should be given to the implications of making it available to a wide audience. The Final Report (2003) summarises a number of the limitations of RIF-based analyses (data errors, boundary definition, small numbers etc.) and hence the need for caution in interpreting findings. Mention was made at the conference of providing a technical support centre but if the intention is that the system be made freely available to non-experts there are substantial ramifications for public health departments in terms of capacity for response.

Careful thought should be given to the extent to which any further phase of EUROHEIS may wish to consider an interactive web-based mapping system. There are several important implications of this approach and serious thought would need to be given to the potential user base. But it should help to focus ideas around potential future directions.

Dissemination

Dissemination of results in academic arenas is good, with a number of relevant peer-reviewed journal articles and several conference presentations, international meetings and workshops completed. Development of a project website and leaflet also enables wider diffusion to a broader, non-academic audience. Project reports and system demonstrations are available through the web. This forms a further and potentially wide-reaching form of dissemination of the research. The project reports are clearly written and represent a useful form of documentation for the project. There are, however, a few minor typographical errors in the reports (eg. reference to tables and section numbers) and these should be rectified.

As well as a set of empirical findings which have been reported on, the project has also produced some extremely useful datasets and software. To what extent these will be made available to other researchers (if at all) needs careful thought.

Future developments

The RIF represents a demonstrable and tangible opportunity to help improve understanding of health-environment associations through a tool which seeks to integrate the functionality of GIS with the principles of epidemiology. Comments have been made on potential future directions of the RIF but it is worth emphasising two key issues. First, directed thought should be given to the intended future users of the RIF. There are arguments both in favour and against widening its use but regardless of this the developers are encouraged to continually emphasise the system's limitations, as well as its benefits, to users and potential users.

The second issue is concerned with the future direction of the RIF's development. One option is to keep the system more or less 'as is' and to continue to use it simply to provide a first pass of the data. An alternative approach would be to consider development of a second major version of the RIF. The latter strategy could involve, for example, embedding some of the statistical analysis into the system; developing the work on exposure estimates from environmental models; or including confounding variables for small areas (eg. migration statistics from population censuses, or data on occupation and exposure in the workplace from community surveys). This strategy has the advantage of making extended analyses available to others although thought would need to be given to how to 'control' who has access where specialist expertise (eg. statistical) is needed to properly use and interpret the added software.

The approach taken to date regarding the use of sophisticated statistical analysis is for it to remain in specialised software largely outside the domain of the RIF (as done by the Spanish partner). If, as seems to be the case, the RIF is to remain a system which allows a quick 'look see' of a dataset for a

limited audience (eg. public health departments) it is difficult to argue a case for making it more sophisticated and complex. That said, there are different degrees to which statistical/RIF 'coupling' could take place and this may be worthy of further thought.

Comment has already been made on the importance of moving away from the notion of simple concentric circular buffers as representations of zones of exposure to an emphasis on modelled contours (eg. air quality, noise, flows in fluvial environments) and this needs serious thought in terms of the future of the RIF. It is encouraging to see that work is underway on specific means of complementing the basic RIF approach, namely the work by the Spanish partner on automatic cluster detection.

In terms of policy implications the work recognises the potential to impact on policy decisions. It is encouraging to see that there are a number of examples of specific case studies providing guidance to policy-makers although, again, the need to emphasise to them the *limitations* remains critical. There are possibilities to exploit policy links further at local, regional, national and European levels. Thus, building on work by the Italian partner and links to WHO, further phases might give attention to the importance of directing, where appropriate, methodological developments to health policy.

There are possibilities for further phases to consider links beyond the initial group of European partners, eg. through existing contacts with workers in the USA such as Wartenberg and Webster. Collaboration where both similar and complementary approaches are being adopted seems appropriate. Inclusion of EU candidate countries such as Poland and Hungary in future work also seems a positive strategy although challenges of data availability and quality are to be expected.

Finally issues related to language need to be considered in future work. Apart from the Spanish version of the RIF, for example, much of the software development and the applications are written in English. As I understand it, all reports, messages etc. are currently hard-coded in the RIF. Any further phases of EUROHEIS should aim to give thought to more flexible means of including text in languages other than English.

Ms Dea Carlsson, Environment

Head of Remediation Section
Swedish Environmental Protection Agency

Stockholm, 17 July 2003

EUROHEIS

European Health and Environment Information System for Exposure- and Disease-mapping and Risk Assessment

The conference marked the conclusion of a three-year project to review feasible and relevant methods for utilizing data from various sources in order to analyse causal relationships between health and environmental factors with the help of GIS technology. Several European countries have contributed to the project with their methods and knowledge, and this has given rise to discussions on various approaches to the collection of available data. Among other things, differences in methods and systems of population statistics have been identified as a co-ordination problem.

This relatively brief report focuses on the project and the results of the conference, primarily with regard to the presentation of knowledge relevant to applications by public authorities.

General Information

Location and facilities. When international conferences are held in Sweden, the most common location is Stockholm. By choosing the northerly city of Östersund, delegates from abroad were provided an opportunity to become acquainted with another interesting region and its culture. It may have also increased their understanding of the specific factors involved in the use of a geographic information system in a country with a large rural sector.

The Radisson SAS Hotel provided excellent service in connection with the conference activities, lodging and dining. The menu had a Swedish flavour, with a particular emphasis on the cuisine of the surrounding Jämtland region.

Extra activities. With a visit to the local museum, delegates had an occasion to study the regional culture of Jämtland. The welcoming address by County Governor Maggi Mikaelsson established an interesting and inviting framework for the conference.

Speeches and documentation. The conference speeches were of a consistently high quality, and most were well-documented. In some cases,

however, the summaries submitted in advance were very brief in relation to the quantity of important information presented, much of it illustrated. For these presentations, the summaries would have benefited from more extensive references. Many of the illustrations appear to have been taken from previous publications. Others were published in connection with the conference or shortly thereafter.

The choice of speakers on the various themes reflected the range of expertise required to elucidate the nature and extent of problems associated with GIS and health issues.

This underscored how important it is, during the earlier stages of a research project, to be aware of the need for various disciplines, modesty, and respect for a critical approach to data.

Poster session. The poster session illustrated the problems that exist, and also what needs to be kept in mind in order to make further progress— thus providing a concrete introduction to the conference. A poster session also provides opportunities for discussions of practical matters.

However, no documentation of the posters was available for the visitors to take with them.

Contents. All of the speakers maintained an objective, critical approach to the pitfalls associated with use of GIS. Particular emphasis was placed on the following issues:

- the importance of choosing the proper level— national vs. local
- the extent to which choice of illustration affects the focus of the results
- implications of the fact that, in this context, a map communicates more efficiently and clearly than words
- the twin uses of GIS, i.e. in the service of both science and society
- the great responsibility that rests with politicians
- the great need for national data centres and interdisciplinary expertise
- the need to develop educational programmes with an interdisciplinary focus
- the lack of a system for identifying individuals in many countries
- the need to improve critical review of the data by researchers' and end users.

Environmental epidemiology and public health: Part 1. Studies of effects linked to point sources of pollution require data of very high relevance. Distance from the source does not, by itself, provide sufficient relevance. A properly conducted study requires detailed investigation at the individual level. In order to interpret results, control data for the essential factor of migration are necessary. The results are also affected by geographical variations such as those relating to genetic similarities or dissimilarities.

GIS and exposure assessment. Studies of environment and health: What are we trying to simulate?

Points?

People

**Health outcome
Points/Areas?**

Risk factors

Individual level

Area level

**Confounding
factors**

**Points?
Areas?**

Pollution : air, water, noise
'Neighbourhood' : services,
housing type/quality, ethnic
groupings/population
mixing, deprivation, crime,
support networks

Predisposing: age, sex,
ethnicity, genetics, birthweight
Lifestyle: smoking, diet, exercise,
alcohol
Socio-economic: occupation,
income, education

People/'Composition

Place/Context

This illustration, which accompanied Samantha Cocking's presentation, provides a useful summary of the questions that need to be addressed when developing a model.

Environmental epidemiology and public health: Part 2. It is often difficult to acquire environmental data, a problem frequently solved by using various kinds of simulation model. One example would be a model that simulates the dispersal of dioxin from a point source in a densely populated area. Such an approach raises the following issues:

- What comes out of a model is no better than what is put into it.
- It is hardly likely that those who dwell in a heavily exposed area remain there constantly. Where do they work, for example?
- If the findings indicate an increased risk of cancer in the vicinity of the point source, how can it be determined that this is due to the presence of dioxin? What are the effects of other factors such as gender, living habits, etc.
- How to guarantee anonymity? In smaller communities, it may be easy to see who is who when data have been charted on a map.

Denmark has a system of social identity numbers and a well-developed GIS network. In Ireland, on the other hand, geographical data are only available at the county level. Such factors determine what kinds of analysis can and cannot be performed.

In some cases, one may be limited to presenting data on a map, without any sort of analysis. But this is a useful first step in itself.

The proper design of a study requires many different types of expertise.

It may also be noted that there is a need for a standardized colour code for maps.

Statistical methods. Existing models seem to be fairly effective at detecting “signals” in the data, and also in accounting for random variation.

But, again, what goes into a model is important. If the quantity of data is limited, the selection of concentration levels becomes especially important. This affects the results. Models must also provide a basis for cluster analysis.

An important point made at the conference was that models and programs must be developed in such a way as to be accessible for others. To do otherwise would be a great waste of effort.

There are statistical methods for detecting clusters. The model presented at the conference was “conservative”, that is it (a) fails to detect clusters in rural areas, (b) exaggerates the size of clusters, and (c) is difficult to use, with many different sources and simultaneous causes.

Environmental epidemiology and public health: Part 3. “Data-made graphics“ have long been important for depicting links between geographic locations and specific phenomena. But it is not always easy to carry out a geographical health impact assessment.

The example from Italy presented at the conference showed that, with regard to respiratory disease among men in that country, place of birth was a more reliable indicator than place of residence. No environmental data were included.

The example from Canada was another data-made graphic based on an extensive interview survey conducted in various parts of Hamilton, Ontario. Environment-related questions were included, and the conclusion was the same as before— namely, that the results vary with occupation, income, age, education, etc.

The Stockholm study dealt with the prevalence of coronary heart disease (CHD). The main questions posed were: Does residential area correlate with risk of CHD? Given that smoking, elevated cholesterol and life style explain one-third of CHD fatalities, how to explain the remaining two-thirds?

The research thesis was that socio-economic class, residential area and education level were all related to risk of CHD. Analyses of Swedish public records were supplemented with questionnaire data, and the results were compared with observed cases. Cluster analysis indicated that there is an increased risk of CHD in sparsely populated areas and in areas with relatively high rates of social problems.

Other studies indicate that problems may arise when certain geographic boundaries are changed, e.g. those associated with postal codes and house numbers.

Public administration perspective

The general approach discussed during the conference reflected sound scientific principles, as well as an unassuming curiosity about the complex and powerful uses to which GIS can be put. Based on the perspective of public administration, I would like to offer the following observations:

- It is necessary to critically review the available environmental data, which have often been gathered for completely different purposes and may therefore lack relevance in other contexts. It is important to review the significance and reliability of concentration levels, among other factors, and to adapt the measurement data to the statistical scales being used. Existing sets of data may lack parameters necessary for GIS applications. Accordingly, there is a need for co-operation among several scientific disciplines. The conference delegates pointed to the great need for national data centres and a

variety of expertise in order to ensure the reliability of environmental and health data. The ideal solution would be for co-operation to begin with the initial planning of a study. There are certainly large amounts of existing data that can be used, but this requires that the data be analysed with standard methods or confirmed by a reliable procedure. This, in turn, requires a common system of standardization. A major effort to develop such a system is under way within the EU, particularly with regard to environmental data. Methods of sampling, analysis and interpretation must be included in the work of standardization. This project has focused attention on the important fact that the data collection procedures of several disciplines should be co-ordinated in connection with standardization.

- It follows that the educational sector should conduct a review of current capacity, at both the national and international levels, to meet the needs of this particular area of education and research. Educational programmes with a specifically interdisciplinary approach must be developed.
- Many of the methods in use are based on models, and are therefore simulations of reality. The results are as good or as bad as the data that is fed into the models. The potential problems are greater for GIS than for many other types of application, since the colour maps produced are easier for laypersons to understand. They comprise an extremely powerful communication media. Who is responsible for their interpretation—the researcher or the end user? My view is that the greatest responsibility lies with researchers, as it is they who are most familiar with the colour-coding keys used for interpretation. Researchers therefore have a responsibility to disclose those coding keys. They must become visible so that public authorities, politicians, journalists and laypersons can be encouraged to adopt the kind of critical analysis that is required. It is only through the choice of colour scale that certain associations can be evoked. For example, red is widely perceived as a warning colour, and green signals “O.K.” This point was emphasized by the conference speaker who noted that GIS is a powerful but two-edged sword in the service of science and society. For that reason, a heavy responsibility rests with politicians. But in order to increase their chances of making correct decisions, they must be provided with scientific information that provides a relevant basis for interpretation. The scientific community and the political sector must therefore develop an effective co-operation in order to achieve optimal results. In Sweden, public authorities play an important role in that co-operation by acting as channels through which research results are processed to provide a suitable basis for political decisions. This applies at all levels— local, regional, and national. The use of GIS for early detection of signals indicating ill health is now and will continue to be an important communication tool. In many cases, it is already being applied in ways that were

demonstrated at the conference. Among the most important questions to be dealt with in the future are:

- How to create systems for identifying individuals and still be able to guarantee their anonymity?
 - How to ensure the quality of input data?
 - How to maintain the integrity of the critical analysis so that it is not obscured or distorted when it is conveyed to various end users?
- From the perspective of public administration, GIS provides an extremely useful tool for seeking causal relationships when analysing large quantities of data, and for communicating the results. Consequently, the standardization of quality control, the choice of models, the selection of standard colours for maps, etc. are very important issues.

It is my hope that this three-year project will be followed by:

1. studies whose results are easier to communicate (the kinds of studies discussed at the conference are often difficult to interpret, as they usually involve several different disciplines)
2. quality-controlled methods for gathering basic data
3. continued discussion of common colour-coding keys for maps
4. the possibility of establishing an education and development center for GIS-related issues in Europe with an emphasis on health and environment.